British Journal of Educational Psychology, 62, 233-246, 1992

THE SPLIT-ATTENTION EFFECT AS A FACTOR IN THE DESIGN OF INSTRUCTION

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SUMMARY. Cognitive load theory suggests that many conventional instructional formats are ineffective as they involve extraneous cognitive activities, which interfere with learning. The split-attention effect provides one example of the consequences of inappropriate cognitive activities caused by poor instructional design. Learners are often forced to split their attention between and mentally integrate disparate sources of information (e.g., text and diagrams) before the instructional material can be rendered intelligible. This preliminary process of mental integration, while an essential precursor to learning, is likely to impose a heavy extraneous cognitive load. Physical integration (e.g., combining text and diagrams) may reduce cognitive load and so facilitate learning. This study reports findings from two experiments investigating the split-attention effect. Using an engineering programming language (Numerical Control programming), the first experiment investigated the possible advantage of physically integrating text and diagrams. In a normal training environment, the integrated instructions group outperformed the conventional group. Experiment 2 was designed to see if the split-attention effect would generalise to an area where mutually referring segments of text are conventionally separated, namely, empirical reports in psychology and education. In a laboratory study, Experiment 2 showed that students in an integrated group spent less time processing instructions yet still outperformed students in a conventional group on test questions. The consequences of these results for cognitive load theory and for instruction design are discussed.

INTRODUCTION

THE last decade has seen an explosive growth in our knowledge of the cognitive processes involved in learning and problem solving. For example, we have now a far better idea of how to package information (Chandler and Sweller, 1991; Ross, 1984, 1987, 1989; Ross and Kennedy, 1990), how and when to use illustrations and diagrams with text (Larkin and Simon, 1987; Levin, 1981; Mandel and Levin, 1989; Mayer, 1989; Mayer and Gallini, 1990) and how to enhance learning and problem-solving skill (Cooper and Sweller, 1987; Gick, 1986; Gick and Holyoak, 1983; Owen and Sweller, 1985; Tarmizi and Sweller, 1988; Ward and Sweller, 1990, Zhu and Simon, 1987). The current study is concerned with the cognitive processes involved in packaging instructional information.

Cognitive load theory and relations between learning and problem solving

Cognitive load theory (Sweller, 1988, 1989) has shown itself to be a useful generative tool in a number of areas of instruction. The theory assumes the well-established notion that working memory is strictly bound and many cognitive activities place heavy restraints on this limited capacity (Bower, 1975; Kahneman, 1973; Miller, 1956). The major aim of this study is to investigate the possible advantages of instructional packages generated by cognitive load theory. While any such successful applications may indirectly support the theory, the emphasis of this paper is theory-generated instructional applications, not theory validation.

The primary concern of cognitive load theory is with how students allocate limited cognitive resources during the processes of learning and problem solving. For instance, the theory suggests that many traditional instructional procedures such as conventional problem solving (i.e., solving relatively large numbers of problems as an aid to learning) impose a heavy cognitive load that interferes with learning. Sweller (1988) suggested that the search strategy used frequently in problem solving (i.e., means-ends analysis — see Newell and Simon, 1972), while facilitating problem solution, was largely incompatible with schema acquisition. To support this assertion, Sweller (1988) used several aspects of production systems (see Anderson, 1983; Langley *et al.*, 1980) to provide measures of cognitive load and, through the use of a production model, indicated that cognitive load was relatively high during means-ends analysis. In addition, Ayres and Sweller (1990) used error analysis techniques to suggest problem locations that imposed a relatively heavy cognitive load. The need for alternatives to conventional problem solving through means-ends analysis was proposed.

Alternatives to conventional problem solving are only likely to be useful if they themselves do not impose a heavy cognitive load. Worked examples are a viable alternative which is used relatively sparsely in most instructional areas. Worked examples consist simply of a problem statement and the appropriate steps to solution. Studying such examples requires a far lower cognitive load than problem solving through means-ends analysis (see Sweller, 1988, 1989). Sweller and Cooper (1985) and Cooper and Sweller (1987) found in the area of algebra that a mix of worked examples and problems resulted in more rapid learning than simply solving numerous conventional problems. In a longitudinal study, Zhu and Simon (1987) confirmed the effectiveness of worked examples using Chinese secondary school students. In one experiment, substituting conventional teaching techniques for a combination of worked examples and conventional problems resulted in a three-year course being completed in two years.

