APPLIED COGNITIVE PSYCHOLOGY
Appl. Cognit. Psychol. **14**: 555–575 (2000)

Learning a Procedural Task: Effectiveness of Multimedia Presentations

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SUMMARY

Three experiments investigated the effectiveness of presenting procedural information through different media and their combinations. Experiment 1 examined the effectiveness of text, line drawings, text and line drawings, video, and video stills for learning a first aid task. The results showed an advantage of text and line drawings and of the video presentation over the other three conditions for both bandaging performance and answering questions about the task. Experiment 2 showed that the beneficial effect of the combination of text and pictures could not be accounted for simply in terms of a dual coding explanation. Rather, the effectiveness of the media and their combinations was influenced by the extent to which they conveyed action information. Finally, Experiment 3 showed no evidence of a contiguity effect: text and pictures were as effective when presented together on the same screen as when they were presented separately. Copyright © 2000 John Wiley & Sons, Ltd.

A classic theory in cognitive psychology in Paivio's (1971, 1983, 1986) Dual Coding theory. According to Paivio, cognitive behaviour is mediated by two independent but richly interconnected symbolic systems, which are specialized for encoding, organizing, transforming, storing and retrieving information. One (the image or non-verbal system) is specialized for dealing with perceptual information concerning non-verbal objects and events, whereas the other (the verbal system) is specialized for dealing with linguistic information. A recent application of Paivio's ideas in relation to learning processes is Mayer's (e.g. 1989, 1997; Mayer and Anderson, 1991) Generative Theory of Multimedia Learning. Mayer proposes that meaningful learning occurs 'when learners *select* relevant information from what is presented, *organize* the information into a coherent mental representation, and *integrate* the newly constructed representation with others' (Mayer, 1997, p. 5). Following Paivio, these cognitive processes are thought to occur within two separate information processing systems: a visual system and a verbal system for processing visual and verbal information, respectively. Learning is generally considered to be better when information is referentially processed through the two channels than through either channel alone (e.g. Paivio, 1986).

Mayer and his colleagues have examined predictions derived from the above theoretical framework through a series of empirical studies. For example, Mayer (1989) and Mayer and Gallini (1990) found that college students' understanding of explanatory passages of various mechanical systems (brakes, pumps, and generators)

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Received 1 March 1999
Revised 30 June 1999
Accepted 1 July 1999

was enhanced when the texts were accompanied by *explanatory* illustrations which depicted how the systems work. Although there were no differences in the retention of information between learners who had received the explanatory pictures, and those who had received *non-explanatory* illustrations (which simply depicted the parts of the system) or no illustrations, the former group showed superior performance on problem-solving tests which required the generation of creative solutions to transfer questions. Mayer and Anderson 1992), using similar measures, also found an advantage of multiple representation displays which combined animation and narration, over single representation of the information through narration alone.

Further studies by Mayer's group have shown an advantage of coordinated rather than separated presentation of verbal and visual media, such as text and pictures (e.g. Mayer, 1989; Mayer *et al*., 1995), and narration and animation (e.g. Mayer and Anderson, 1991; Mayer and Sims, 1994). Mayer has termed this the *contiguity effect*. In a review of 10 studies (Mayer, 1997), he found consistent evidence for a contiguity effect: students generated a median of 50% more creative solutions to transfer problems when verbal and visual explanations were coordinated than when they were presented separately. According to Mayer, the coordinated presentation allows learners to develop good mental models of the systems described, by helping them to build referential connections between the visual and verbal information. In other words, the contiguous presentation is more likely to engage the learner in the processes of meaningful learning. Moreover, the contiguity effect has been found to be greater for learners with low, rather than with high prior knowledge of the learning material (e.g. Mayer *et al*., 1985; Mayer and Gallini, 1990). Low prior knowledge learners have poorer mental models of the systems to be learned, and are therefore less likely to generate such models independently, without the aid of the multimedia display.

In general, Mayer's studies have concentrated on the effectiveness of combining verbal and visual media for understanding scientific passages which contain cause-and-effect explanations. They have not examined non-explanatory information, such as information describing procedural tasks. Learning of such procedural tasks requires understanding of the steps in the procedure, retention of the information, and ability to apply the information in terms of performing the procedure (preferably without the need to refer back to the instructions). A number of early studies had reported positive effects of combining verbal and visual information for learning of procedural tasks (e.g. Kieras and Bovair, 1984; Biegler and Glock, 1984; Stone and Glock, 1981; see also Levie and Lenz, 1982). Most of these studies examined the relative effectiveness of different presentation formats in relation to only the initial training phase, e.g. in terms of the time and number of errors made when performing the procedural task for the first time in the different experimental conditions. For example, Stone and Glock (1981) found that college students who received text and picture presentation made fewer errors on an assembly task than students who received text alone. Other studies which have examined retention, and performance of procedural tasks from memory have found mixed results (e.g. Palmiter *et al*., 1991; Palmiter and Elkerton, 1993; Large *et al*., 1995; Ellis *et al*., 1996; Tindall-Ford *et al*., 1997). For example, Palmiter and Elkerton (1993) examined adults' learning of various Hypercard authoring tasks. Although there was an advantage of animated instructions in terms of faster learning times, text presentations resulted in better performance on tasks that were similar (but not identical) to those performed in the initial learning

