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ABSTRACT

This report describes a procedure for developing multimedia instructions that are "optimized" according to certain criteria, and in particular, compares the effect on performance in building from memory using: (1) interactive videodisc-based assembly instructions or (2) passive videotape instructions. It was found that the group permitted to "build" during interactive training never performed better than the group not permitted to build (on structure or efficiency), and sometimes performed significantly worse. An explanation for these findings is offered using a framework for multimedia concepts in memory: when practice is mixed with simultaneous audiovisual instruction, the motoric elements created by practice do not become an integrated part of the concept of building the object formed from the audiovisual information. Instead, motoric elements remain "outside" the concept. Motoric elements can be integrated into the visual and linguistic concept only with more extensive practice, or when practice and audiovisual instruction are presented sequentially and not simultaneously. One figure and seven tables are provided. (4 bibliographic notes and 12 references) (Author/EW)

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A goal in this research is to learn how to use high-technology computer systems effectively in education and training. This paper reports a procedure for developing multimedia instructions that are "optimized" according to certain criteria. It describes the design of interactive videodisc-based assembly instructions using IBM's infoWindow system. Research comparing interactive videodisc-based assembly instructions and passive videotape instructions is presented. Performance in building from memory an 80-piece object (made from the Fischer-Technik assembly kit) is assessed for six different groups. The main comparison is between groups which have interactive instructions and are allowed to build during training, and groups which have the same instructions but are not allowed to build during training. The "build" groups never perform better from memory than the "no build" groups (on structure of efficiency) and sometimes perform significantly worse! An account is offered using a (See other side)

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ABSTRACT

A goal in this research is to learn how to use high-technology computer systems effectively in education and training. This paper reports a procedure for developing multimedia instructions that are "optimized" according to certain criteria. It describes the design of interactive videodisc-based assembly instructions using IBM's InfoWindow system. Research comparing interactive videodisc-based assembly instructions and passive videotape instructions is presented. Performance in building from memory an 80-piece object (made from the Fischer-Technik assembly kit) is assessed for six different groups. The main comparison is between groups which have interactive instructions and are allowed to build during training, and groups which have the same instructions but are not allowed to build during training. The "build" groups never perform better from memory than the "no build" groups (on structure or efficiency) and sometimes perform significantly worse! An account is offered using a framework for multimedia concepts in memory: When practice is mixed with simultaneous audiovisual instruction, the motoric elements created via practice do not become an integrated part of the concept of building the object formed from the audiovisual information. Instead, motoric elements remain "outside" the concept. Motoric elements can be integrated into the (visual and linguistic) concept only with more extensive practice, or when practice and audiovisual instruction are presented sequentially and not simultaneously.

I. Introduction

The main goal of our current research is the implementation of an interactive multimedia tutoring system for assembly, repair, and understanding of real physical objects (Baggett, Ehrenfeucht, & Hanna, 1987). As a preliminary to the so-called "intelligent" implementation, we worked first with interactive videodisc-based instructions which try to teach people to build an 80-piece object, called a *lift,* made from the Fischer-Technik assembly kit. The lift is shown in Figure 1. The instructions were not meant to be "intelligent" in the sense of Sleeman and Brown (1982). For example, there was no diagnosis of errors, nor were there different levels of instructions for different subjects. But, as we will show, the conceptual units (the breakdown of the lift into parts and subparts) and the names for the units were derived from "typical" subjects and are therefore "natural." The system and software we used were provided by IBM. In this early phase of the work, we wanted to give the equipment and software a test run, and to learn how to use multimedia computer-aided instruction efficiently in procedural tasks.

Insert Fig. 1 about here.

This article compares the performance of six groups of subjects in building from memory. One group watched a 27-min videotape showing step-by-step construction of the lift, and then built it from memory. The other five groups watched interactive videodisc-based instructions showing the same images as the videotape. These groups could replay segments and pause the image, using a touch screen, as will be explained below. Three of the five interactive groups built the lift once on-line, as they watched, and then a second time from memory. The remaining two interactive groups were not allowed to build on-line, but could only replay and pause; they built only once, after training, from memory. In all groups our interest was in memory performance.

We first give an overview of the computer equipment and the stimulus materials, including the design of the passive and interactive presentations. Predictions about performance from memory are made from our theoretical framework. We then report the very surprising results and the practical and theoretical conclusions.

II. Computer Equipment and Stimulus Materials

A. Equipment

The equipment provided by IBM is their InfoWindow system. Ours is XT-based, with a special monitor and videodisc. Input can be via keyboard and touch screen. Output is moving and still video with text and/or color graphics overlay. There are three sources of speech: two from the two videodisc soundtracks, and one from a limited speech synthesizer. IBM also provided canned software, called Composer/Conductor, for designing and delivering videodisc-based presentations. Composer has a spread-sheet design and is fairly easy to learn.

B. Videodisc

The optical videodisc required by InfoWindow contains up to 54,000 frames, each with its own address. Displaying 30 frames/sec, the disc contains up to 30 min of playing time. On our equipment (using a Pioneer LD-V6000 videodisc player) the access time from one frame to any other is approximately 1.6 sec maximum. Our videodisc was pressed from a 3/4" videotape, precisely the tape used in the videotape instructions group. Its length was 27 min.

C. Stimulus Materials

Both the passive videotape instructions and the interactive ones were intended to teach the viewer to build the lift. The videotape instructions were designed as follows. (See Baggett, 1983, 1985; Baggett & Ehrenfeucht, in press, for details.) A group of subjects built the lift a total of 47 times, copying from a physical model. The order in which each subject selected the pieces for assembly was recorded. Using a computer package for cluster analysis by Perry (1983), the "most typical" conceptualization (breakdown into parts, subparts, etc.) among the 47 was selected. This hierarchical structure, given by a single subject, is shown in Figure 2 as an ordered tree. (Seventy percent of subjects' conceptualizations were minor variants of the "typical" one.) A videotape showing assembly of the lift was made, based on the typical hierarchical structure and on the particular subject's order of selecting pieces. The videotape was shot top down, depth first, and the steps were shown in an executable order. Two cameras were used, one showing the current goal (or subassembly) and the other showing hands working toward the goal. In addition, each subassembly (for example, the *string guide*) contained a two-part sequence: (1) get the pieces needed; and (2) assemble the part. The instructions were thus modularized into "natural" conceptual units.[1]

Insert Fig. 2 about here.

The videotape instructions were also "optimized"" according to two other parameters analyzed in previous studies:

(1) The verbal descriptions (names) used in the narration have been shown to be better than some others. They were selected from collections of names generated by subjects. See Baggett, Ehrenfeucht, and Perry (1986) for the procedure.

(2) The temporal overlap of visual material and spoken narration leads to good

associations between names for objects or actions and their pictorial referents (Baggett, 1984): the visual material precedes, or is in synchrony with, the spoken material; spoken does not precede visual.

The optimization of conceptualization and sequencing, naming, and temporal overlap occurred in the video presentations of all six groups tested. Thus it would have been easy to make presentations such that subjects' performance was worse. However, the task of building the lift is so difficult that the average observed performance is only 50 to 60% of the possible performance. No subject, working for 90 or 100 minutes, could learn to do the task perfectly. So we manipulated factors to try to get some significant difference in performance. But large differences could not be expected.