While cognitive load theory was used to predict that studying worked examples could be superior to solving the equivalent problems, the theory also was used to predict that not all worked examples would be effective. Many worked examples, particularly in mathematics and science, consist of two or more sources of mutually referring information. Diagrams with an accompanying textual explanation are a common example. For instance, worked examples in areas such as geometry and trigonometry consist of both a diagram and a set of textual statements. Usually, neither source of information is intelligible by itself, and meaning can be extracted only by mentally integrating the text with the diagram. Mental integration requires searching and matching each statement in the text with its appropriate entity on the diagram. According to cognitive load theory, this preliminary process of searching and matching text with diagram has the same consequences for learning as searching for operators to solve a problem through means-ends analysis. In both cases, cognitive effort is directed to a search process that is unrelated to learning. Attention is misdirected and cognitive resources are inappropriately allocated to an activity that is only engaged in because of the way the material is structured. Different structures can eliminate the search process freeing resources for learning.

Tarmizi and Sweller (1988), using geometry, and Ward and Sweller (1990), using physics, confirmed this hypothesis. They found that worked examples that required mental integration in order to be understood were no more effective than conventional problem solving through means-ends analysis. In accordance with cognitive load theory, it was suggested that if the extraneous cognitive activity of mentally integrating diagrams and text was removed or reduced then cognitive resources would be freed for learning. This could be achieved by physically integrating textual information with the related diagram and thus reducing the split-attention effect. Results from both studies confirmed that such reformatted worked examples were superior to both conventional split-source worked examples and conventional problems.

Applying cognitive load theory to introductory instructions

The format of introductory instructions is traditionally guided by such factors as visual elegance and convenience. They often involve split-source formats consisting of multiple sources of mutually referring information, with each source of information unintelligible until it has been integrated with other sources of information. It can be predicted that the split-attention effect is applicable to initial instruction as well as worked examples. Specifically, physically integrated instructions should be superior to conventional split-source instructions because of the reduced extraneous cognitive load. Sweller *et al.* (1990) and Chandler and Sweller (1991) confirmed this hypothesis using a variety of areas including mathematics, biology, electrical wiring and numerical control machine programming. The participants studied the instructions and were immediately tested after the brief instructional period. They were tested individually and the instructions were not part of the participants' normal training. Because of the importance of programming in an industrial context, there is a need for further studies that involve detailed instructional notes and extensive testing in a realistic training environment. The first experiment was designed with these points in mind.

EXPERIMENT 1

As noted earlier, there exists a considerable body of literature investigating the role of illustrations and diagrams as devices for assisting students to understand text (Levin, 1981; Mayer, 1989; Mayer and Gallini, 1990; Waddill *et al.*, 1988). Levin (1981) and Levin *et al.* (1987) noted that illustrations can have various effects on learning, and proposed five functions of text illustrations: (1) decorational — text-irrelevant illustrations used to make textbooks more attractive, (2) representational — illustrations that reinforce key events in narrative passages, (3) organisational — illustrations designed to organise events into a coherent structure, (4) interpretational — illustrations that clarify complex and abstract concepts in the text and (5) transformational — illustrations that assist in recalling important information. In a meta-analysis of 100 experiments Levin *et al.* (1987) found that illustrations with representational, organisational, interpretational and transformational functions enhanced learning, with transformational illustrations showing the strongest positive effects.

The nine illustrations used in this experiment served an interpretational function. The experiment was designed to demonstrate the split-attention effect in a realistic training environment using the area of numerical control (NC) machine programming. Numerical control machines are used for the control of industrial machinery. They incorporate a computer-based technology that is rapidly replacing traditional engineering machines such as mills and lathes (see Chandler *et al.*, 1988; Hesketh and Chandler, 1987). On a traditional hand-operated machine, movement is achieved through the use of handles, knobs, levers and buttons. Movement on a NC machine is controlled by NC program code. One of the key conceptual skills involved in NC programming is the ability to work within an appropriate co-ordinate system. Learners have to relate a specific co-ordinate system to spatial movements (Chandler *et al.*, 1988; Hesketh *et al.*, 1988).

Experiment 1 used NC programming instructional notes for a numerically controlled mill. The experiment was conducted in an industrial training setting over a one-week period. There were two groups in the experiment. The first group received their NC programming notes in a conventional split-source format. Interpretational diagrams and related text were presented separately. The second group received very similar information in a modified format. Mutually referring diagrammatic and textual information were physically integrated into unitary sources. In accordance with cognitive load theory, it was predicted that the modified group would exhibit superior performance over the conventional group.

METHOD

Sample

A total of 26 first year apprentices from a Sydney company participated in the experiment. All 26 apprentices had completed at least Year 10 of school and were enrolled in first-year trade courses at various technical colleges. Since the instructional material for the experiment was designed as an introduction to NC programming, only apprentices with no formal training in NC programming were used.

