Visual Displays and Contextual Presentations in Computer-Based Instruction

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The effects of two instructional strategies, visual display and contextual presentation, were investigated in the acquisition of electronic troubleshooting skills using computer-based instruction. Three types of visual displays (animation, static graphics with motion cues, and static graphics without motion cues) were used to represent structures and functions of electronic circuits and troubleshooting procedures. The first hypothesis was that animation would be more effective than static graphics, but that static graphics with adequate motional cues representing the dynamic aspects of the task would accomplish results similar to animation. Results supported this hypothesis. The second hypothesis was that context-dependent instruction would be more efficient than context-independent instruction for solving problems in similar contexts, but that context independent instruction would be more effective in solving problems encountered in different contexts. The results supported this hypothesis. A general conclusion of this study is that the use of visual displays and contextual presentation should be based on the learning requirements of the task and the expected roles of the strategy in the learning.

☐ Since Wundt (1912) claimed at the turn of the century that all thought processes were accompanied by images, numerous studies have been conducted to understand visual thought processes (see Kosslyn, 1980) and to investigate instructional strategies facilitating those processes in learning (diSessa, 1982; Levin & Lesgold, 1978; Mayer & Anderson, 1991, 1992; Mayer, Bover, Bryman, Mars, & Tapangco, 1996; Mayer & Sims, 1994; Reiber, 1990a). The instructional effectiveness of animation as a device for facilitating the visual learning process has been a primary issue in many recent computer based instructional (CBI) studies because of animation's perceptually attractive, realistic and engaging attributes. The use of animation—artificially generated movements of pictures or graphics in computer displays—will continuously increase as the capacity of computers to develop and present such displays improves.

Many studies have been conducted to investigate the effects of animation in different instructional delivery environments, including film, television and computer, since the early 1900s (Freeman, 1924; Park & Hopkins, 1993). However, the results are inconsistent, with animation having positive effects in some studies (Baek & Layne, 1988; Park & Gittelman, 1992; Reiber, 1990b; Reiber, Boyce, & Assad, 1990; Rigney & Lutz, 1976), but no reliable differences between animation and static visual displays showing in other studies (Peters & Dalker, 1982; Reed, 1985; Rieber, 1989; Reiber & Hannafin, 1988). After reviewing 25 empirical studies in which the instructional effects of different visual displays, including animation and static graphics/pictures, were investigated, Park and Hopkins (1993) concluded that the inconsistent findings resulted from theoretical and methodological problems associated with the use of the specific attributes (i.e., motion) of the visual displays investigated. According to Park and Hopkins, most studies that found significant effects of dynamic visual displays were guided by theoretical rationales which derived the appropriate uses for dynamic and static features of visual displays and their presumed effects. Accordingly, the learner variables, the learning requirements in the task, and/or the medium characteristics were adequately coordinated in most of these studies.

Visual displays, whether animated or static, facilitate learning only when their attributes are congruent with the specific learning requirements of the given task (Mayer & Gallini, 1990; Mayer, Steinhoff, Bower, & Mars, 1995; Reiber, 1990b). Consequently, features of such displays should be applied selectively. For example, graphical animation has been effectively used to teach abstract and dynamic concepts in physics, such as Newton's Law (diSessa, 1982; Kaiser, Proffitt, & Anderson, 1985; Reif, 1987; Reiber, 1990b). Visualizing an object's movement using animation is helpful for the understanding of dynamic concepts such as velocity (White & Frederiksen, 1990) because direct observation of those concepts in the movement of actual objects is practically impossible. However, many studies have given little consideration of theoretical and pedagogical rationales for using specific attributes of visual displays in congruence with learning requirements of the given task and students. Also, many visual displays, including animation, have been used without accompanying adequate verbal information. Studies by Mayer and his associates (Mayer, 1997; Mayer & Anderson, 1991, 1992; Mayer et al., 1996; Mayer et al., 1995) suggest that more meaningful learning is fostered when visual displays are presented with adequate narratives explaining their instructional roles in the given content.