phase. Large *et al.* (1995) compared the relative effectiveness of multimedia presentations including combinations of text, animation, and captions, on 12-year-old children's learning of various procedural tasks. Here, there were no differences among the presentation groups in verbal recall of the information, but children who received a combination of text and animation showed superior performance in enacting the procedure compared to children who read the text alone.

Given the rather mixed findings to date, the current study examines the effectiveness of different visual and verbal presentations of material for adults' learning of a simple procedural task. Three experiments are reported. Experiment 1 examined the effectiveness of five 'media' presentations for learning of a first aid task. Experiment 2 examined possible explanations for the results obtained. In particular, it asked whether the beneficial effect of the combination of text and pictures was due to the fact that the learning material was referentially processed through two different channels, or because the verbal channel contained additional 'action' information, which was not explicit in the line drawings. Finally, Experiment 3 investigated contiguity effects in the combination of visual and verbal information.

EXPERIMENT 1

Experiment 1 examined the relative effectiveness of five different visual and/or verbal presentations of material for learning a first aid procedural task, namely, how to bandage a hand. Specifically, the steps required for bandaging a hand were presented through the following media: text only, line drawings only, video (which involved only a visual component), and video stills (see Appendix A for examples). Following on from the work of Paivio and Mayer, we were interested to see whether combining visual and verbal information in a single presentation (text plus line drawings) would lead to significantly enhanced performance compared with text or line drawings alone. In addition, we were interested in whether performance could be improved when presenting information in a single (visual) channel, by making the learning materials more realistic (video stills) and realistic and dynamic (video). The effectiveness of the different formats of presentation was assessed in terms of the learners' performance on the bandaging task (i.e. application of retained knowledge), and their general understanding of the procedure (as assessed by a set of written post-task questions). The participants had little or no prior knowledge of the task, and were therefore likely to benefit from effective multimedia presentations (Mayer, 1997).

The experiment included an initial learning phase in which learners were asked to study the learning material until they felt confident that they could perform the task themselves. An important consideration in the selection and adaptation of the learning materials to be used in each experimental condition was that the information was conveyed as clearly as possible in different media. For example, preliminary pilot testing showed that some of the line drawings were ambiguous; these were therefore modified so that they could be understood when presented alone (without the need for additional information). In the testing phase, participants were asked to perform the bandaging task from memory (assessing how well they could apply their retained knowledge). They were also asked to answer a series of questions about the procedure, half of which were presented as text and half as line drawings. Given that our task

involved learning procedural rather than explanatory information, these measures were necessarily different from those used by Mayer and colleagues.

In line with Paivio's (1986) dual coding theory, and the general findings from research on text and pictures, it was predicted that the combination of text and line drawings would be superior to text alone, for both bandaging performance and question answering. That is, the line drawings should help the learners to visualize the information described in the text. Whether the combination of the two media would also have an advantage over line drawings alone was less clear. As noted earlier, most studies examining the relative effectiveness of text and pictures have concentrated on learning of explanatory or declarative information. Given the nature of the information, the combination of text and pictures has typically been compared to text alone. The reason for this is that pictures can rarely convey all of the explanatory or declarative information to be learned. This is not the case for procedural information, where pictures often contain all of the information required for successful completion of the task. For example, many do-it-yourself product instructions contain pictures with limited or no text. Although a number of studies has shown beneficial effects of adding text to pictures, this has been primarily through the inclusion of captions and labels on pictures (e.g. Mayer *et al*., 1995; Large *et al*., 1994), rather than in terms of 'dual' representation of the information through two different media, as it was in the present experiment. It is reasonable to assume that if our line drawings were self-explanatory, the addition of descriptive text would be of little value. As Tindall-Ford *et al*. (1997) point out, where one source of information is intelligible by itself, a secondary source may be unnecessary for learning. If this is the case in our study, the text plus line drawings condition should be no better than line drawings alone.

It was also difficult to make predictions about the relative effectiveness of static visual presentations (i.e. line drawings and video stills conditions) compared to dynamic (video) presentation. Intuitively, given the nature of the task to be learned, the latter presentation would appear to be preferable. However, recent reviews of empirical studies examining learning through static and dynamic visual displays show that the results are very inconsistent (e.g. Park and Hopkins, 1993; Large, 1996). This is mainly due to the diversity of approaches, and the differences in experimental measures. Despite this, animated presentations are generally recommended for procedural tasks, where it is important to convey the sequential actions within the task (Park and Hopkins, 1993). In the present experiment, the video presentation contained a visual but not a verbal element. The dynamic nature of the presentation should convey the information better than the static visual displays; however, it was not clear how it would fare against the text plus line drawings condition. According to dual coding theory, the latter should be better.