Materials

The instructional materials for the experiment consisted of two sets of detailed instructional notes (conventional and modified) designed as a basic introduction to Numerical Control programming for a NC milling machine. Both sets of instructions were divided into nine sections covering important aspects of introductory NC programming. Specifically, there were notes on the following: (1) history of NC machines; (2) co-ordinate systems for a NC milling machine; (3) absolute and incremental programming (absolute programming commands locate a point solely by reference to the origin of the X, Y and Z axes, while incremental programming commands locate a point by referring to its current position and treating that position as the origin); (4) writing a simple NC program using the X and Y axes only; (5) programming with the Z axis; (6) setting up a NC program; (7) a NC program for drilling; (8) a NC program for cutting out a triangular groove; (9) avoiding obstructions in a NC program.

The conventional instructional materials were contained in an 11-page booklet. These instructions were in a conventional split-source format with text and related diagrams presented separately. An example of the conventional instructions is shown in Figure 1. The modified instructional materials contained the same information, but in an integrated form. Related textual and diagrammatic information were integrated into unitary sources of information. The difference between the two sets of instructions was in the format of presentation. An example of the modified instructions is displayed in Figure 2.

FIGURE 1

An Example of Conventional NC Instructions

We assume that the tool is located at the origin. Firstly, we have to instruct the machine to quickly go to the point A. The NC command for a quick movement *without* cutting is G00 and is denoted with a broken line. We also have to instruct the machine where to go. Point A has the absolute position (20,30). The NC command for a movement to the point A is **X20 Y30**. The complete command for this movement is therefore **G00 X20 Y30**. A straight line cut from A to B is required. The NC command for a straight line cut is **G01** and is denoted by an unbroken line. We now have to instruct the machine to cut to the point B. To achieve this the NC command for the point B is required. The NC command for the point B is **X-20 Y10**. The complete command for this movement is **G01 X-20 Y10**. The NC command to return the tool back to the origin is simply **G00 X0 Y0**. This completes the NC program code for this job. You will notice that we ignored the Z axis in this program. In the remaining NC programs we will include the Z command statements.

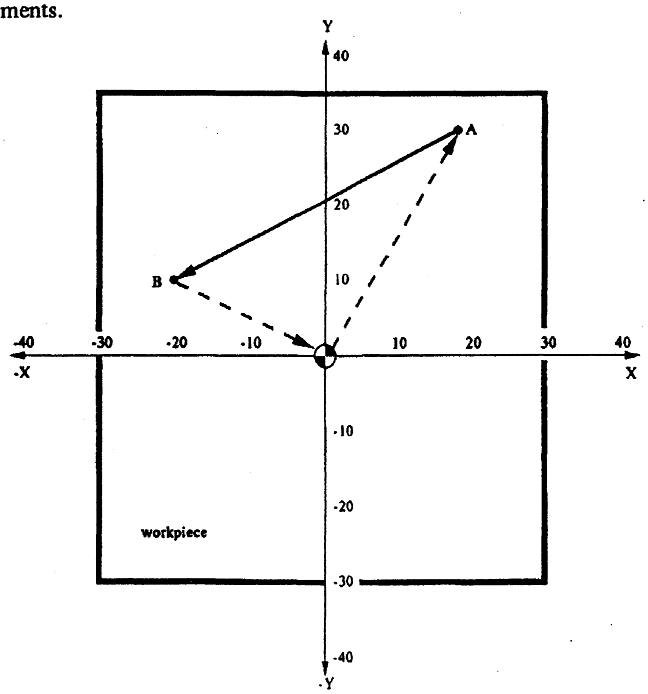
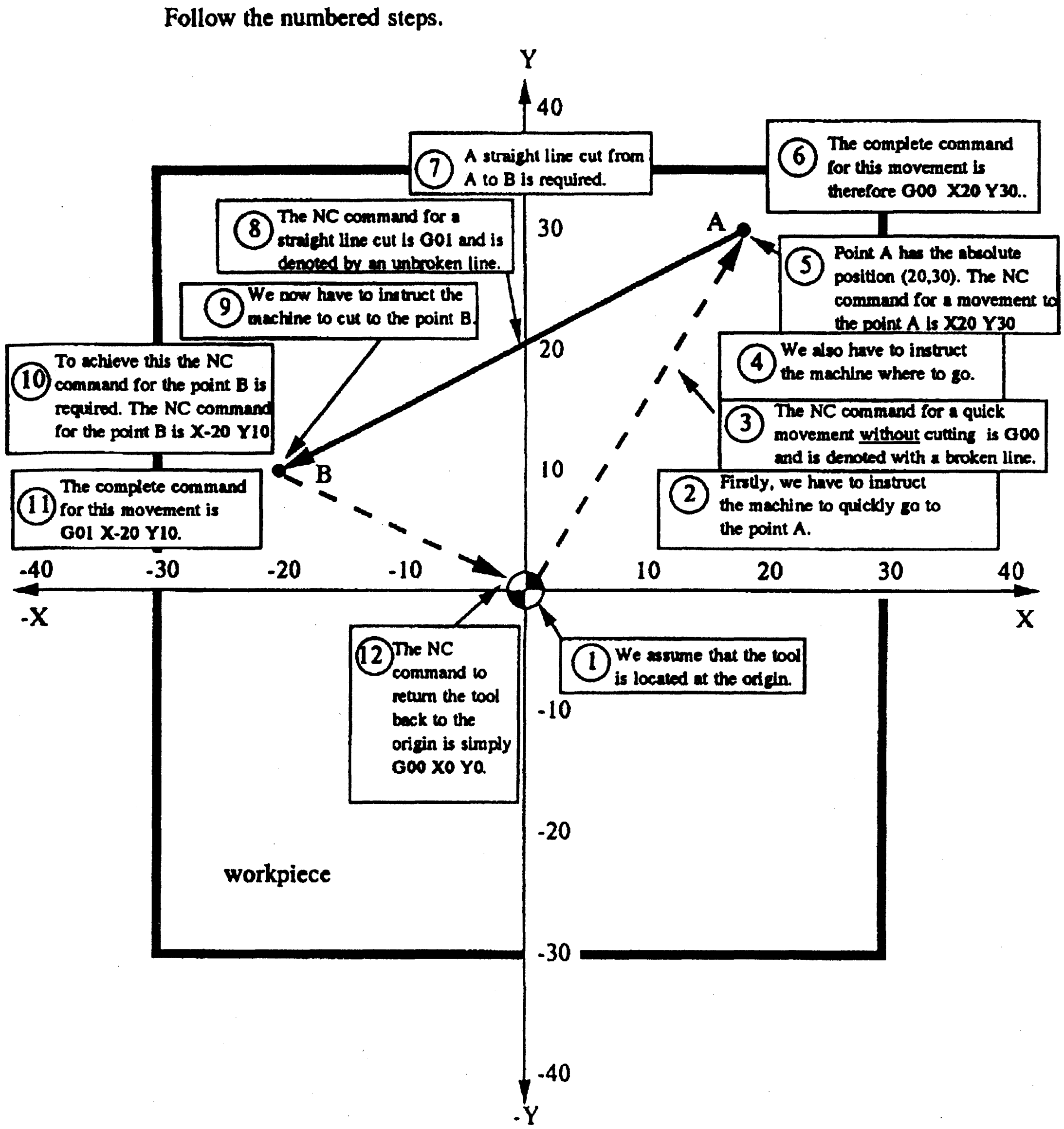