D. Design of the Interactive Presentation

The interactive instructions were designed using the same images and narration found on the videotape. (The videotape was pressed into a videodisc.) The design was as follows:

- Just as with the videotape, the assembly was modularized into conceptual units, showing a step-by-step executable procedure, with "get pieces" and "assemble part" subunits.
- The only input permitted from the subject was touches to the touch screen (no keyboard input). From touches, a viewer could manipulate what was seen.
- The viewer was forced to see all information once. (No information could be skipped.) The subject could not skip around in the presentation but had to see the assembly in a predetermined executable order.
- Figure 3 shows the structure of the interactive presentation. Options available to the viewer are shown as arrows. The presentation

stopped at the end of each conceptual subunit (e.g., "get" or "assemble"), giving a still frame. The subject could continue or replay with a touch. (Words used as instructions for touches appeared at the bottom of the screen as text over moving or still video.) For example, after watching the assembly of the crank handle, the viewer could replay "assemble crank handle,' or both "get pieces and assemble crank handle." Or the viewer could go ahead to "get pieces for string guide."

Insert Fig. 3 about here.

- During replay of a unit, the viewer could touch the word "next" and skip the rest of the replay, moving to the next unit.
- Subjects could stop the video at any time, by touching "pause." This gave a still frame. They could resume the video by touching "resume."
- The presentation was *not* menu-based. That is, while choices were available, they were not hierarchically arranged, and they were typically of the form "next" or "replay." (See Fig. 3.)

III. Theoretical Predictions

The main purpose of the experimental work was to determine the role of practice in interactive multimedia instruction.[2] Namely, for good performance and retention of a procedure, should a person practice while being (interactively) taught the procedure?

In our theoretical framework, concepts are the basic units used for thinking. Our formulation (Baggett & Ehrenfeucht, 1982, 1985; see also Baggett, Ehrenfeucht, & Hanna, 1987) assumes that concepts are multimedia. This means that information that is put together into a concept comes from different sources, for example, visual and auditory. It also means that a concept contains other information, such as motoric information. An example of motoric information is information about how to move one's hand, or how to put two blocks together. *Processors*[3] are assumed to create and use concepts. We hypothesize that there is one processor, which we call *central*, whose main task is to form and modify concepts. Other processors provide values for concepts. For example, the visual processor might provide an encoding of size or shape or color. The linguistic processor might provide a verbal label. And the motoric processor might provide instructions which direct movement, such as sneeze, move the left hand, or chew.

In an assembly task, the central processor ideally forms the concept of how to build the object. The visual processor provides information about how pieces of the object look, and their configuration. The linguistic processor provides names of pieces and subassemblies. And the motoric processor provides information about how to put pieces together. Thus in our tasks, information comes from four processors: central (the concept of building the object), motoric, from practice (one *does* it), visual, from practice and from video (one *sees* it), and verbal, from narration (one *hears* it). We have interpreted our experimental work using this framework. For example, in Baggett, 1987, we hypothesized that integrated concepts (concepts with motoric, visual, and linguistic elements linked together as subconcepts of the abstract concept of how to build the object) are best for procedures, leading to good performance from memory and good retention over a delay. In the stud some subjects watched a videotape showing assembly of a toy he while others first built the helicopter using a model as a g then watched the videotape (or first watched the videotape and then built from a model). All three groups were then tested from memory. The groups who built during training performed more than twice as well (on both structural and functional measures) as the group who did not build during training. Further, during instruction, the groups who built were given all three conceptual elements, motoric, visual, and verbal (motoric and visual from building; visual and verbal from the videotape). The group who did not build was given only visual and verbal elements (from the videotape). Using our multimedia framework, we interpreted this to mean that when instruction provides motoric, visual, and verbal elements, they are automatically integrated into one concept, i.e., motoric, visual, and verbal elements become subconcepts of the abstract concept of building the object, and such a concept gives good performance from memory.

We schematically represent the situation as shown in Fig. 4, part I. The abstract concept A of building the object has three subconcepts, B, C, and D, as indicated on the left by solid arrows. B is visual information, C is linguistic, and D is motoric. When all three are present in instruction, we hypothesized, they become subconcepts of the same concept, namely, they are chunked as a whole. (On the right of Fig. 4 is the same situation, but drawn as a Venn diagram.)

Insert Fig. 4 about here.

Other situations are possible in our framework, however. Besides the *subconcept* relation between concepts, there is also a *pointer* or *association* relation, which we indicate by a dotted arrow. The pointer is interpreted as causality, expectation, or temporal contiguity. Suppose, for example, that motoric information (gained from practice) is not integrated into the concept as a subconcept, but only associated to it. This situation is schematically represented in Fig.4, II. What performance would we expect if such a conceptual structure is built? First, a concept and its subconcepts, as in Fig. 4, I, forms a chunk and can be processed as a unit. But information that is only associated, as in Fig. 4, II, is not chunked with the information that points to it. It is likely that one can activate the concept A but not be able to follow the pointer to D. Intuitively, the subconcept relation brings with it annexation, while the association relation provides only a path.

IV. The Experiments

In our first experiment in this study, we compare performance of people who build the lift from memory after watching the videotape to performance of those who build from memory after interactive instructions during which they actually build the lift. If the above theoretical hypothesis is correct, that motoric, visual, and verbal elements automatically become subconcepts of the same concept when they are present in interactive instruction with simultaneous practice, then the prediction is straightforward: Interactive instruction with building on-line should be better than passive video. The first allows integrated concepts; the second provides no motoric component.

Method

Subjects. Sixty-four students, 32 of each gender, participated as part of the University of Colorado Psychology 100 course requirement. Half (16 of each gender) were assigned to the videotape group and half to the interactive build-on-line group.

Design. The design was a 2 (instructions) x 2 (gender) between subjects ANOVA.

Stimulus materials. The videotape and interactive videodisc-based presentations described above were used.

Procedure. Subjects were run individually. First they filled out a short questionnaire asking their major, native language, and an estimate of their experience with assembly kits. They were told, "Today you're going to be given instructions on how to build a fairly complicated object from a kit of pieces. After the instructions, you'll be asked to build the object from memory, so try to learn as much as you can from the instructions. You will be instructed via videotape (one group) or by using an interactive videodisc-based computer system (the other group)."

Subjects then performed a matching task, with the following instructions:

"First, to get you accustomed to the pieces in the assembly kit and their names, please do this matching task. You have before you a collection of one of each of the 48 different pieces in the kit and some sheets of paper containing the 48 names. Spread the sheets out in front of you and put each piece by its correct name. This is not a test. If you have trouble or want assistance, just ask the experimenter, and she (or he) will help. When you're done, the experimenter will check your matches and correct any you missed."

The matching task took about 5 min.

Subjects in the videotape group were positioned before a 15 in. color tv monitor and reminded to learn as much as possible for the memory trial. They placed their chair across from the monitor at any distance they wanted, and the 27 min tape was started.

After the tape was completed, they moved to another table to begin the memory trial. They were reminded to build a lift as much like the one they had seen built as possible, and they were told there was no time limit. The experimenter had a kit of pieces, and the subject was required to ask for them one-by-one, either by name or by pointing. The subject had a folder with color photos of the pieces and their names, to aid in getting the pieces. The subject was told that pieces did not have to be used once they were requested; they could be left aside and never used if the subject desired. The experimenter recorded the time the subject requested the first piece and the time the subject quit, and the order in which the subject requested the pieces.

(A subjective observation of experimenters testing subjects from all groups was that they very much enjoyed doing the task. They typically started off quite accurately, and when their memories began to fail, they would create, making comments such as, "I can make a lift better than the one in the instructions." Experimenters were encouraging and positive to all subjects, and subjects did not seem to lack motivation, although this was not objectively measured.)

Subjects in the interactive videodisc-based group, after doing the matching task, sat before the InfoWindow monitor. The experimenter explained that the presentation showed a step-by-step procedure for assembling the object, and that the subject could have some control over what was shown by touching labels on the touch screen. The labels were: *next, pause, short replay, long replay, very long replay*, and *replay whole presentation.* The meaning of each was explained. The subject was told to build the object once while watching and to prepare for a memory trial immediately afterwards. He or she was told that there was no time limit; the instructions could be reviewed as long as the subject wanted, and played again from the beginning if the subject desired. The subject could build at any time: while the video was moving, or while there was a still frame. During the presentation, subjects were required to ask for pieces one-by-one. (They had folders with photos and names of pieces as above.) The experimenter provided the pieces and typed in their abbreviated names as they were requested. These names and all touches made by subjects were automatically recorded (with time stamps) on a log file provided by IBM's Composer/Conductor software.