Finally, there is also little agreement in the literature regarding the benefit of realistic compared to schematic pictorial displays (e.g. Alesandrini, 1984; Dwyer, 1982; Levie, 1987). Again, intuitively, it might be predicted that the realistic video stills would have an advantage over the schematic line drawings. However, extensive research by Dwyer and his colleagues on the effects of pictures for learning factual information (e.g. about the human heart), has shown that line drawings are generally more effective for focusing learners' attention on details, particularly when study time is fixed and limited. In line with this, and given the nature of the learning phase for the present study, line drawings could be expected to have an advantage over video stills.

Method

Participants
The participants were 75 undergraduate students, aged between 18 and 45, from the University of Reading. Around two-thirds of the participants were women.

Design
The experiment had five experimental conditions which differed in terms of the media used for the presentation of the learning material: text only, line drawings only, text and line drawings, video and video stills. Fifteen participants were allocated at random to each experimental condition.

Material/apparatus
The experiment was run on an IBM compatible 486 PC, with a 15-inch colour monitor. In all experimental conditions, the information to be learned was displayed in the centre of a computer screen. A number of control buttons also appeared on the computer screen; these allowed participants to control different aspects of the presentation. The nature and method of presentation of the learning material, and the control buttons displayed on the computer screen, differed across the experimental conditions; these are described in more detail below.

Text only condition. The learning material consisted of short (mean length of 20 words per step) descriptions of seven steps required for the bandaging of a hand (see Appendix A). This information was based on that provided in current first aid manuals and was displayed through a set of seven successive 'information screens'. On each of these screens the text appeared in the centre of the display and there were four control buttons on the left hand side of the screen. The **Go to Start** button allowed participants to return to the first information screen; the **Previous** button allowed them to return to the preceding information screen, and the **Next** button allowed them to go to the following information screen. The first two buttons were only available after all of the information screens had been viewed once; before this, they appeared in a 'greyed out' form which indicated that they could not be selected. Finally, on the top left hand corner of the screen was the **Confident** button, which participants were asked to select when they felt confident that they carry could out the bandaging procedure on their own.

Line drawings only condition. The learning material included seven line drawings of steps in the bandaging of a hand, which corresponded to the text descriptions of the Text only condition (see Appendix A). Again these were adapted from first aid manuals. One line drawing was presented in the centre of each of seven information screens. The control buttons were the same as those for the Text only condition.

Text plus line drawings. The learning material was composed of the text descriptions plus line drawings used in the Text only and Line drawings only conditions, respectively. The text information appeared in the lower centre of the screen, with the

corresponding line drawing displayed above it. The control buttons were the same as for the Text only condition.

Video condition. The learning material was 1.5-minute video clip with showed a certified first aider performing the bandaging procedure on an injured hand. The control buttons included a Start/Stop button, and a slider which could be moved to a desired point of the video clip, when the video had been viewed once. On the top-left corner of the screen was the **Confident** button which participants were asked to select when they felt confident that they could bandage a hand themselves.

Video stills condition. The learning material comprised seven video stills, taken from the video clip of the Video condition, which corresponded to the seven text descriptions of the steps of the bandaging procedure (see Appendix A). The control buttons were the same as those of the Text only condition.

Test materials

The following materials were used for the test phase:

- A 127×90 cm triangular bandage, folded lengthwide into a long narrow band
- A cast model of a hand (in the form of a fist) which could be attached to a laboratory bench using a G-clamp.
- *Confidence questionnaire*. Participants were asked to indicate how confident they were to bandage a hand themselves (using the procedure they had just studied) on a 5-point rating from 1: not at all confident, to 5: very confident. They were also asked to provide background information about themselves, including whether they had an Arts or a Science educational background, whether they had ever taken a first aid course, and whether they had experience of bandaging a hand themselves.
- *Questions booklet*. This included six questions in total, three of which were in text form and three in line drawings form. Each question described or depicted (for the text and line drawings questions, respectively) a stage in the bandaging of a hand. Participants were asked first to judge whether the step in the bandaging procedure described or depicted was correct or incorrect. If they thought the step to be correct, they then had to describe or draw (although they were also allowed to explain their drawings in words) the next step in the bandaging of a hand. If they thought the step to be incorrect, they were asked to indicate what the error was. The order of the text and line drawing questions within the booklet was counterbalanced. Participants were instructed to answer the question on each page, without looking back to their previous responses. There was no time limit on the answering of the questions.