Animation has several important instructional roles, including: (a) attracting and directing student attention; (b) representing domain knowledge involving explicit or implicit movement (e.g., diSessa, 1982; White, 1984), and (c) explaining complex knowledge or phenomena such as structural and functional relationships among system components (e.g., Woolf, Blegan, Jansen, & Verloop, 1986). For example, Park and Gittelman (1992) used animation to explicitly represent the invisible behaviors of an electronic circuit (e.g., current flow), simulate system functions (e.g., working light bulb), and demonstrate troubleshooting procedures (e.g., step-by-step actions). Their study suggests that this strategic application of animation helps learners form mental models (Gentner & Stevens, 1983) that facilitate understanding of the system's structure, functions, and related troubleshooting procedures. Static graphics were not as effective because learners needed to construct their own motional images representing the system's behaviors from separate individual displays presented in static forms. However, some research (e.g., Kieras & Bovair, 1984; Norman, 1983; Park & Gittelman, 1995) suggests that people form mental models from their understanding of the system or task rather than from the form of externally presented information. For example, in Park and Gittelman's (1995) study, 76.6% of 48 subjects who studied electronic circuits using static graphics indicated that they imagine motion when they think about electronic circuits. This result suggests that static graphics can accomplish results similar to animation if they contain appropriate cues facilitating one's understanding of the system's dynamic functions and formation of appropriate mental models.

The present study investigated the instructional effects of three different types of visual displays: animation, static graphics with motion cues, and static graphics without motion cues. Electronic circuit troubleshooting was selected as the subject domain because the structural and functional representation of the circuit and troubleshooting procedures require the extensive use of visual displays, including animation. Having considered the advantages of animation for representing dynamic aspects of the task (i.e., functional behavior of electronic circuits), it was hypothesized that animation would be more effective than static graphics; but, static graphics with motion cues adequately representing the dynamic aspects of the task would accomplish similar results.

Along with visual displays, this study investigated contextual effects in instruction. Context in instruction is determined by the setting in which domain content is presented and learning takes place. Many researchers believe that both knowledge and skills are highly dependent on the context in which they are acquired (Choi & Hannafin, 1995; Lave & Wenger, 1991) and suggest that instruction should take place in appropriate contexts (Tessmer & Richey, 1997). Advocates of situated learning argue that cognition is intrinsically tied to contexts and that knowledge isolated from context cannot be transferred to real-life problems (Brown & Palincsar, 1989; Cognition & Technology Group at Vanderbilt, 1990,1993; Collins, Brown, & Newman, 1989; Spiro, Feltovich, Jacobson, & Coulson, 1991). In many formal learning settings, however, knowledge and skills are taught independently of context, even though people use concrete referents and tools extensively in every day situations, referencing thought and knowledge to specific contexts (Choi & Hannafin, 1995). Thus, it appears that context-dependent instruction is important for many educational settings in which students are supposed to develop intellectual ability for solving real-world problems. However, there is a significant amount of research evidence demonstrating the effectiveness of context-independent cognition on the transfer of knowledge and skills (Brown, 1994; Brown & Campione, 1994; Singley & Anderson, 1989). For example, most mathematical knowledge and skills learned through context-independent classroom instruction are successfully generalized to novel real-world contexts (Bassok & Holyoak, 1989; Elio, 1986; Reder & Ritter, 1992; Schoenfeld, 1985).

These inconsistent views and research evidence suggest that the value of context-dependent instruction varies in different learning situations. The context may be narrow and the context in which knowledge and skills are learned may be different from that in which they should be applied. Anderson, Reder, and Simon (1996) argue that the effect of context-dependent instruction is different depending upon the relation of the materials originally learned to the situation in which they should be applied.

The present study investigated the instructional effects of context in a well structured, narrowly defined domain. Unlike the ill-defined authentic contexts often experienced in daily life, the context for a well-defined domain is limited by its physical and functional structure, and the background setting or task environment is not critical for the acquisition of the required knowledge and skills. For example, troubleshooting electronic circuits requires following specific procedures such as checking the function of the output device and different components (e.g., voltage sources, gates, transistors, etc.) while searching for and correcting the cause of the problem. Most electronic circuits consist of the same basic components and their troubleshooting requires basically the same procedures, although their physical structures and functional applications are seemingly different. Consequently, when the domain is constrained and well defined as are electronic circuits, decontextualized learning may be as easily transferred as context-based learning.

In well-structured and narrowly defined domains, specific learning tasks (e.g., troubleshooting circuit components) and the context (e.g., a circuit) can be examined in the relationship of a whole and its parts. Also, whole- and part-task training research findings seemingly provide useful implications for the selection of contextual presentation strategies. The research shows that whole-task training is better when the interdependency is high among the parts, while part-task training is more effective when the interdependency is low and they represent "natural sub-units" of the entire task (Ash, 1988; Knerr et al., 1987; Mane, Adams & Donchin, 1989; Naylor, 1962; Naylor & Briggs, 1963; Newell, Carlton, Fisher & Rutter, 1989; Patrick, 1992; Wightman & Sistrunk, 1987). However, whole- or part-task training is different from context-dependent or -independent presentation because both types of training, whole- or part-task, can be presented in a same context. For example, an electronic circuit can be taught as a whole task in a context-independent situation or presented as a context in teaching its components (e.g., transistors and gates).