The procedure for these subjects' memory trial was identical to that described above for videotape subjects.

Results

Scoring.. An abstract graph of each subject's lift built from memory was drawn. Pieces were drawn as nodes, and physical connections were drawn as links. A graph of the correctly assembled lift is shown in Figure 5. (The solid and dotted lines in Fig. 5 correspond to the sub- and subsubassemblies shown in Fig. 2.) Nodes are numbered to correspond to particular pieces in the lift, as shown in Figure 1. To score a subject's lift, the number of correct connections was counted. (There are 104 connections in the correctly built lift.) For example, is node 1 connected to node 4? 2 to 4? 2 to 80? This measure tells how similar in structure the lift built from memory is to the correctly assembled lift. In addition, a functional score, either yes or no, was taken. Does the lift work? Namely, can something be turned resulting in a carrier going up and down a tower? (Lifts were scored by two people, and when there was disagreement, a third person broke the tie.) We first note that not one subject in any group built a perfect lift from memory.

Insert Fig. 5 and Table 1 about here.

Comparison of Interactive vs. Passive Instruction. Rows 1 and 2 of Table 1 give memory performance for both structure and function in the two groups, broken down by gender. (Measures of time and efficiency, and number of pieces used in the memory trial, discussed below, are also given.) First, there are no gender differences. But more surprisingly, there are no significant differences in structure or function between the group viewing the videotape and the group receiving interactive instructions and building on-line! (F values < 1 in all cases;

statistics are reported below.)

The question is, why is interactive instruction with building on-line not better than passive video? Why can't people listen and watch and do simultaneously? Baggett & Ehrenfeucht, 1983, showed that people can listen and watch very well simultaneously, e.g., a movie. But here we find that when practice is added, there is no additional benefit. The theoretical hypothesis was that when instructions provide motoric, visual, and verbal components, they automatically sit together in the same concept (become subconcepts of the same concept), as in Fig. 4, I. Hence performance and retention of a procedure are best. What modification of the hypothesis is needed? We note that the interactive instructions with building on-line are quite a different situation from the helicopter experiment reported above, in Baggett (1987). For example, here practice is mixed with video; above they were entirely separate.

Interactive Instructions with No Building On-line

We first hypothesized that the interactive-build group above had a dual motoric task (build the lift *and* operate the touch screen). Perhaps, we thought, operating the screen interferes with learning to build. Therefore we hypothesized that subjects who used the interactive instructions as above (i.e., operated the screen) but who were not allowed to build on-line would perform even worse from memory than either the group with video alone or the group building on-line: the motoric processor would have a task (operate the screen), but the movements required are not related to learning to build the lift. Thirty-two subjects were run as before. They were given interactive instructions but were not allowed to build on-line. They built only once from memory, after their interactive trial.

The results from this group, termed interactive no-build, are given in Row 3 of Table 2. They perform best of all, although not significantly so. We define a new measure, efficiency, as the number of correct connections per minute of total time to work. (Total work time = study time + memory trial time.) Using the efficiency measure, the interactive no-build group (efficiency = .645) is significantly better than the interactive build group, efficiency = .51 (t(90 df) = 2.96, $p < .01$; Winer (1971), p. 385), and significantly better than the passive video (.565) and interactive build groups together (multiple comparisons, F(1,90) = 5.86, $p < .05$), but not significantly better than the passive video group alone (t(90 df) = 1.93, n.s.).

The fact that the no-build group performs as well as the build group on structure and function, and better on efficiency, is both theoretically and practically interesting. For this task, motoric elements during interactive instruction do not help later performance, and, when the measure is efficiency, actually hinder performance! We note that the motoric elements required in the task of building the lift are actually known to all subjects: everybody can join together two blocks. What subjects must do is associate known motoric actions with the task of building the lift. This situation is different from, for example, learning to play tennis, where people have to learn basic motoric skills. In tennis, the most important element is practice.

Interactive Instructions with Building while Screen is Black

Thus far, it appears that motoric elements given during training are not integrated into the task of building the lift. We next hypothesized that the problem for the interactive-build group was one of divided attention for the visual system: One must watch the screen, and watch one's hands while building. Perhaps this dual visual task was causing the decrement in performance. So we ran a fourth group of subjects as follows. Subjects were given interactive instructions and required to build on-line, but they could build only when the screen was *black* . A small modification was made to the interactive instructions used previously. A new touch area, labeled "build," was added. Whenever the subject desired to build on-line, he or she was required to touch "build," and the screen went black, with the word "return" in the corner. When the subject finished building, he or she touched "return" and the screen returned to the exact frame at which it had gone black. The subject could then check what had been built, and if changes were needed, "build" had to be touched again.

In the black screen presentation, at a given moment, a viewer's attention is not divided. One watches the screen or watches one's hands, but not both. The subject actually performs a memory trial *during* the interactive trial. Namely, the subject builds, working only from what he or she has in his or her head, without a picture. The subject actually gets *less instruction* , in the sense that instruction is taken away! Also the subject engages in problem solving during the interactive trial. That is, the subject must figure out what to do; in the other interactive build group, the subject could merely copy from the screen.

Forty-four subjects (22 of each gender) were run in the black screen group. The procedure was identical to the other interactive groups, except subjects were told that they could build on-line only when the screen was black, and about how to make the screen black and to bring it back to normal using the touch screen. They were told to prepare for a memory trial after their interactive trial, and immediately after the interactive trial, they built the lift from memory.

Table 2, Row 4 gives the results on the memory trial for the black screen group. Building only when the screen is black helps males -- they score 64% on structure from memory. This is highest of any group, but not significantly higher than the interactive-no build males, who score 61.2%. But the black screen instruction hurts females -- they score only 49% on structure, lowest of any group, but not significantly lower than the interactive-build females (51%) or the passive video females (51%). Overall, the black screen presentation leads to slightly but not significantly worse performance than the interactive-no build presentation, and for the first time there is a significant gender difference, with males performing better than females, $t(42\ df) = 2.39$, $p < .03$.

Thus far, then, we have not found a presentation condition in which practice is included in instruction and performance on a later memory trial yields significantly better structural or efficiency scores than when practice is not included!

Interactive Instructions with 7-day Delay Between Training and Test

In the toy helicopter experiment of Baggett (1987), people who practiced during training far outperformed those who received only audiovisual instruction, when the test was a later memory trial. (Their practice, as discussed above, was copying from a model; it was not practice mixed with interactive instructions.) Further, when a 7-day delay was put between training and test, the difference in favor of the group who practiced was even greater. Theoretically, the result showed that *retention* of a procedure for assembly is especially poor when no motoric component is provided in the original instruction.

In one last attempt in this study to find an experimental condition in which practice during interactive instruction gives an advantage over no practice, we ran two more groups. They were identical to groups 2 and 3 in Table 1 (interactive-build and interactive-no build), except a one-week delay was put between their training and test sessions.

Thirty-two subjects (16 of each gender) were run in each of the 7-day delay groups. The procedure was the same as before; one group built on-line during instruction, and the other did not. Both were told to prepare for a memory trial session 7 days later. Rows 5 and 6 of Table 1 give the results.

Two ANOVAs were performed, on both structural and efficiency measures. Each was 2 (gender) x 2 (instruction: build vs. no build) x 2 (delay: 0 vs. 7-day). For the ANOVA analyzing structure, delay was the only significant effect, $F(1,120) = 21.8$, $p < .001$. The ANOVA on efficiency yielded two significant effects. First was instruction, $F(1,120) = 9.1$, $p < .01$; delay was also highly significant, $F(1,120) = 61.9$, $p < .001$. Thus, the no build groups perform better than the build groups on efficiency, and those tested at zero delay perform better than those tested after a week.