Procedure

The experiment included three phases: practice, study and a test. Participants were tested individually. At the start of the experiment, they were given written instructions which introduced them to their task. Specifically, they were informed that they would be presented with information about how to bandage a hand, which they had to study

until the point that they felt confident that they could carry out the procedure on their own. They were also given a brief description about how the information would be presented to them (e.g. in the Text only condition, participants were told that they would be presented with the learning material through seven information screens), and what control buttons would be available to them. Participants were instructed to read through or look at (depending on the experimental condition) the material once, and then revise it in any order and/or rate they preferred, until the point that they felt confident that they could bandage a hand themselves.

A practice session was given to familiarize participants with the learning environment and the control options available in their experimental condition. Participants were presented with sample learning material (from the medical domain but not related to bandaging) and asked to practise using the control button on the screen, and then to select the **Confident** button when they felt confident to proceed to the experimental session.

In the study phase, participants studied the learning material until the point that they felt confident that they could bandage a hand by themselves. In the test phase, participants were first given the *Confidence questionnaire*. They were then given a bandage and asked to carry out the bandaging procedure on the model hand. They were told to imagine that the model was an injured hand, that it had been given initial first aid treatment and that it was ready to be bandaged. Participants were instructed to bandage the hand using the procedure they had studied. After the completion of this task, they were given the *Questions booklet*.

Results

Learning phase

Two measures were calculated for the learning phase: the average amount of time taken to study the learning material until confident to bandage a hand, and a mean rating of confidence in answering the questions at the end of the study period. The means for the five experimental conditions are shown in Table 1. Two one-way analyses of variance on these measures showed no significance differences between the groups in the time taken to study the learning material, $F(4,70) < 1$, and in confidence to carry out the procedure at the end of the study period $F(4,70) = 1.84$, $p > 0.1$.

Bandaging performance

A scoring system was devised to assess participants' performance in bandaging a hand. One point was given for the completion of each of the seven steps in the

Table 1. Experiment 1: Mean time taken to study the learning material until confident, and mean ratings of confidence to carry out the bandaging procedure at the end of the study period

Presentation condition	Time (in minutes) taken to study learning material until confident (std)	Confidence (std)
Text only	3.66 (1.53)	3.80 (0.77)
Line drawings only	3.32 (1.28)	3.67 (0.62)
Text plus line drawings	3.56 (1.22)	4.00 (0.53)
Video	3.64 (1.98)	3.87 (0.91)
Video stills	4.31 (2.32)	3.33 (0.72)

bandaging procedure. Two additional points were awarded for their speed/fluency in carrying out the procedure, and one additional point was given for neatness. It is important to note that each of the steps was scored individually, independent of whether the previous step(s) had been performed correctly. For example, participants could be awarded one point for correctly tying the ends of the bandage in a knot in front of the fingers (i.e. the last step in the procedure), even if they had not successfully carried out the previous steps. The scoring was carried out by a trained first-aider who was familiar with the bandaging procedure presented to participants, but was blind as to the particular experimental condition to which learners had been allocated.

The mean bandaging scores, out of the total possible of ten, for each of the five groups, are shown in Table 2. A one-way analysis of variance indicated that there was a significant difference in the performance of the five groups $F(4,70) = 7.73$, $p < 0.0001$. *Post-hoc* Student–Newman–Keuls tests ($\alpha = 0.05$) showed that the video and the text plus line drawings conditions performed significantly better than the video stills, text only, and line drawings only groups. There were no significant differences between video and text plus line drawings, or between video stills, text only and line drawings only. Thus the text and line drawing was significantly better than text only and line drawings only, and video was significantly better than video stills.

Questions booklet

One point was awarded for correctly judging whether the text description or the line drawing was correct or incorrect. A further two points were given for correctly stating what the next step would be or what the error in the procedure was, with one point awarded for partially correct responses. Table 2 shows the mean question scores, out of a total possible of 18 for the five experimental groups. Scores were collapsed across question type (text versus line drawings) as no differences were found in any of the three experiments.

A one-way analysis of variance showed a marginally significant effect of presentation condition, $F(4,70) = 2.49$, $p = 0.05$. A Least Significant Differences *post-hoc* test ($\alpha = 0.05$) showed that the text plus line drawing condition performed significantly better than the text, video stills and line drawing conditions, and that the video condition performed better than the video stills and line drawings conditions.