Many mental model researchers (e.g., Gentner & Stevens, 1983; Greeno, 1989; Kieras, 1988; Kieras & Bovair, 1984; Norman, 1983) argue that people form mental models from their perceived properties of the situation in which the task is presented and the mental models influence the process of their later interactions with other related situations. Thus, it is assumed that mental models formed in context-dependent learning environments will be most beneficial for solving problems encountered in similar contexts. However, mental models formed in decontextualized situations may be more beneficial than context-bound ones in solving problems encountered in new and more divergent situations because the context-bound models may not be directly applicable to the given situation and need to be substantially changed. Although most tasks are presented in a context, they frequently exist independent of the context or can be isolated from the context. Thus, mental models formed in decontextualized situations can be directly applied in any situation if they consist of essentially the same task components as the problem in the newly encountered situation. Because mental models are formed based on the perceived properties of the given situation, context-dependent instruction will help form the context-bound mental models; context-independent instruction will help form task-based mental models independent of the context. Consequently, it was hypothesized that context-dependent instruction would be more effective than context-independent instruction in solving problems in similar contexts; however, context-independent instruction would be more effective than context-dependent instruction in solving problems in new and divergent situations.

METHOD

Subjects

Subjects (n = 96) were 37 female and 59 male first year undergraduate students recruited from an introductory psychology course at George Mason University, Fairfax, VA. Before beginning the experiment, subjects were given a short questionnaire to ensure that they had little, if any, previous knowledge in electronic circuits and no experience with electronic troubleshooting. No subjects were eliminated from the data analysis because of their previous knowledge or experience. Subjects, who volunteered for the experiment, were paid $10 for their participation.

Design

A 3 × 2 factorial design was used, with 16 subjects randomly assigned to each treatment condition. The three levels of the first independent variable—the visual display—were graphic animation (GA), static graphics (SG), and static graphics with motion cues (SG-MC). The two levels of the second independent variable—contextual presentation—were context-dependent presentation (CDP) and context-independent presentation (CIP).

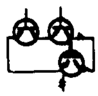
Each level of the two independent variables is described in detail in the following section (learning programs). The treatment conditions were parallel in all aspects except in the manipulation of the independent variables.

The dependent variables were: (a) number of trials needed to troubleshoot faulty electronic circuits that were structurally the same as the one used for instruction, in a performance test; (b) amount of time spent troubleshooting the faulty circuits in the performance test; (c) number of trials needed to troubleshoot faulty circuits that were structurally different from the one used for instruction, in a transfer test; and (d) amount of time spent troubleshooting the faulty circuits in the transfer test.

Learning Programs

The CBI program was designed by the experimenter, with consultations from a subject-matter expert (i.e., an electronic engineer), to faithfully represent basic electronic principles in such a manner that subjects would be able to understand and apply the information for troubleshooting faulty circuits after relatively brief instruction. The content was validated by the subject-matter expert. The program consisted of three parts: (a) a tutorial lesson for teaching the basic concepts, structures, and functions of electronic circuits (e.g., different levels of voltage and their sources, transistors, different types of gates, and output device) and the troubleshooting procedures (e.g., problem-space splitting and signal tracing); (b) a computer-based performance test consisting of 8 simulated electronic troubleshooting problems that required learners to identify and fix faulty components (transistor) in the same circuit as the one used for the tuto-

Table 1 ☐ Electronic Circuit Components Taught in Tutorial Lesson*

Name	*Function*	*Symbol*
Low-Voltage Power Source	Generates and sends low voltage to any component directly connected to it.	
High-Voltage Power Source	Generates and sends high voltage to any component directly connected to it.	
Transistor	The basic component of a circuit. The center piston moves to allow high or low voltage to the rest of the gate or circuit.	
OR Gate	Consists of two transistors joined side by side with two inputs and one output. Emits high voltage if either or both transistors receive high voltage. Emits low voltage if both transistors receive low voltage.	
NOT Gate	Consists of one transistor with one input and one output. Inverts voltage. Emits high voltage if low voltage is received. Emits low voltage if high voltage is received.	
AND Gate	Consists of three transistors with two inputs and one output. Emits high voltage only if both inputs receive high voltage. Emits low voltage if either or both inputs receive low voltage.	
Output Device (Light bulb)	Flashes to simulate lighting if all of the components in the circuit are positioned and operating properly.	