FIGURE 2

AN EXAMPLE OF INTEGRATED NC INSTRUCTIONS



The test materials consisted of a nine-page test booklet. The test booklet was divided into 10 parts covering questions on all sections of the instructional materials, except the section on the history of NC machines. Questions 1 and 2 of the test booklet covered information from co-ordinate systems for a NC milling machine as well as absolute and incremental programming. The first question was scored out of 16 while the second question was allocated 8 marks. Question 3 covered information from the section on co-ordinate systems for a NC milling machine and was scored out of 3. Questions 4 and 5 covered information from the sections on writing a simple NC program, programming with the Z-axis and setting up a NC program and was scored out of 14 and 9, respectively. Question 6 covered information from the sections on programming with the Z-axis, setting up a NC program and NC programming for drilling and was allocated 9 marks. Questions 7 and 8 included information from the sections on writing a simple NC program, programming with the Z-axis and NC programming for cutting a triangular groove. Question 7 was scored out of 20 while question 8 was scored out of 12. Questions 9 and 10 covered information from the sections on writing a simple NC program, programming with the Z-axis and avoiding obstructions in a NC program. A total of 17 marks were given for question 9 and 12 marks were allocated for question 10.

Procedure

The experiment was conducted as a normal part of the company's training programme. A training instructor from the company randomly distributed the instructions, allocating apprentices to either a conventional or modified instructions group until there were 13 apprentices in each group. It was explained to the apprentices that the instructions were to be considered an introduction to NC programming for a milling machine. Apprentices were informed that they were to study the materials carefully at their own pace as many times as they wished. They were also told that they would be tested on the instructional materials in one week's time. The allocation of instructions and testing procedure used in the experiment were similar to the training methods regularly used by the company.

Apprentices were tested one week after the instructions were distributed. They were required to attempt the test booklet described in the materials section. Apprentices were instructed to attempt each test question and allowed up to 50 minutes to complete the test. They did not have access to their instructional notes during testing.