Discussion

The results showed a clear advantage of the combination of text plus line drawings over the presentation of either text or line drawings alone, in terms of both per-

Table 2. Experiment 1: Mean scores for bandaging performance (out of 10) and for questions of the *Questions booklet* (out of 18)

Presentation condition	Bandaging: performance: score out of 10 (std)	Questions: Total scores out of 18 (std)
Text only	2.87 (2.29)	8.07 (3.28)
Line drawings	3.93 (2.46)	8.73 (4.49)
Text plus line drawings	5.73 (2.68)	11.13 (3.83)
Video	6.93 (2.31)	10.47 (3.35)
Video stills	3.40 (2.06)	7.33 (4.51)

formance on the bandaging task and correct responses to questions about the procedure. Video presentation was found to be significantly better than static visual presentation through line drawings and through stills taken from the video. However, it led to similar levels of performance on the bandaging task as the text plus line drawings condition. These differences in performance among the experimental groups occurred despite the fact that there were no differences in time taken to study the information and confidence at the end of the learning phase.

The advantage of the combination of text and line drawings over the presentation of either text or pictures alone is in accord with Paivio's (1986) dual coding theory, which predicts better learning when information is processed through both the verbal and visual systems. However, this theory does not explain why the combination of text and pictures was not better than video presentation which, in this case, contained only visual information. The most likely explanation is that the dynamic presentation of the information in the video allowed learners to develop a sufficiently good mental model of what was required for the task. Given that the line drawings were created to be largely self-explanatory, one might also have expected them to be sufficient for learning of the task (cf. Tindall-Ford *et al.*, 1997). However, the results clearly indicate that the addition of the verbal channel/information resulted in better understanding of, and subsequent performance on, the bandaging task.

The question that arises is, why was the combined text plus pictures presentation condition better than the line drawings alone? Was it because the learning material was referentially processed through two different channels, or because the verbal channel contained additional information that was not present in the visual channel? The fact that the video presentation was also superior to the line drawings (and video stills) alone, suggests that it is not necessary for information to be processed through both visual and verbal channels in order to enhance learning. An important difference between the video and line drawing conditions was that the video presentation was dynamic, whereas the line drawings (and video stills) were relatively static. One possibility, therefore, is that the text provided additional action information which complemented the static line drawings. In particular, the text conveyed more information about what action needed to be taken to get from one step in the procedure to the next than was apparent in the line drawings. Experiment 2 attempted to distinguish between these two different explanations for the advantage of text and line drawings over line drawings alone, by examining the role of *action* information in learning to perform the bandaging task.

EXPERIMENT 2

The aim of Experiment 2 was to examine whether the advantage of text plus line drawings (and video) condition of Experiment 1 over the line drawings alone condition was due to better representation of the actions required to get from one step in the procedure to the next. We hypothesized that if this action information is important for learning the task, then the degree to which it is conveyed in the different media presentations, will affect their relative effectiveness in terms of learners' understanding of, and ability to perform, the procedure.

In particular, we predicted that the effectiveness of the combination of text and line drawings should be reduced if text simply disambiguates the line drawings, i.e. by

describing a line drawing, without providing information on the action needed to get to the particular state shown, or to get to the next step in the procedure. Similarly, the effectiveness of line drawings presented alone should improve if these are enhanced by features that better convey the action information, for example, with arrows showing in what direction the ends of the bandage should be moved to get to the next step of the procedure.

Experiment 2 compared five media presentations: simple line drawings only; enhanced line drawings (with arrows); standard text plus line drawings; reduced text (i.e. text with action information removed) plus line drawings; and standard text plus enhanced line drawings. The general design of the experiment and the measures were the same as in Experiment 1. As discussed above, we predicted that the enhanced line drawings should have an advantage over the simple line drawings. This presentation could also lead to similar levels of performance than the standard text and line drawings condition. The standard text plus line drawings should be better than reduced text and line drawings. Finally, the standard text plus enhanced line drawings was included to examine whether addition of the arrows on the line drawings would further improve the text plus line drawings presentation.

Method

Participants

The participants were 80 undergraduate students, aged between 18 and 45, from the University of Reading. None had taken part in Experiment 1. Again, around two-thirds of the participants were women.

Design

There were five experimental conditions: simple line drawings, enhanced little drawings, standard text plus line drawings, reduced text plus line drawings, standard text and enhanced line drawings. Sixteen participants were allocated to each of the experimental conditions. In all other respects, the experimental design was the same as for Experiment 1.

Materials

The learning materials for all conditions were presented in the centre of seven information screens, as in Experiment 1. The control buttons were the same as those displayed in the text only condition of Experiment 1.

The learning materials for the simple line drawings and the standard text plus line drawings conditions were the same as those used for the line drawings only and text plus line drawings conditions, respectively, of Experiment 1.

Reduced text plus line drawings. The learning material was the same as that used for the text plus line drawing condition in Experiment 1, except that the content of the text was modified. The 'reduced' text described the corresponding line drawings, but did not provide information about the sequence of steps within the procedure. That is, it provided little action information as to the direction in which the ends of the bandage had to be moved to get to the next step in the procedure (see Appendix B).