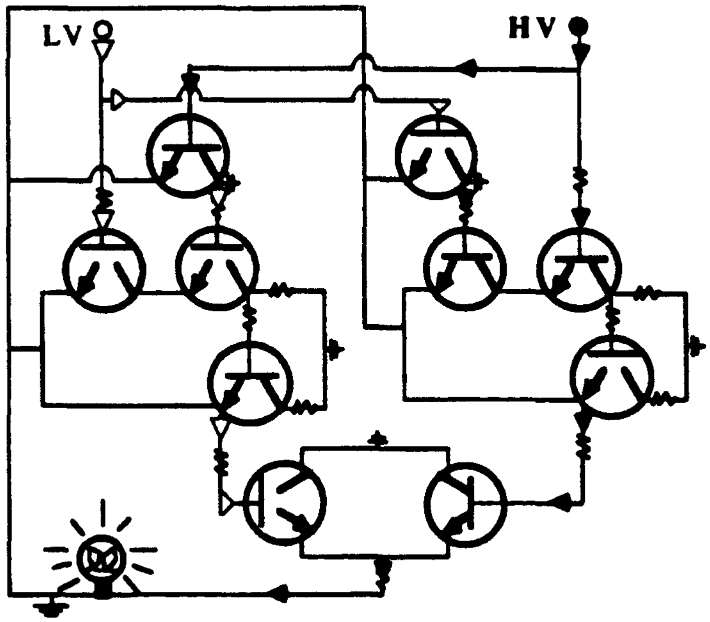
* Each circuit consists of a combination of one or more of each of these components.

rial lesson; and (c) a computer-based transfer test consisting of 15 simulated electronic troubleshooting problems that required learners to identify and fix faulty components in 15 different circuits.

The tutorial lesson was divided into an introductory overview of the lesson and six additional sections: four sections, each covering a major component of the circuit (see Table 1); one section on the structure and functions of a complete circuit (see Figure 1); and one section covering troubleshooting procedures. The performance-test problems were developed by modifying the circuit used for the tutorial lesson, which consisted of two voltage sources, one output device (a light bulb), five different gates, and ten transistors (see Figure 2). One or two transistors in the circuit were replaced with faulty ones, which prohibited the current flow and the proper function of the output device. The first four problems had one faulty transistor and the remaining four problems contained two faulty transistors. The subject was required to locate and replace the faulty transistor in the given circuit by moving and clicking the computer mouse on the target transistor.

The transfer-test problems were generated from 15 uniquely designed circuits (see Figure 3). The basic nature of the transfer-test problems was similar to the performance-test problems, but the problems were more varied and complex for most cases in terms of the number of compo-

Figure 1 ☐ Electronic Circuit Used for Tutorial Lesson*



* This figure shows the stilled view of an electronic circuit in the graphic animation (GA) condition or the visual display for the static graphic with motion cues (SG-MC) condition. The visual display for the static graphics (SG) condition did not have motion cues (see Figure 2).