RESULTS AND DISCUSSION

Due to absences, only 20 (10 from each group) of the original 26 apprentices allocated instructional materials were available for testing. Table 1 displays the mean test scores, standard deviations and effect sizes for the two groups, on all 10 questions of the test booklet. Inspection of this table indicates that the direction of means favoured the modified group on all 10 test items.

TABLE 1

MEAN TEST SCORES, STANDARD DEVIATIONS AND EFFECT SIZES FOR BOTH GROUPS ON SEPARATE TEST ITEMS OF EXPERIMENT 1

	Group				
Test	Conventional		Integrated		
Items	Mean	SD	Mean	SD	Effect Size*
1	8.0	2.7	9.7	2.8	0.22
2	1.7	2.6	2.4	3.9	0.06
3	1.2	1.0	2.1	1.0	0.90
4	5.7	4.5	10.7	3.2	0.33
5	6.0	3.3	6.9	2.0	0.12
6	4.6	2.4	6.9	1.8	0.51
7	6.7	4.7	11.9	3.6	0.30
8	7.8	3.6	9.1	3.2	0.11
9	7.8	3.9	10.3	3.0	0.21
10	4.6	3.3	6.7	3.3	0.19

*Effect Size for each item is calculated as follows: mean of integrated group – mean of conventional group/pooled standard deviation

Overall, the modified group outperformed the conventional group with a significantly higher total test score, $t(18)=2.78$. (The 0.05 level of significance is used throughout this paper unless otherwise specified.) In fact, the total mean test score for the modified group was over 40 per cent higher than the mean score for the conventional group. (It might be noted that individual tests on each of the questions indicated that the modified group was superior to the conventional group on Questions 3, 4, 6 and 7; may have demonstrated a real superiority on Questions 1, 9, and 10 using a 0.1 level of significance; with no differences on Questions 2, 5, and 8.) Effect sizes (see Table 1) on individual items ranged from 0.06 to 0.90. As might be expected, the largest effect sizes were on Questions 3, 4, 6 and 7 ranging from 0.30 to 0.90. Questions 4, 6, and 7 were questions that required apprentices to write the NC program code that corresponded to a given diagram, a key skill in NC programming.

The results of this experiment demonstrated, using detailed notes in a technical area, a degree of superiority of integrated instructional formats over conventional split-source instructions. The overall results showed a distinct difference between the two groups, with the modified group attaining a mean total test score considerably higher than that of the conventional group. While the effect sizes were at best only moderate, the direction of results favoured the modified group on every specific test item with no evidence of conventional group superiority in any area of testing.

This experiment demonstrated the split-attention effect between illustrations and text in a realistic setting. It is very much in accordance with several laboratory based studies by Sweller *et al.* (1990) and Chandler and Sweller (1991) which have demonstrated large effects in a number of instructional areas using tightly controlled experiments. In these laboratory experiments instructional time was used as indirect measure of cognitive load. Despite spending less time processing instructions, integrated instructional groups in these experiments still demonstrated their superiority in all areas of testing. Because of the realistic nature of Experiment 1, such measures were not possible.

Conventional illustration and text instructions are not the only form of split-source formats. Instructional packages often split attention between two or more sets of textual information. Experiment 2 was designed to investigate the possibility that the "split-attention" effect would generalise to areas where various sets of text are separated.

EXPERIMENT 2

At present there are very limited data comparing conventional and integrated formats in areas where attention is split between various sets of textual information. The current experiment investigated the split-attention effect using an area that commonly uses multiple sources of mutually referring text, namely, psychology and education reports of experiments.

The manner in which psychologists report their procedures, data and conclusions has been standardised for decades. Empirical papers introduce a problem by discussing relevant literature and its relation to the problem, a method section describes the procedures used to collect data, the data are described in a results section while the consequences of those results and their relation to other research are discussed in a final, discussion section. This sequence is intuitively clear and logical. As a consequence, with some minor variations, the Introduction, Method, Results and Discussion format has become traditional.

The conventional structure of reports of experiments provides a prime example of a format in which readers must mentally integrate the information of two or more sections before deriving meaning from the material. Consider the Method and Results sections of most experimental reports. Almost invariably, research results cannot be mentally processed without close reference to the methodology. Unless the methodology has been memorised, either because it is reasonably standardised or because the reader has spent a considerable time studying it, the Results sections of many reports only can be properly processed by constant reference back to the Method section. Many readers will recognise the symptoms in their own behaviour. For any reasonably complex paper, assimilating the contents of a Results section is likely to require frequent flipping of pages to remind oneself of methodological details.

The cognitive effort required to mentally integrate various sections of a research report are essential only because of the conventional structure used. With a different structure in which various sections are physically integrated, the requirement to mentally integrate material may be reduced. Cognitive resources freed should be available to assimilate the information.