Enhanced line drawings condition. The learning material consisted of the same line drawings used for the line drawings only condition of Experiment 1, but these were enhanced with arrows which indicated the direction in which each end of the bandage had to be placed in order to arrive at the next step in the bandaging procedure (see examples in Appendix B).

Standard text plus enhanced line drawings. The materials and presentation were the same as for the standard text plus line drawings, the only difference being that enhanced line drawings with arrows were used instead of the simple line drawings.

Test materials. The test materials were the same as those used in Experiment 1.

Procedure
This was the same as Experiment 1.

Results

Learning phase
The average amount of time taken to study the learning material until the participants felt confident to bandage a hand themselves, and their mean confidence to carry out the bandaging procedure at the end of this study period were calculated. The means for these measures are shown in Table 3. A one-way analysis of variance found no significant differences in study time, $F(4,75) < 1$. However, a significant difference was found in participants' confidence to carry out the procedure at the end of this time, $F(4,75) = 2.94$, $p < 0.05$. *Post-hoc* Student–Newman–Keuls tests ($\alpha = 0.05$) showed that participants in the standard text plus enhanced line drawings, the reduced text plus line drawings, and the enhanced line drawings conditions, gave significantly higher ratings of confidence to carry out the task at the end of the study period than the participants in the standard text plus line drawings and simple line drawings conditions. No other differences between the conditions were significant.

Table 3. Experiment 2: Mean time taken to study the learning material until confident, and mean ratings of confidence to carry out the bandaging procedure at the end of the study period

Presentation condition	Study time, in minutes, until confident (std)	Confidence (std)
Simple line drawings	3.36 (1.17)	3.37 (0.62)
Enhanced line drawings	3.08 (1.21)	3.94 (0.57)
Standard text plus line drawings	2.85 (1.46)	3.75 (0.58)
Reduced text plus line drawings	3.16 (1.22)	3.94 (0.57)
Standard text plus enhanced line drawings	3.30 (1.20)	4.00 (0.63)

Table 4. Experiment 2: Mean scores for bandaging performance (out of 10) and for questions of the *Questions booklet* (out of 18)

Presentation condition	Bandaging performance score out of 10 (std)	Questions: total score out of 18 (std)
Simple line drawings	3.81 (1.97)	10.06 (4.84)
Enhanced line drawings	6.44 (2.03)	13.37 (3.03)
Standard text plus line drawings	6.75 (2.29)	10.75 (3.66)
Reduced text plus line drawings	4.94 (1.84)	12.19 (3.56)
Standard text plus enhanced line drawings	7.19 (2.20)	13.12 (2.78)

Bandaging performance

The scoring system for assessing the bandaging performance was the same as that used for Experiment 1. The mean bandaging scores, out of a total possible of ten, are shown in Table 4.

The conditions which provided more information about the sequences of events in the bandaging procedure (i.e. the standard text plus line drawings and the enhanced line drawings), were generally more effective than the conditions which provided less of this information (i.e. the simple line drawings and the reduced text plus line drawings).

A one-way analysis of variance showed that there was a significant difference in bandaging performance among the five groups $F(4,75) = 7.37$, $p < 0.0001$. *Post-hoc* Student–Newman–Keuls tests ($\alpha = 0.05$) showed that participants in the enhanced line drawings condition and the standard text plus line drawings (and standard text plus enhanced line drawings) performed significantly better than those in the simple line drawings condition, and in the reduced text plus line drawings condition. No other differences were significant.

Questions booklet

The scoring of the question booklet was the same as for Experiment 1. Table 4 shows the mean scores, out of a total possible of 18.

A one-way analysis of variance showed a significant effect of presentation condition, $F(4,75) = 2.55$, $p < 0.05$. A Least Significant Differences *post-hoc* test ($\alpha = 0.05$) showed that both the enhanced line drawings and the standard text plus enhanced line drawing conditions performed significantly better than the simple line drawing alone condition. The enhanced line drawings group also performed significantly better than the standard text plus line drawing condition.

Discussion

The results clearly demonstrate that the representation of action information through the different media influences the relative effectiveness of the presentations in terms of the learners' understanding of and ability to perform the bandaging task. In particular, the effectiveness of the text plus line drawings presentation was reduced when the text simply disambiguated the picture without providing information about the next step; a finding which is not easily accounted for by Paivio's dual coding

theory (e.g. Paivio, 1986). Similarly, the effectiveness of simple line drawings was significantly improved when these were enhanced with arrows which more clearly showed the actions required to get to the next step in the procedure. Participants who were shown the enhanced line drawings performed as well on the bandaging task as participants presented with standard text with pictures, and in fact showed marginally better understanding of the task in terms of their performance on the questions. However, there was no additional benefit of adding text descriptions to the enhanced line drawings (a finding which also goes against Paivio).