Figure 2 ☐ Electronic Circuit Used for Performance Test

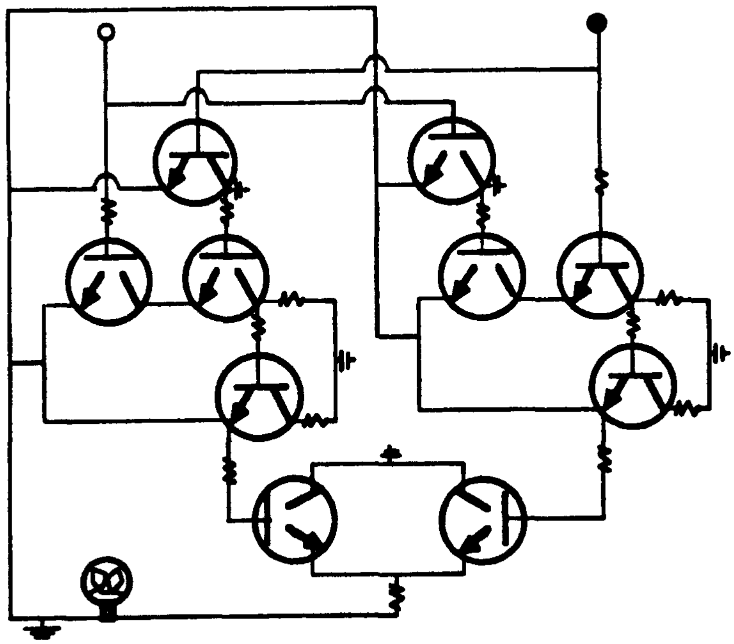
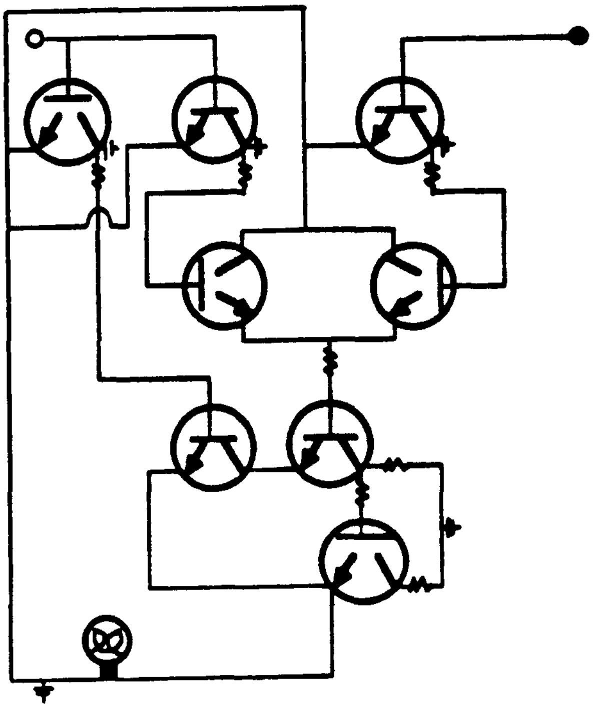


Figure 3 ☐ A Sample Electronic Circuit Used for Transfer Test

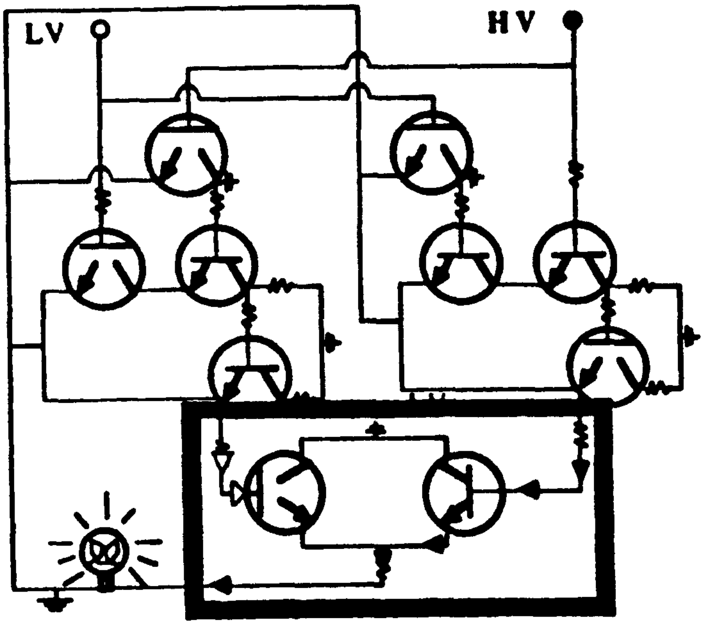


nents and their connections in the circuit. Of the 15 problems, 10 contained one faulty transistor and the remaining 5 had two faulty transistors. In the transfer test, the problems with one or two faulty transistors were presented in a random order to prevent the subjects from anticipating how many faults the given circuit contained. The circuits in the transfer-test problems consisted of two voltage sources, one output device (a light bulb), four to six different gates, and eight to fourteen transistors.

The three levels of visual display were manipulated in the tutorial lesson and performance test. For the GA condition, the functional behaviors of the electronic circuit and the procedural actions for troubleshooting were dynamically represented in the tutorial lesson using graphic animation (see Figure 1 for the stilled view of the circuit presented for the GA condition). For example, the flow of current in the circuit was represented with the movement of arrows (a solid arrow for high voltage and an outline arrow for low voltage), opening and closing of the transistors were simulated with the movement of the center piston, and functioning of the light bulb was shown with a graphical simulation of light flashing. In the performance test, the results of the student's troubleshooting action were dynamically represented on the visual display of the circuit through the animated simulation of the circuit's reactions to the input (i.e., transistor repositioning and light bulb functioning). For the SO-MC condition, the same functional behaviors of the circuit and the troubleshooting procedures were presented in the tutorial lesson and performance test, but with manipulation of static graphics (i.e., similar to the presentation of a series of slides), including motion cues (e.g., nonmoving arrows). The visual display of the electronic circuit and components for the SO-MC condition was the same as the stilled view of those in the GA condition (see Figure 1). The SG condition was basically the same as the SO-MC condition except that it did not have the motion cues (see Figure 2).