The results are fairly straightforward to interpret. Once again, there is no advantage to practicing during interactive instruction: overall, the no build groups perform as well as or better than the build groups. On structural scores, females tested after a week average 43.4 (build) and 33.6 (no build). A two-sample t-test determined that the difference was not significant, $t(30\ df) = 1.52$.

The last column in Table 1 shows the mean number of pieces requested during the memory trial. It varies from 63 to 74, with the 0-delay build and no build groups averaging 68 and 74 respectively, and the 7-day delay build and no build groups averaging 64 and 67 repectively. These differences show that the build groups have good visual recognition of the pieces needed in the lift. While they do not score higher on structure or function than the no build groups, they are somewhat better at picking out the correct pieces. Thus practice during interactive instruction gives a small (but not significant) advantage: piece selection is more accurate.

Insert Figs. 6 and 7 about here.

Figure 6 shows percentage correct connections for the 0-delay build and no build groups as a function of section of the lift worked on. The x-axis lists the subassemblies of the lift in the *order in which they were presented in the instructions*. For example, subassembly 1 is T-platform, subassembly 2 is stopper, etc. (See Figure 3 for the order.) Figure 7 shows the 7-day delay data, divided by gender. These graphs show that performance within a subassembly is quite stable over groups, that subassemblies vary considerably in their difficulty, and that performance gets steadily worse the later in instructions it is taught. One reason for the degradation, of course, is that later connections in the lift are sometimes dependent on earlier ones. For example, one cannot correctly connect the column to the lift base unless certain parts of the lift base are built correctly.

Discussion

When this experimental work was begun, the expectation was that practice during interactive procedural instructions ought to aid in learning and retaining the procedure. Yet we found, in a series of six different experimental conditions, that groups who practiced never significantly outperformed those who did not practice, and sometimes the practice groups performed significantly worse.[4]

The procedure to be learned, assembling an 80-piece object from a kit of pieces, is quite lengthy but does not take much skill. For example, people building the object from a model can copy it perfectly without much difficulty. Thus the problem is not in acquiring the skill to perform the actual movements. Rather, our view is that one must link together *as a subconcept* the movements required and the concept of building the object. It appears that this subconcept linkage is not formed when practice is mixed with interactive instruction. Rather, we hypothesize that the situation is like that shown in Fig . 4, II: the motoric components are merely pointed to. However, it *does* happen when practice occurs mixed *sequentially* with video instruction (Baggett, 1987). Namely, the situation is like that shown in Fig. 4, I: the motoric elements are a subconcept. In order to change the linkage of the motoric components from pointer to subconcept, as shown in Fig. 4, III, we hypothesize that one of two things must happen: (1) practice must be sequentially and not simultaneously arranged with audiovisual instruction; or (2) there must be more extensive practice, as we discuss below.

Related Explanations

We offer here three related interpretations of the findings of this study. In our framework of multimedia concept formation, different processors can work simultaneously. The interaction between processors can be competitive or cooperative. If it is competitive, two processors share some resources (Norman and Bobrow, 1975) and compete for who is going to control the resource. If it is cooperative, one processor has information that is needed for another, and simply provides it. It as if the processor says, "I already prepared this--you can use it."

1 and 2. Overloading a Processor or Sharing a Resource

In the task given to our subjects, we have hypothesized that several processors are involved, and we have also hypothesized about what each is doing. When performance is better than one would expect in the situation, it is an example of cooperation. When it is worse, we look at two possible interpretations:

1. Overloading of one of the processors: One processor is doing more than expected, and therefore there is a bottleneck. For example, the results of the interactive build group (2 in Table 1) made us suspect that the *motoric* processor was overworked. It is involved in hand movements (operating the screen and building the lift) and in eye movements (directing the eyes). The "extra" task of building on-line could have created an overload. In our framework, if a processor is overloaded, its needs exceed the resources available. For example, the processor cannot do the task in the time allotted, or it cannot do it with the memory allotted. So something must go.

In forming a multimedia concept, the central processor creates a motoric node. The motoric processor provides a value for the node. That is, during encoding, the motoric system prepares a value that is stored. It might be that when one practices on-line, the motoric system does not prepare a value that is stored. Instead, it keeps track of what the person is doing, and this prevents it from providing a value that goes into the node.

To put it another way, movements seem to distract one from paying attention. A possible explanation is that any kind of coordinated physical movement requires a large amount of information to pass between the brain and peripheral nervous system. This means, informationally, that the system is working at full capacity. Therefore there is no room for passing other information; there is too much traffic.

A hypothesis, then, is that there is a three-part scheme: plan, execute, reflect. Perhaps learning and planning take part before or after the action, but not during.

Or it could be that the visual system is overloaded. Here we hypothesize the same mechanism as above, but now the motoric system is putting an extra requirement on the visual system, to look and keep track.

Theoretically, these two hypotheses could be distinguished. The first (the motoric system is overloaded and does not provide a motoric value) implies that there would be poorer performance in speed or accuracy when the person was presented with a visual or verbal stimulus and told to do the task. The second (visual system overloaded) implies that a task involving just visual recognition would be impaired. As we noted above, visual recognition (ability to choose the right pieces) is slightly better in the build groups, indicating that if there is an overload, it probably lies with the motoric processor.

2. If two processors are in competition, one could be impaired because of having to share a resource. This hypothesis is difficult to distinguish from the previous one, because it is not easy to specify what a shared resource might be.

3. Timing and Synchronization

Another explanation involves timing. Timing could be a problem if, from the point of view of each processor, there is no difficulty, but passing information between processors, i.e., communication, is out of synchrony. Within the model, no processor is overloaded. Each element (node and value) in the multimedia concept formation is created correctly, but they're not assembled correctly. The elements are satisfactory, but the graph formed is not.

This hypothesis we think is worth pursuing, because, if it is true, following further the black screen idea, to force a person to perform specific tasks with specific timing, could lead to very strong differences in performance. Another reason it is worth pursuing is that it is optimistic. It means people are good information processors if information is organized correctly. It leaves open the possibility that one can learn by doing.

Subjects in the no build groups above were not given practice during training. But it is possible that they constructed motoric values for their concepts based on what they were shown, i.e., they imagined the (correct) movement. Subjects in the build groups were given actual practice, which they might have stored as motoric values. But they did not perform better that the no build groups. People building on-line did not always build lifts perfect in every detail, and there were certainly moves made in on-line assembly that had to be corrected. When one is not satisfied with practice, one may have a conflict between how it should be done and how one did it. What would one remember from training?

If hypothesis three is correct, then there is a definite prediction. If the subject is allowed to practice until he or she is proficient, then practice should not interfere and should help. If the subject is forced to quit before he or she is proficient, then practice is harmful. Partial knowledge may be worse than none.

We certainly do not consider that this study settles the issue of the role of practice in interactive procedural instructions. But it does dispel one popularly held intuition: that on-line practice always gives better performance.

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Footnotes

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[1] After running the passive video group, we learned that the particular videotape used resulted in significantly better performance than did two other videotapes showing the lift's construction that we have used in previous work (Baggett & Ehrenfeucht, in press).

[2] Since our interest was the role of practice in interactive instruction, we did not compare performance from many other possible groups, e.g., a group whose training consists of simply copying from a physical model (as in Baggett, 1987).

[3] In our framework (Baggett & Ehrenfeucht, 1982), a processor is a partial function from a state of memory and some input into a state of memory and possibly some output. It changes the state of memory and provides interaction with the environment.