Experiment 2 was designed to compare a conventional empirical report with a modified report that physically integrated sets of mutually referring text. We predicted that the modified, integrated group would outperform the conventional group.

METHOD

Sample

The participants were 20 Educational Psychology I students from the University of New South Wales.

Materials

The instructional materials were two versions (i.e., conventional and integrated) of a modified report of an experiment run by Sweller *et al.* (1990). As an example of the alteration from the conventional to the integrated version, the results of a particular procedure were presented simultaneously with the description of the procedure. The two versions are presented in Appendices 1 and 2.

The test materials consisted of 34 questions on details from all sections of the report. The questions are listed in Appendix 3. Each question was marked either correct or incorrect giving a total score out of 34.

Procedure

Students were randomly allocated to two groups: a conventional or an integrated group. All students were tested individually. The experiment was conducted in two phases. The first phase was the instruction phase. Students were presented with the instructions and asked to read them at their own pace. They were informed that they would be required to answer questions concerning the contents of the instructions. Students were asked to indicate when they had finished. The time for completion of the instructions was noted.

A test phase followed. Students were asked to attempt all 34 test questions. They were allowed as much time as necessary to complete the test; however, they were not permitted to re-attempt a question to which a response had already been given.

RESULTS AND DISCUSSION

Instruction times and test scores were the major variables under analysis. Results showed that the students presented the conventional materials required a mean of 216 seconds to process their instructions while those presented the integrated version required 190 seconds. This difference is significant, $t(18) = 1.85$, S.E.diff = 13.60. These results suggest that the integrated version was easier to process.

The students presented the conventional materials obtained a mean score of 17.5 questions correct while the students presented the integrated materials obtained a mean of 21.4 questions correct. This difference is significant, $t(18) = 2.31$, S.E.diff = 1.69.

Results indicated that, despite spending less time processing their instructions, the integrated group attained a significantly higher test score than the conventional group. This experiment demonstrates that the split-attention effect may generalise well beyond the text and diagram instructions to which it was applied in Experiment 1.

The advantage of the integrated group in Experiment 2 was obtained despite the fact that the integrated group materials consisted of a block of text with no breaks or headings. Since previous research has indicated that headings can enhance intelligibility (e.g., Loman and Mayer, 1983). Experiment 2 was partially replicated with suitable headings such as "Subjects, Design and Hypotheses" and "Procedure, Results and Discussion for the Instruction Phase" interpolated into an integrated text. We assumed this procedure would equate both groups with respect to headings and so possibly increase the split-attention effect. This experiment found that students reading an integrated report with headings clearly outperformed both an integrated group without headings and a conventional group. In fact, the integrated group with headings achieved a mean test score almost double that of the conventional group. This replication experiment provided additional evidence for the split-attention effect using textual materials and indicated that the effect could be quite substantial providing the groups were equated with respect to variables such as the presence or absence of headings.

GENERAL DISCUSSION

We believe that the findings of this study have important implications for instructional design. Before discussing these implications, we will summarise the results. Experiment 1 compared conventional text and diagram instructions with physically integrated instructions using Numerical Control programming. The results favoured the integrated instructions group with a mean test score considerably higher than the conventional group. This finding replicates and extends the findings of laboratory and field studies by Sweller *et al.* (1990) and Chandler and Sweller (1991). There now exist several separate experiments demonstrating the split-attention effect with diagrams and related text, in a number of different instructional areas. Experiment 2 was designed to generalise further these findings. It tested the possibility that the effect is equally applicable to areas where mutually referring sources of text, rather than text and diagrams, are presented separately. Using different versions of a modified empirical report, Experiment 2 demonstrated the superiority of integrated formats over conventional formats. We believe the demonstration of the split-attention effect in widely disparate areas to be the major finding of this paper.

Methodological and theoretical issues

In Experiment 1, the primary independent variable was the format of presentation: conventional or integrated. As can be seen from an inspection of Figures 1 and 2, this is not the only difference. The integrated group has the verbal information partitioned into separate chunks and this separate information is also sequenced. It could be suggested that these factors may have accounted for the difference between the groups. This argument gains no support when considering the results of Experiment 2 as well as previous studies. For example, Chandler and Sweller (1991) and Sweller *et al.* (1990) have compared conventional instructions with identical integrated versions, where both groups had textual information partitioned and sequenced. In these experiments, the integrated groups had textual superiority in all areas of testing. In Experiment 2 of the present study the information was neither partitioned nor sequenced for the integrated group. In fact, it was the conventional group that had their information partitioned into headings. Despite this, the integrated group outperformed the conventional group. The conclusion consistent with the data is that the difference between the groups was caused by the split-attention effect.