In this experiment, unlike Experiment 1, there was a difference between experimental conditions in terms of the learning measure of how confident participants felt that they could bandage a hand themselves at the end of the study period. In particular, participants in the standard text plus enhanced line drawings, the reduced text plus line drawings, and the enhanced line drawings alone conditions gave significantly higher ratings of confidence to carry out the bandaging task than participants in the standard text plus line drawings and simple line drawings conditions. It is interesting to note that these differences in confidence at the end of the learning phase were not predictive of subsequent level of performance on the task. For example, the reduced text plus line drawings group performed significantly worse on the bandaging task than the standard text plus line drawings group, despite the former group's higher ratings of confidence in performing the task at the end of the study period.

In summary, the results of Experiment 2 suggest that effective media for learning of simple procedural tasks (like our bandaging procedure) are those which clearly convey action information which helps learners understand how to get from one step in the procedure to the next. This action information can be conveyed through the appropriate combination of verbal and visual media, or by a single medium (i.e. line drawings), enhanced with appropriate symbols or features to represent the action.

EXPERIMENT 3

In Experiments 1 and 2, in the 'combination' conditions, the text descriptions and corresponding line drawings were displayed together on the same screen. According to Mayer and his colleagues (e.g. Mayer and Anderson, 1992; Mayer and Sims, 1994), for explanatory information, this way of presenting text with pictures is most beneficial due to the 'contiguity effect'. The simultaneous (contiguous) presentation is thought to help learners integrate the information from the two media (i.e. to build one-to-one connections between elements, actions and causal relations in the visual representation and in the verbal representation), and thereby develop appropriate mental models. The aim of Experiment 3 was to examine the contiguity effect in relation to learning to perform our bandaging task. If the beneficial effect of the combined text and line drawings presentation in our experiments was due to the additional action information present in the text (which complemented the static line drawings), was it necessary for the two sources of information to be presented contiguously in order to enhance learning? Experiment 3 addressed this question by examining whether the advantage of the combination of text and line drawings (over either text or line drawings alone) would be observed if corresponding text and drawings were presented sequentially on different screens, and, in addition, whether learning would be det-

rimentally affected by increasing the distance (i.e. the number of intervening screens) between the corresponding text and drawings.

Five presentation conditions were compared: text only, line drawings only, text plus line drawings simultaneous; text and line drawings sequential; and text plus line drawings separated. The first three conditions were the same as the corresponding ones of Experiment 1. In the text plus line drawings sequential condition, each text description was followed (or preceded) by its related line drawing, while in the separated condition, all of the text screens were followed (or preceded) by the full set of line drawings. According to Mayer's formulation (e.g. Mayer, 1997), visual information must be held in visual working memory at the same time as the corresponding verbal information is held in verbal working memory in order to benefit learning. If the same condition holds in our learning situation, we could expect participants in the simultaneous condition to perform better than those in the sequential condition, who in turn should perform better than participants in the separated condition.

Method

Participants

The participants were 108 undergraduate students, (aged between 18 and 45) from the University of Reading. About two-thirds were women. None had taken part in Experiments 1 or 2.

Design

There were five experimental conditions: text only, line drawings only, text plus line drawing simultaneous, text plus line drawings sequential, and text plus line drawings separated. Participants were allocated at random to the experimental conditions. Twenty participants were allocated to the text only, line drawings only, and text plus line drawings simultaneous conditions. Twenty-four participants were allocated to the text plus line drawings sequential and text plus line drawings separated conditions, with half of the participants in each condition receiving text before the pictures, and the other half receiving the information in the reverse order. In all other respects, the experimental design was the same as for Experiments 1 and 2.

Apparatus/materials

The learning material for all conditions was presented in the centre of seven information screens. The control buttons were the same as those displayed in the Text only condition of Experiment 1.

Separated and sequential presentations. In the sequential presentation, for half of the participants, each text screen was followed by the corresponding picture; for the other participants, text and line drawing screens were presented in the reverse order. In the separated condition, all of the seven text screens were presented first, followed by all of the line drawing screens, or vice versa.

Test materials. The test materials were the same as those used in Experiment 1.

Table 5. Experiment 3: Mean time taken to study the learning material until confident, and mean ratings of confidence to carry out the bandaging procedure at the end of the study period

Presentation condition	Study time, in minutes, until confident (std)	Confidence (std)
Text only	3.72 (1.38)	3.30 (0.76)
Line drawings only	2.65 (1.07)	3.65 (0.87)
Text plus line drawings simultaneous	4.09 (1.76)	3.90 (0.55)
Text plus line drawings sequential	3.30 (1.16)	3.67 (0.56)
Text plus line drawings separated	3.52 (1.16)	3.67 (0.87)

Procedure
This was the same as Experiment 1.

Results

Preliminary analysis of the results from the sequential and separated conditions showed that there were no differences in the order of presentation of text and pictures on any of the measures. The data from the two orders in each condition were therefore combined in subsequent analyses.