[4] It is possible that some other experimental arrangement, such as having only the correct pieces available during training and/or test, would lead to better performance by groups that practice. Our framework does not make a specific prediction about this; the question could be answered empirically.

Figure Captions

1. An 80-piece object, called a *lift*, made from the Fischer-Technik assembly kit.

2. "Typical" breakdown of the lift into sub- and subsubassemblies. This hierarchical tree was derived from data from humans, as explained in the text.

3. Design of the interactive videodisc-based instructions for assembly of the lift. Arrows indicate options available to subjects via touches to labels on the touch screen. Touching "next" took a subject to the next unit. "Short replay" replayed the unit just viewed. "Long replay" replayed the previous two units. "Extra-long replay" replayed an entire subassembly. And "replay whole presentation" replayed from the beginning.

4. Three possible relationships among concepts and subconcepts, as viewed in our multimedia framework. I shows a concept A with 3 subconcepts, B (visual), C (linguistic) and D (motoric). II shows A with 2 subconcepts, B and C; A is associated to (pointing to) D, but D is not a subconcept of A. III shows the incorporation or annexation of D as a subconcept of A.

5. Abstract graph of the lift shown in Fig. 1. Nodes indicate pieces in the lift, and links indicate physical connections. The numbers in Fig. 1 correspond to the identically numbered nodes in Fig. 5. The graph is divided into the same subassemblies (solid lines) and subsubassemblies (dotted lines) given in Fig. 2.

6. Mean percentage correct on each subsubassembly when building from memory for the four groups tested at zero delay, as a function of when the instruction was presented. A linear regression analysis yields y = 85.6 - 4.14x, R = 0.72.

7. Mean percentage correct on each subsubassembly when building from memory for the groups tested after a 7-day delay, as a function of gender and when the instruction was presented. A linear regression analysis yields y = 65.8 - 3.4x, R = 0.62.

Table 1.

Data from six groups of subjects who built the lift (shown in Figure 1) from memory after different types of instruction and different delays.

	mean % correct connections in lift built from memory (lift has 104 connections)	number of functional lifts built from memory	mean time taken for training trial (passive video group: tape length; other groups: interactive trial length (minutes)	mean time taken for performance from memory (memory trial) (minutes)	mean total time for instruction (training + memory) (minutes)	mean overall efficiency (% correct connections + total time)	average number of pieces requested in memory
group:							
1. passive video (32 subjects)	50.4	17 of 32	27	64.95	91.95	.565	73.45
males (16)	49.4	9 of 16	27	70.8	97.8	.53	76.8
females (16)	51.4	8 of 16	27	59.1	86.1	.60	70.1
2. interactive-build (32 subjects)	52.2	16 of 32	59.7	43.45	103.1	.51	66.5
males (16)	53.1	9 of 16	60.1	42.9	102.9	.51	69
females (16)	51.3	7 of 16	59.3	44.0	103.3	.51	64
3. interactive-no-build (32 subjects)	59.5	19 of 32	44.25	49.6	93.85	.645	74.7
males (16)	61.2	12 of 16	43.6	49.3	92.9	.67	78
females (16)	57.8	7 of 16	44.9	49.9	94.8	.62	71.4
4. interactive-build when screen black-0 delay (44 subjects)	56.9	19 of 44	72.3	45.25	117.55	.50	69.45
males (22)	64.2	17 of 22	70.2	43.4	113.6	.59	74.7
females (22)	49.4	7 of 22	74.4	47.1	121.5	.41	64.2
5. interactive-build-7 day (32 subjects)	42.85	19 of 32	62.7	83.9	146.6	.295	63.75
males(16)	42.3	11 of 16	56.7	82.1	138.8	.30	66.2
females (16)	43.4	8 of 16	68.7	85.7	154.4	.29	61.3
6. interactive-no build - 7 day (32 subjects)	40.6	19 of 32	43.0	82.0	125.0	.355	66.75
males (16)	47.6	12 of 16	40.6	82.0	122.6	.43	72.6
females (16)	33.6	9 of 16	45.4	82.0	127.4	.28	60.9