In Experiment 2 we demonstrated that integrated versions of experimental reports could outperform conventional versions. It should be made clear that we are not proposing that conventional formats are entirely inadequate. There are, of course, advantages to the traditional empirical report format that are not addressed by the current theorising or data. For example, many papers, especially complex ones, need to be re-read on several occasions before their contents are fully assimilated. The re-reading process may be assisted by the standard format because we know where to look for a particular section, such as the Method. When re-reading, we may wish to skim some sections and concentrate on others. It may be useful to know immediately where to look for a specific section. Of course, a properly organised report should require less re-reading and should have clear headings indicating the location of various units of information.

In the experiments reported here, inexperienced report readers (i.e., educational psychology students) gained advantage from the integrated version of a relatively simple experimental report. The results may well have been different if we had used "experts" or if more complex reports had been used. Ultimately, the formats we use should be determined by appropriate theorising and experimentation. The major result from Experiment 2 is that modified instructional formats that integrate disparate sources of textual information may have advantages in many instructional areas where mutually referring text is traditionally kept separate.

In the current group of experiments there was only a limited measure of cognitive load. We have suggested in past research (e.g., Sweller *et al.*, 1990) that processing time for instructions may be a valid indirect measure of cognitive load. In Experiment 2 processing time for the conventional group was significantly longer than the integrated group. This supports the assertion that cognitive load is heavier when studying conventional instructions. There is, however, a clear need to investigate different instructional formats with more direct measures of cognitive load.

It should again be emphasised that we were not engaged in a theory validation exercise in this paper. We were not concerned with testing or falsifying cognitive load theory. The theory has been used as a generative tool which has provided new and viable methods of instructional design in a wide variety of areas. While other explanations may be available for our results, they did not generate our experiments.

Instructional applications

The findings of this study have immediate and direct implications for instructional design. In areas where mental integration between diagrams and text is essential in order to make sense of the material, then integrated instructional formats should replace conventional formats. This split-attention effect is very general. It may apply to all areas requiring mental integration between disparate sources of information. Not only should many diagrams and text be integrated, the evidence is strong that learning can be enhanced by physically integrating mutually referring, disparate sources of purely textual information.

Acknowledgments.—The work reported in this article was supported by a grant from the Australian Research Council to John Sweller. We would like to extend our thanks to the training staff of Email Ltd. for their co-operation and assistance.

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(*Manuscript received 3rd June*, 1991)

APPENDIX 1

CONVENTIONAL VERSION OF THE REPORT USED IN EXPERIMENT 2

EXPERIMENT

The materials for this experiment were instructions designed to introduce subjects to a computer-based technology, namely Numerical Control (NC) programming. There were two groups in the experiment. The first group received their instructional material in a conventional format with diagramatic and textual information separate. The second group received the instructional material in a modified format where written and diagrammatic materials were integrated into a single source of information. The only difference was the format of the presentation. Based on our hypotheses, it was predicted that the modified group would exhibit superior performance as it did not have to reformulate the material in order to understand it.

METHOD

Subjects

The subjects were 20 first year trade apprentices from a Sydney company.

Procedure

Subjects were randomly allocated to either of the two groups. All subjects were tested individually. The experiment was conducted in two phases. The first phase was the instruction phase. The experimenter began this phase by informing subjects that they would be asked to read some instructional material for NC programming. The subjects were presented with the instructions, asked to read them at their own pace and indicate when they had finished reading. Time for completion of instructions was noted.

A test phase followed the instruction phase. Three problems were presented, one at a time. The first problem was similar to the problem discussed in the instructions. The second problem reversed the procedure of the first problem and so tested for transfer. The third problem was a more difficult transfer problem. Solution times for each problem were noted.

Subjects were allowed a maximum of five minutes for each of the test problems. If a solution had not been obtained in the allowed time, the subject was instructed to move to the next problem.

RESULTS

Results showed that the modified group with a median of 168.5 seconds spent significantly less time on the instructions than the conventional group which had a median of 239.5 seconds.

We predicted that a lower cognitive load during instruction would result in superior test performance by the modified group during the test phase. The modified instruction group attained solution faster than the conventional group on the first test problem and the second test problem. There was no difference between the groups with respect to solution times for the third test problem.

Test scores were noted for each problem. Twenty marks were allocated for the first test problem. Twelve marks were allocated for the second test problem. Five marks were allocated for the third test problem.

The modified instruction group scored significantly higher than the conventional group on both the first test problem and the second test problem. There was no significant test score difference between the groups on the third problem.

Seven subjects from the modified group solved the first test problem. This compared with only two subjects from the conventional group. Seven subjects from the modified group solved the second test problem. This compared with only three subjects from the conventional group. Both groups found the third problem very difficult with only two subjects from each group attaining solution.