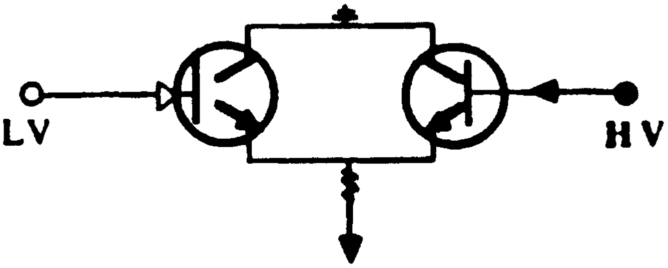
The two levels of contextual presentation were manipulated only in the tutorial lesson. For the CDP condition, the entire circuit was first

Figure 4 ☐ Context-Dependent Presentation of an OR Gate*



* This figure shows an example of context-dependent presentation (CDP) in the graphic animation (GA) and static graphics with motion cues (SG-MC) conditions. The same presentation for the static graphics (SG) condition did not have motion cues.

Figure 5 ☐ Context-Independent Presentation of an OR Gate*



This figure shows an example of context-independent presentation (CIP) in the graphic animation (GA) and static graphics with motion cues (SG-MC) conditions. The same presentation for the static graphics (SG) condition did not have motion cues.

presented, and then each component was isolated with a mark within the circuit to teach its structure and function (see Figure 4). For the CIP condition, each component of the circuit was independently presented without the complete circuit or other components (see Figure 5).

In the transfer test, unlike in the performance test, subjects did not receive any verbal feedback on their troubleshooting actions. However, the circuit's reactions to the subject's troubleshooting inputs were visually represented to simulate what could be observed in an actual troubleshooting situation. For example, when a subject took an unnecessary action by selecting a non-

Table 2 ☐ Treatment Conditions and Learning Program Segments

Treatment Conditions		*Learning Program Segments*		
		Tutorial Lesson	*Performance Test (8 Problems)**	*Transfer Test (15 Problems)*
Animation	Context-Dependent	Animation; Full-circuit based	Animation; Based on the same full-circuit as one used in the tutorial lesson	
	Context-Independent	Animation; Circuit-component based		
Static Graphics	Context-Dependent	Graphics; Full-circuit based	Graphlcs; Based on the same-full circuit as one used in the tutorial lesson	Animation for only the output device function; 15 full-circuits, each uniquely designed
	Context-Independent	Graphics; Circuit-component based		
Static Graphics with Motion Cues	Context-Dependent	Graphics with motion cues; Full-circuit based	Graphics with motion cues; Based on the same full-circuit as one used in the tutorial lesson	
	Context-Independent	Graphics with motion cues; Circuit-component based		

*The variation of the visual display during troubleshooting was made in the circuit's reaction to the subject's input.

faulty transistor, no change was made to the visual representation of the circuit. But, when a subject took a right action by selecting a faulty transistor, the visual representation changed to show the correctly positioned transistor and the properly functioning output device, the lighted bulb. All the subjects received the same visual representations of the circuit's reactions to their troubleshooting inputs. The segments of the learning programs and the manipulation of treatment conditions in the segment are summarized in Table 2.

The program was self-paced, allowing the learner to take full advantage of the individualization of CBI. The experiment, from the registration through debriefing, required approximately 70 minutes to complete: an average of 45–50 minutes for general instructions and the tutorial lesson, 8–10 minutes for the performance-test instruction and problem solving, and 12–15 minutes for the transfer-test instruction and problem solving. Subjects' data, including the amount of time and number of trials needed to solve each of the performance-test and transfer-test problems, were automatically collected on a diskette.

Procedure

The experiment was conducted in a computer room at George Mason University, which was equipped with four personal computers. As subjects arrived, they were randomly assigned to one of the computer stations, in which the learning programs had already been installed and given identification code numbers. After the experimenter gave general directions and a brief demonstration on the use of the computers, subjects were asked to enter the appropriate command on the computer to begin the learning program. Before receiving the tutorial lesson, subjects were asked to answer a few multiple-choice questions about their knowledge and experience with electronic circuits and troubleshooting. The information gained from these questions was used to ensure that none of the subjects could be considered overqualified for the experiment.