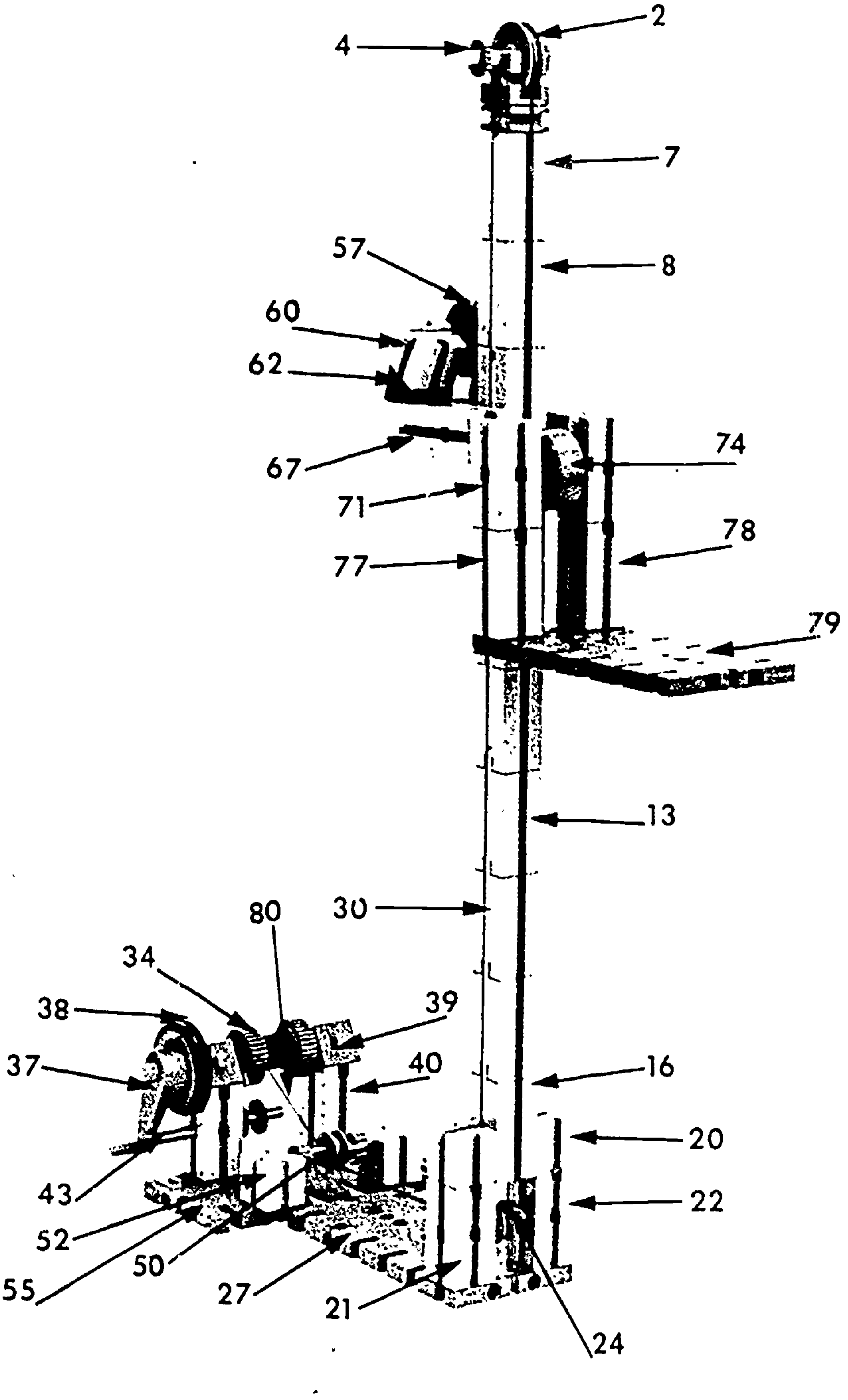
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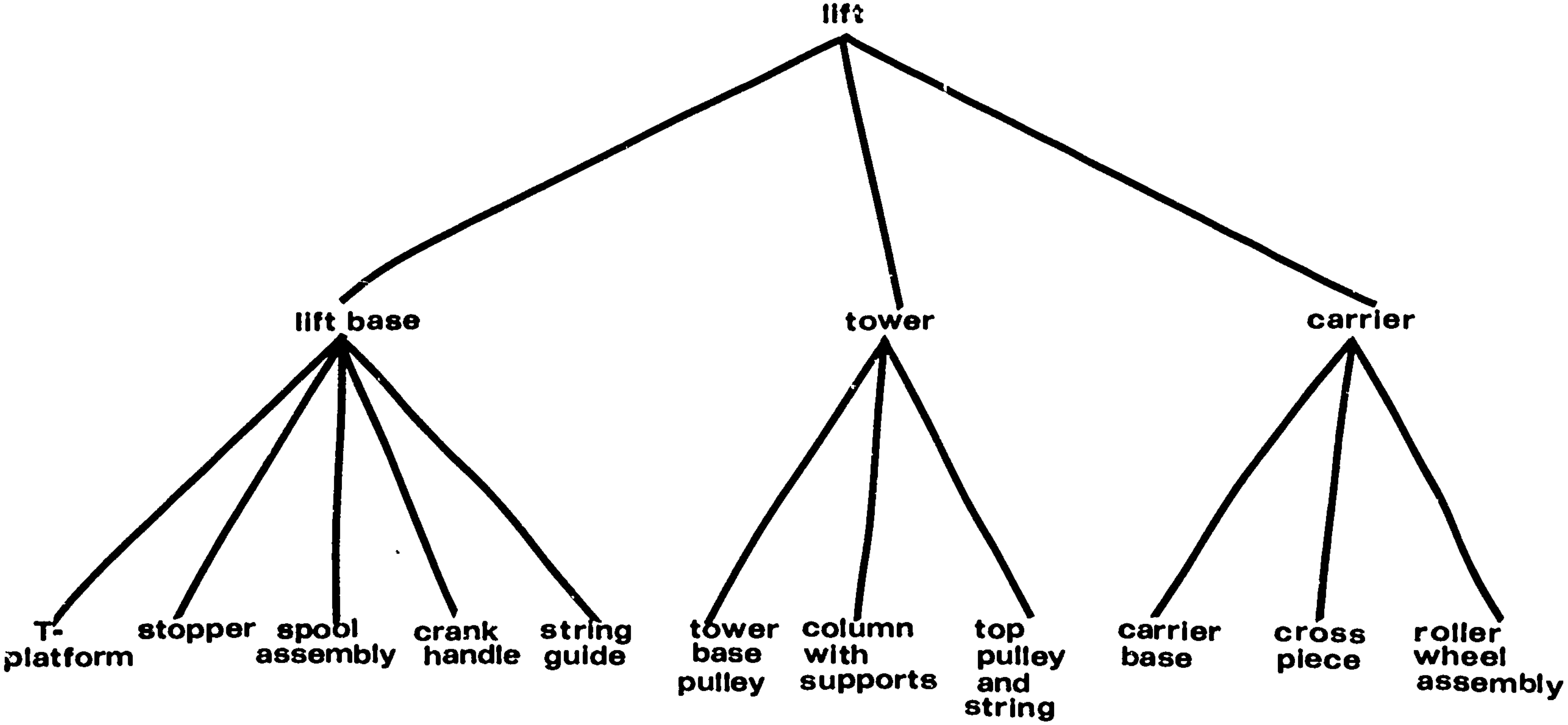
Figure 1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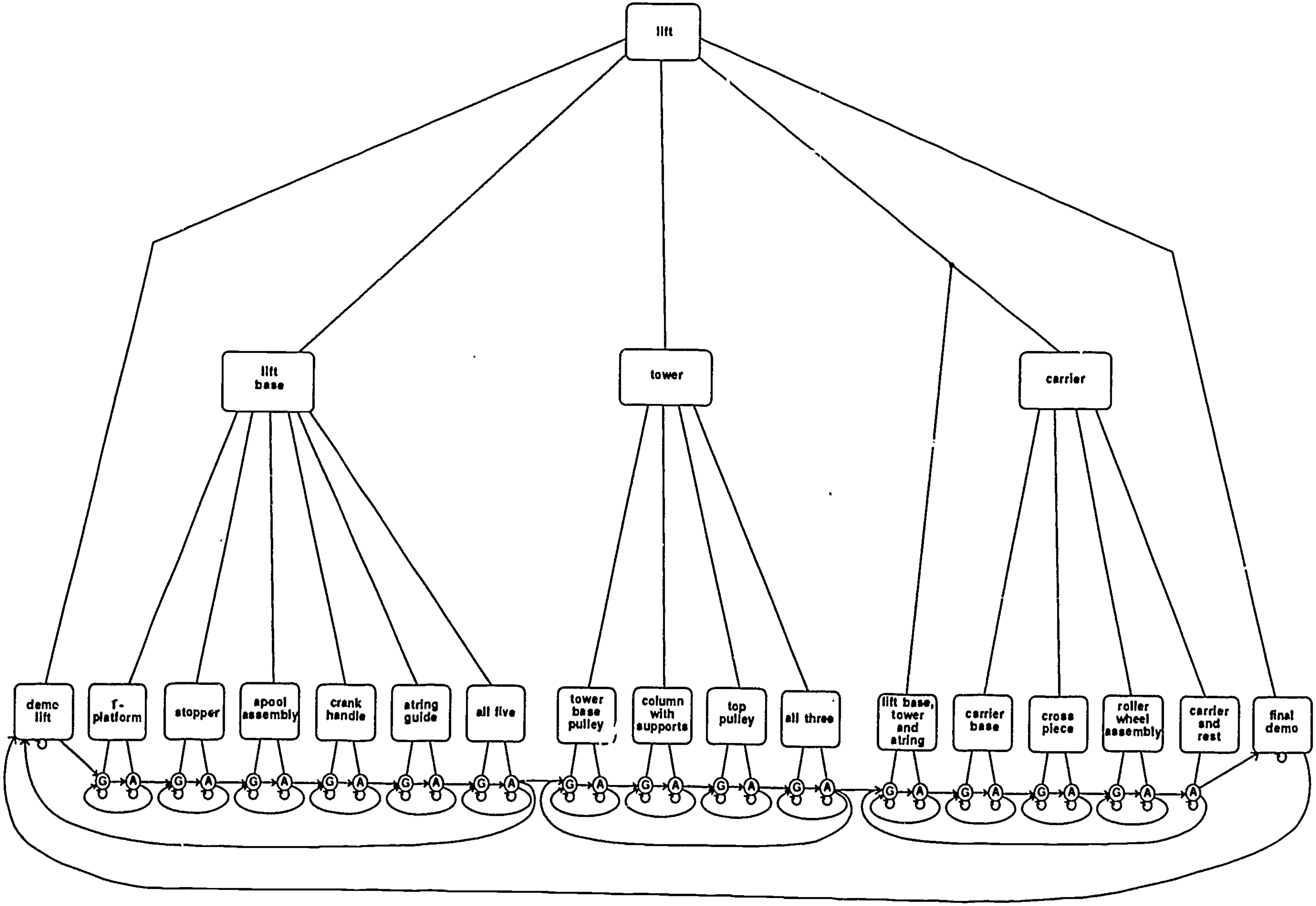
column with supports
top pulley and string
carrier base
cross piece
roller wheel assembly

Figure 2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tower base pulley
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carrier base
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roller wheel assembly
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Figure 3