DISCUSSION

We suggest that results from the instruction phase provide evidence that the modified instructions, packaged in an integrated format, imposed a lower cognitive load than the conventional instructions due to a reduced need to reformulate the material before assimilation. The test phase results clearly favoured the modified instructions group. Despite spending less time on the instructional material, the modified group performed considerably better than the conventional group on two of the test problems, including a transfer problem, with respect to both time and test scores.

APPENDIX 2

INTEGRATED VERSION OF THE REPORT USED IN EXPERIMENT 2

EXPERIMENT

The materials for this experiment were instructions designed to introduce subjects to a computer-based technology, namely Numerical Control (NC) programming. There were two groups in the experiment. The subjects were 20 first year trade apprentices from a Sydney company and were randomly allocated to either of the two groups. The first group received their instructional material in a conventional format with diagramatic and textual information separate. The second group received the instructional material in a modified format where written and diagramatic materials were integrated into a single source of information. The only difference was the format of the presentation. Based on our hypotheses, it was predicted that the modified group would exhibit superior performance as it did not have to reformulate the material in order to understand it.

All subjects were tested individually. The experiment was conducted in two phases. The first phase was the instruction phase. The experimenter began this phase by informing subjects that they would be asked to read some instructional material for NC programming. The subjects were presented with the instructions, asked to read them at their own pace and indicate when they had finished reading. Time for completion of instructions was noted. Results showed that the modified group with a median of 168.5 seconds spent significantly less time on the instructions than the conventional group which had a median of 239.5 seconds. We suggest this result provides evidence that the modified instructions, packaged in an integrated format, imposed a lower cognitive load than the conventional instructions due to a reduced need to reformulate the material before assimilation.

A test phase followed the instruction phase. We predicted that a lower cognitive load during instruction would result in superior test performance by the modified group during the test phase. Three problems were presented, one at a time. Subjects were allowed a maximum of five minutes for each of the test problems. If a solution had not been obtained in the allowed time, the subject was instructed to move to the next problem. Solution times and test scores were noted for each problem. Twenty marks were allocated for the first test problem. The first problem was similar to the problem discussed in the instructions. As expected the modified instruction group attained solution faster and also scored significantly higher than the conventional group. Seven subjects from the modified group solved the first test problem. This compared with only two subjects from the conventional group.

The second problem reversed the procedure of the first problem and so tested for transfer. Twelve marks were allocated for the second test problem. The modified group attained solution faster and scored significantly higher than the conventional group on the second problem. Seven subjects from the modified group solved the second test problem. This compared with only three subjects from the conventional group.

The third problem was a more difficult transfer problem. Five marks were allocated for the third test problem. There was no difference between the groups with respect to solution times or test scores for this problem. Both groups found this problem very difficult with only two subjects from each group attaining solution.

The test phase results clearly favoured the modified instructions group. Despite spending less time on the instructional material, the modified group performed considerably better than the conventional group on two of the test problems, including a transfer problem, with respect to both time and test scores.

APPENDIX 3

TEST QUESTIONS FOR EXPERIMENT 2

(1) What technical area was used for the instructional material in the experiment?

(2) How many groups were in the experiment?

(3) Name these groups.

(4) How was the format of the modified instructions different to the conventional instructions?

(5) Which group was expected to display superior performance?

(6) Why was this group expected to display superior performance?

(7) How many subjects were there?

(8) Where were the subjects from?

(9) How were the subjects tested?

(10) How many phases were there in the experiment?

(11) Name these phases.

(12) How many test problems were there?

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(13) Which problem/s tested for transfer?
(14) What was the maximum time allowed for each question?
(15) Which group spent the most time studying the instructions?
(16) What was the median time for this group?
(17) What was the median time for the other group?
(18) What was the hypothesis for performance on the test problems?
(19) Which group attained solution quicker for the first test problem?
(20) Which group attained solution quicker for the second test problem?
(21) Which group attained solution quicker for the third test problem?
(22) How many marks were allocated for the first test problem?
(23) How many marks were allocated for the second test problem?
(24) How many marks were allocated for the third test problem?
(25) Which group scored higher marks on the first test problem?
(26) Which group scored higher marks on the second test problem?
(27) Which group scored higher marks on the third test problem?
(28) How many subjects from the conventional group solved the first test problem?
(29) How many subjects from the conventional group solved the second test problem?
(30) How many subjects from the conventional group solved the third test problem?
(31) How many subjects from the modified group solved the first test problem?
(32) How many subjects from the modified group solved the second test problem?
(33) How many subjects from the modified group solved the third test problem?
(34) What theoretical factor was said to explain the differences between the groups?