When subjects raised their hands to inform the experimenter that they had completed the tutorial lesson, the experimenter entered a command to start the performance test. Upon completing the test by successfully troubleshooting all of the 8 faulty circuits, subjects raised their hands again and the experimenter entered another command to begin the transfer test. After successfully troubleshooting all of the 15 faulty circuits in the transfer test, subjects received a message on the computer display to leave the computer room quietly. Outside the computer room, subjects were personally debriefed and paid the $10 stipend for their participation.

RESULTS

Multivariate analysis of variance (MANOVA) was performed for the four dependent variables: (a) total number of trials needed to troubleshoot 8 faulty circuits in the performance test; (b) total amount of time spent on the performance test; (c) total number of trials needed to troubleshoot 15 faulty circuits in the transfer test; (d) total amount of time spent on the transfer test). MANOVA was followed by stepwise univariate tests on each significant dependent variable. The tests for homogeneity of variance of within-class and between-class linearity were not significant, $p > .05$. The MANOVA on the main effect of visual display was not significant, $p > .05$. However, the main effect of contextual presentation was significant, $F(4, 87) = 2.62$, $p < .05$. The interaction effect between the two independent variables was not significant, $p > .05$. Means and standard deviations of the four dependent variables for each of the two independent variables are presented in Table 3.

Univariate Analyses for Dependent Variables

The univariate analysis test for the total number of trials needed to solve the eight performance-test problems was not significant on the main effect of contextual presentation, $p > .05$. For the total amount of time needed for the test, however, the main effect of contextual presentation was significant, $F(1, 94) = 8.80$, $p < .005$. Subjects in the CDP condition ($M = 289.41$) required significantly less time than subjects in the CIP condition ($M = 384.52$).

The univariate test for the total number of tri-

Table 3 ☐ Means and Standard Deviations for Time* and Number of Trials Required in Performance and transfer Tests

	Static Graphics		*Static Graphics with Motion Cues*		*Animation*	
Dependent Variables	*Context-Dependent M (SD)*	*Context-Independent M (SD)*	*Context-Dependent M (SD)*	*Context-Independent M (SD)*	*Context-Dependent M (SD)*	*Context-Independent M (SD)*
Number of Trials in Performance Test	21.50 (11.54)	20.56 (11.95)	19.69 (11.13)	20.69 (7.31)	21.13 (10.56)	15.75 (10.04)
Amount of Time in Performance Test	308.45 (78.50)	361.75 (256.22)	295.52 (89.70)	372.34 (168.18)	264.27 (104.30)	419.47 (179.95)
Number of Trials in Transfer Test	58.13 (34.47)	48.00 (25.45)	49.19 (24.77)	44.56 (19.47)	47.44 (22.12)	32.81 (17.61)
Amount of Time in Transfer Test	653.62 (356.74)	519.09 (254.92)	548.65 (241.65)	542.54 (164.81)	467.14 (175.34)	599.17 (305.99)

*Represents time (in seconds) spent actually troubleshooting the faulty circuits; time spent on test instructions is not included.

als required to solve the 15 transfer test problems was near significant on the main effect of contextual presentation, $F(1, 94) = 3.76$, $p < .06$. Subjects in the CIP condition ($M = 41.79$) required fewer trials than subjects in the CDP condition ($M = 51.59$).

Follow-Up Exploratory Analysis

Although the main effect of visual display was not significant on any of the four dependent variables, the data indicated that subjects in the GA condition ($M = 40.13$) seemed to need fewer trials than subjects in the SG condition ($M = 53.07$) in solving the transfer problems. Furthermore, the data indicated that most subjects across the treatment conditions could successfully solve the simple problems (circuits with one faulty transistor) with a very small number of trials (an average of 2.2). Thus, two one-way analyses of variance were conducted to examine the effects of the three different visual display conditions separately on the simple problems and complex problems in the transfer test. The F-test for the simple problems was not significant, $p > .05$. However, the F-test for the complex problems was significant, $F(2, 93) = 3.35$, $p < .05$. A Student-Newman-Keuls test showed that subjects in the GA condition ($M = 20.63$) needed significantly fewer trials than subjects in the SG ($M = 30.16$). The number of trials that subjects needed in the SO-MC condition ($M = 23.47$) was not significantly different from that of subjects in the GA condition or SG condition.