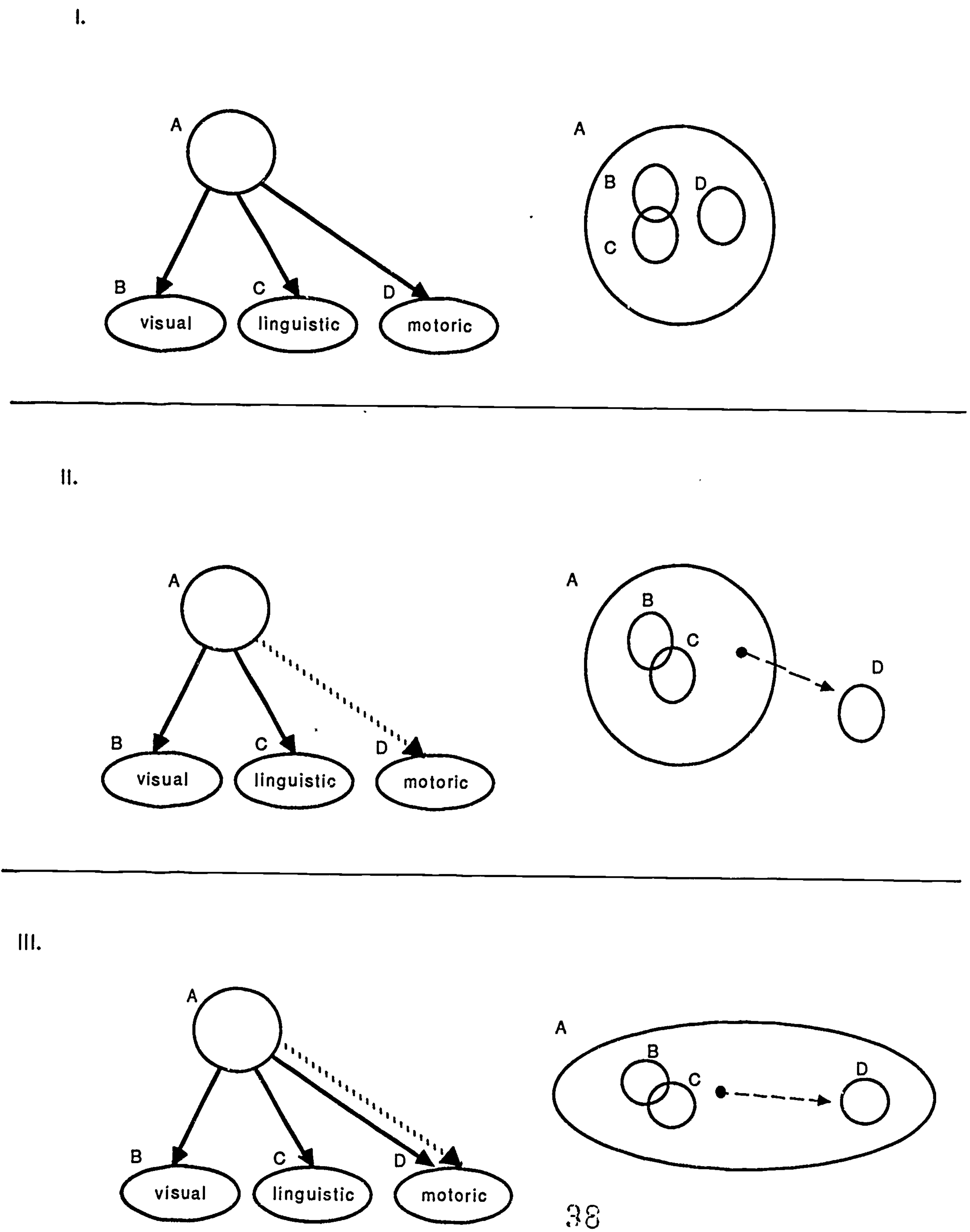
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Figure 4