DISCUSSION

The initial results of this study did not demonstrate the superior effect of animation over static graphics in CBI. However, the follow-up exploratory analysis indicated that animation is more effective than static graphics if static graphics do not adequately represent the dynamic nature of animation. Specifically, the GA condition was more effective than the SG (without motion cues) condition in troubleshooting complex problems in the transfer test. The nonsignificant differences between the GA and SG conditions on the performance test and on the simple transfer problems can perhaps be attributed to the simplicity of the problems.

Because the troubleshooting problems in the performance test were presented using the same electronic circuits as the one used for the CDP condition in the tutorial lesson, half of the subjects were already familiar with the context (i.e., the circuit structure and functions) and could directly apply the troubleshooting procedures they learned during the lesson. The small number of trials required to solve the problems supports this argument. Subjects needed 20 trials on average to solve the eight performance-test problems and 22 trials to solve the ten simple problems on the transfer test. Theoretically, only 12 trials for the performance test (one trial for each of the four one faulty transistor problems and two trials for each of the four two-faulty transistor problems) and 10 trials for the simple transfer problems were required to solve them without error. However, the number of actual trials the subjects needed was close to the minimum because the troubleshooting procedure required them to check additional transistors connected to the target transistor while tracing the current flow during the troubleshooting. The superiority of the GA condition over the SG (without motion cues) condition on the complex problems in the transfer test suggests that understanding the functional behaviors of circuits is important for performing the troubleshooting task and simulating the functional behaviors with GAs was helpful for the understanding.

However, the nonsignificant difference between the GA and SG-MC conditions suggests that SGs can accomplish similar results to GAs if the dynamic functions of motions of GAs are adequately represented in the design of SGs. It implies that learners can understand the dynamic characteristics of a system by inferring its motional function as well as by directly observing them. Motion cues in SGs seem to help learners infer the dynamic functions of a system and form mental models reflecting the functions. These results suggest that SGs with motion cues should be considered as an alternative to GAs in the development of CBI if such cues can adequately represent task attributes, particularly because the development of GAs requires more time and advanced programming skills. For most cases, however, animation is likely a better choice than static graphics for teaching dynamic characteristics of a task. Depending upon cognitive requirements in the task and student learning ability, it may be easier for learners to understand the dynamic attributes of the task from the direct observation of the animated simulation than to infer them from motional cues in SGs. The inferring process requires additional cognitive processes and may not always be accurate.

The effects of two contextual presentation strategies varied for different types of problems. CDP required less time than CIP in troubleshooting faulty circuits for the performance test in which all problems were presented using the same circuit as one used in the tutorial lesson. In contrast, CIP was more effective than CDP for the transfer test in which each of the troubleshooting problems was presented in the context of a uniquely designed circuit. These varying effects of the two strategies seem to have resulted from different mental models of electronic circuits and troubleshooting procedures that subjects formed during training. Subjects in the CDP condition appeared to have formed system-bound mental models based on a whole circuit presented during training (Bjork & Richardson-Klavehn, 1989), while subjects in the CIP condition seemed to have formed context-free, component-based mental models. The system-bound mental models appeared to be more efficient in identifying faulty transistors presented in the context of the same system (i.e., circuit). Component-based mental models were less efficient probably because they, unlike system-bound models, had to be assessed for the applications in the given context. These findings are consistent with Eich's (1985) argument that if students learn and elaborate knowledge or skills with materials from a specific context, it becomes easier to retrieve the knowledge in the same context, but harder in other contexts.

However, component-based mental models appeared to be more effective in troubleshooting newly encountered faulty circuits, particularly complex ones, on the transfer test. Surface structural differences of the circuits did not seem to be important for subjects in the CIP condition because every circuit consisted of the same components as the ones in their mental models. Subjects in the CDP condition were apparently less flexible in applying their system-bound mental models to the newly encountered problems presented in structurally different contexts. These findings are similar to Singley and Anderson's (1989) and Klahr and Carver's(1988). In teaching several different text editors and LOGO programming language debugging procedures, they found that large transfer occurred between tasks that were very different in surface structure but that had common abstract or componential structure.

These varying effects of the two contextual presentation strategies suggest that contextual information should be selectively used on the basis of instructional objectives. When knowledge and skills learned will be used mostly for the same contextual situation and the surface structure of tasks to learn and transfer is similar, CDP will be better. However, if surface structures of the task to be performed are likely to vary and componential parts of the task are to transfer, CIP will be better. □

Ok-Choon Park is with the Office of Educational Research and Improvement, U.S. Department of Education. When this study was conducted, he was with the U.S. Army Research Institute. The opinions expressed herein are the author's and do not express or imply the views of the U.S. Department of Education or the U.S. Army Research Institute.

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