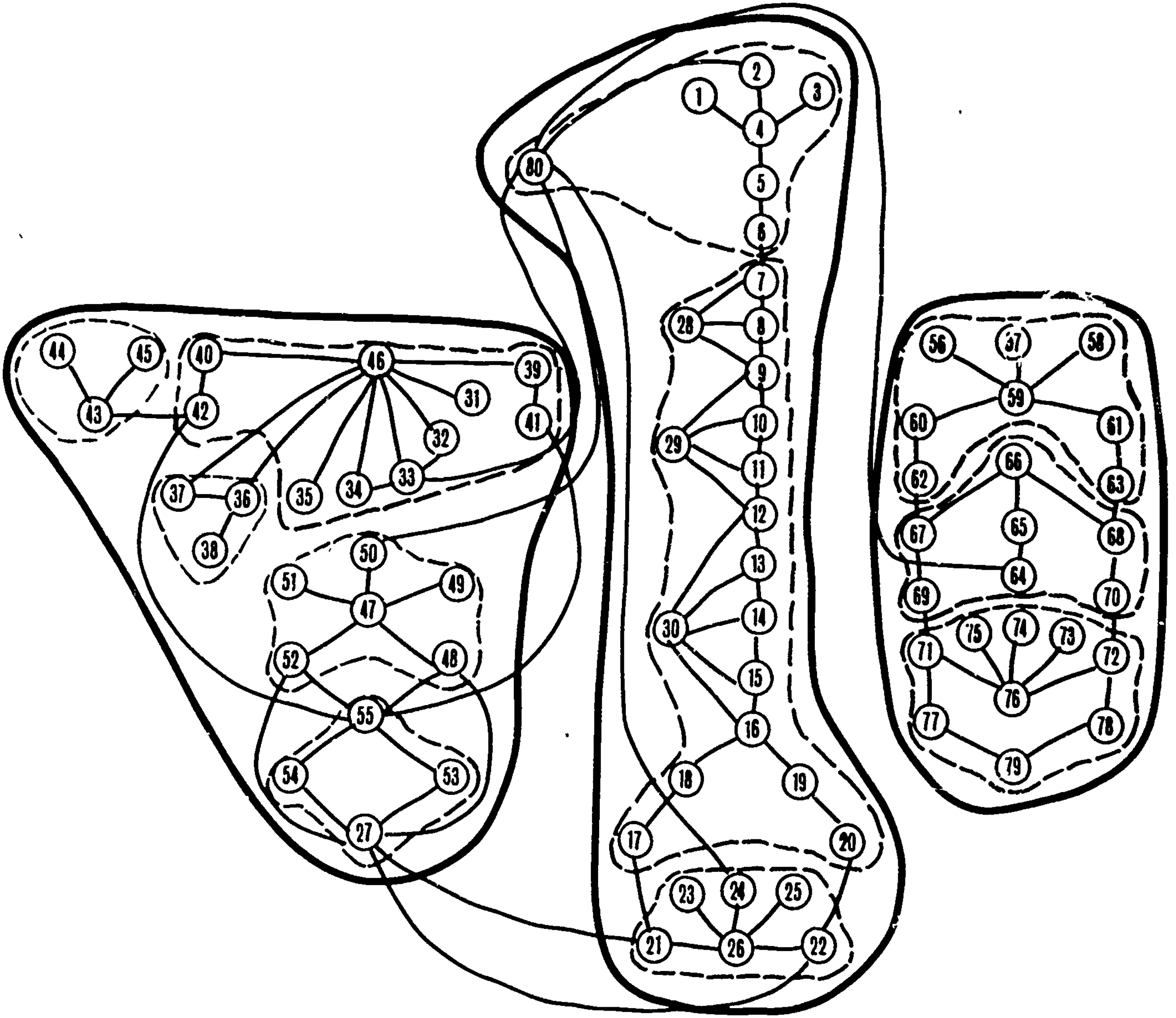

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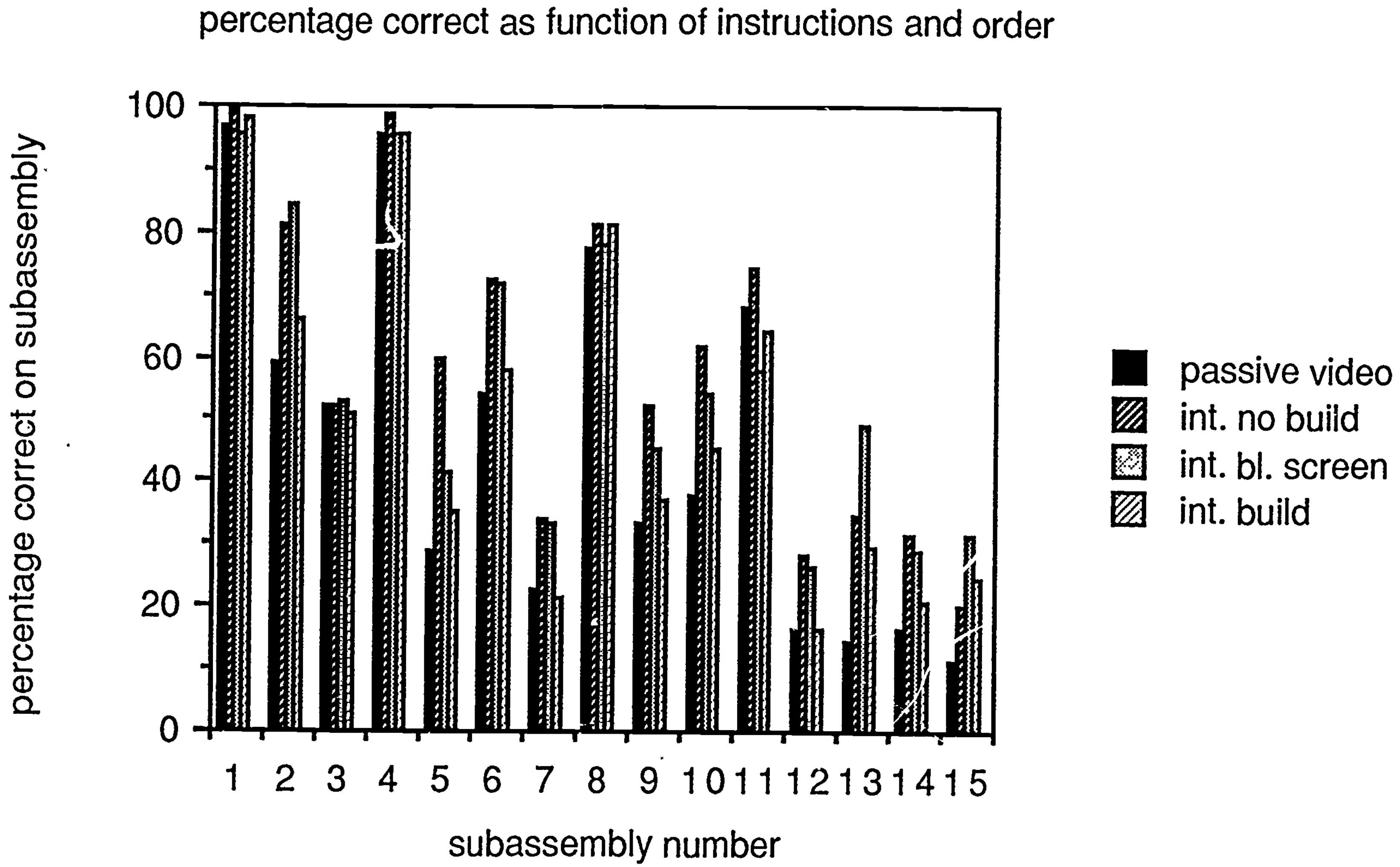
Figure 5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percentage correct on subassembly
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subassembly number
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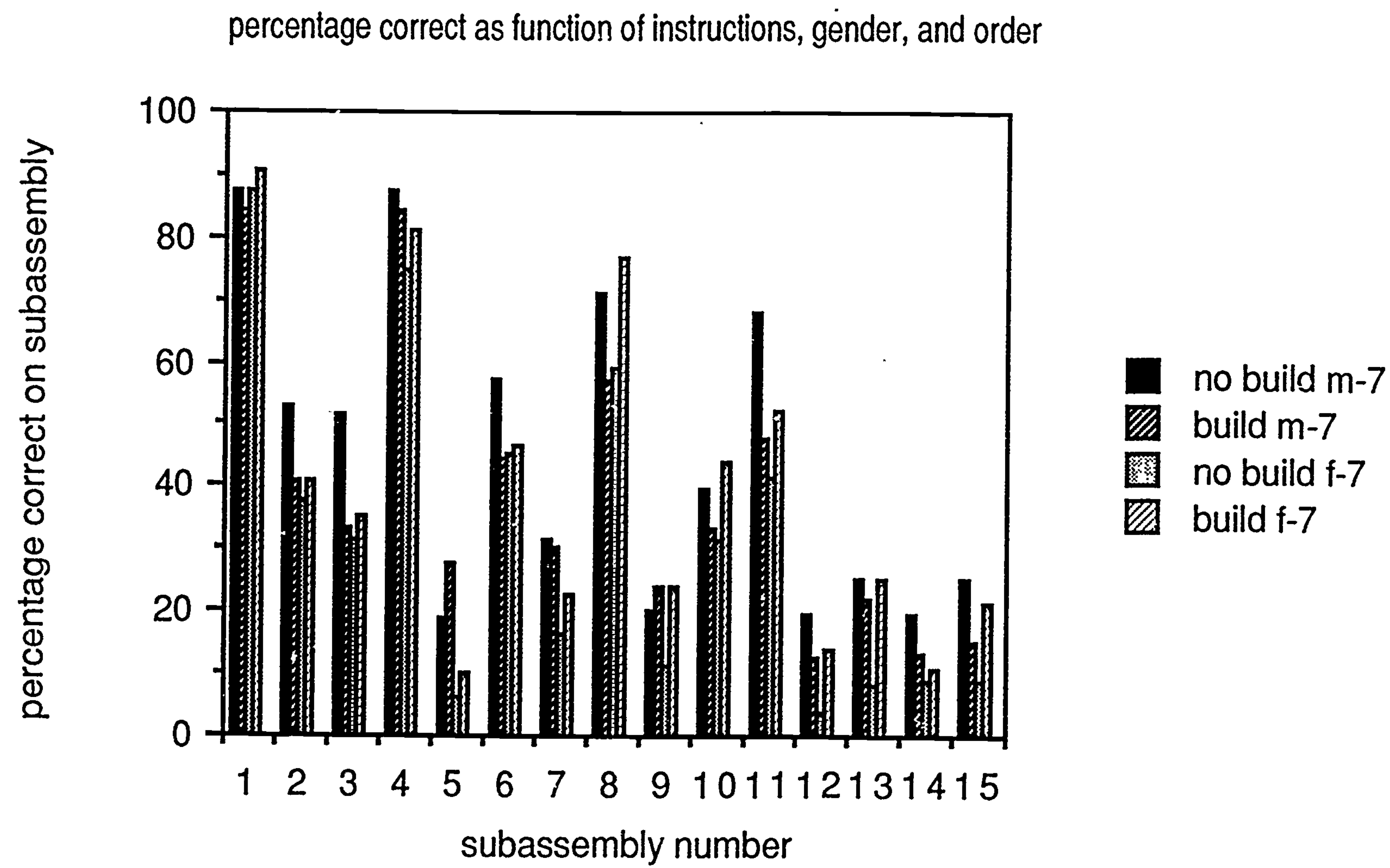
int. bl. screen
int. build

Figure 6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■ no build m-7
▨ build m-7
▩ no build f-7
▨ build f-7

Figure 7

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