Learning phase
The average amount of time taken to study the learning material until the participants felt confident to bandage a hand themselves, and their mean confidence to carry out the bandaging procedure at the end of this study period were calculated. The means for these measures are shown in Table 5. A one-way analysis of variance found a significant difference in study time, $F(4,103) = 3.29$, $p < 0.05$. *Post-hoc* Student–Newman–Keuls tests ($\alpha = 0.05$) showed that participants in the simultaneous text and line drawings condition spent significantly more time studying the material than the line drawing alone group. No other differences were significant. A one-way analysis of variance found no significant differences in confidence to carry out the procedure at the end of the study time $F(4,103) = 1.86$, $p > 0.1$.

Bandaging performance
The scoring system for assessing the bandaging performance was the same as that used for Experiment 1. The mean bandaging scores, out of a total possible of ten, are shown in Table 6.

Table 6. Experiment 3: Mean scores for bandaging performance (out of 10) and for questions of the *Questions booklet* (out of 18)

Presentation condition	Bandaging performance score out of 10 (std)	Questions: total score out of 18 (std)
Text only	2.80 (1.39)	11.80 (3.98)
Line drawings only	3.55 (1.93)	8.95 (3.75)
Text plus drawings simultaneous	6.00 (2.38)	12.50 (3.80)
Text plus line drawings sequential	5.21 (2.34)	12.71 (3.59)
Text plus line drawings separated	5.79 (2.32)	13.33 (3.41)

A one-way analysis of variance showed that there was a significant difference in bandaging performance among the four groups $F(4,103) = 9.23$, $p < 0.0001$. *Post-hoc* Student–Newman–Keuls tests ($\alpha = 0.05$) showed that participants in all three text plus line drawing conditions (i.e. simultaneous, sequential and separated) performed significantly better than line drawings only and text only. No other differences between the groups were significant.

Questions booklet

The scoring of the question booklet was the same as for Experiment 1. Table 6 shows the mean scores, out of a total possible of 18.

A one-way analysis of variance showed a significant effect of presentation condition, $F(4,103) = 4.50$, $p < 0.01$. *Post-hoc* Student–Newman–Keuls tests ($\alpha = 0.05$) showed the three text plus line drawing conditions and the text only condition were significantly better than the line drawings only condition. No other differences were significant.

Discussion

In line with Experiment 1, the presentation which combined text and line drawings led to significantly better performance than the presentation of either text or line drawings alone. However, in contrast to Mayer's (1997) findings with explanatory materials, there was no evidence of a contiguity effect with our bandaging task and materials. Although the simultaneous group's performance level on the bandaging task was numerically better than that of the other two combination groups, the difference was small and not statistically significant. Moreover, there was no effect of the distance between the corresponding text and line drawings.

One explanation for lack of a contiguity effect is that learners were given the chance to review the information until the point that they felt confident they could perform the task. So, although the sequential and separated tasks could be considered as being more difficult than the simultaneous presentation, learners may have been able to integrate the information through repeated exposure. However, given the constraints on working memory, it is still surprising that integration of information was not easier in the sequential condition compared to the separated condition, where the learners always had to scroll through six screens of information between each line drawing and section of corresponding text. Observation of participants while performing the task suggested that most people did not 'skim' over the intermediate pages to get to corresponding text and/or line drawings, but followed through the text and drawings in sequence. After looking at the full set of text and line drawings, the majority of learners revisited the set of drawings more times than the text. Future research needs to examine the point at which the successive viewing of visual and verbal material becomes beneficial. For example, using our task, would a single exposure to the text be sufficient to benefit learning with the line drawings alone? At present, these results tell us that, for a simple procedural task (like learning to bandage a hand), visual and verbal information does not necessarily *have* to be presented contiguously in order to benefit learning.

GENERAL DISCUSSION

Overall, our results are in line with studies in the literature which have shown an advantage of the combination of text and pictures over either medium alone (e.g. Mayer and Gallini, 1990), and of animated (video) presentation for the learning of procedural tasks (e.g. Large *et al.*, 1994). In addition, our findings extend what is currently known in this area. Experiment 2 showed that the superior performance of the combined pictures and text condition could not be easily accounted for in terms of a simple dual coding explanation (i.e. that the information was referentially processed through two different channels). Rather, the effectiveness of the different media and their combination for learning of a procedural task was influenced by the extent to which they conveyed action information. Moreover, in contrast to findings with explanatory materials, Experiment 3 showed no evidence of a contiguity effect when people were learning to perform our bandaging task. Text and pictures were as effective when presented together on the same screen, as when they were presented separately, even when the distance between corresponding text and pictures was considerable. We are not arguing here that our findings disprove Mayer's theory in any way. Rather, we have shown that with different materials and learning measures (retention and application of procedural knowledge), a different pattern of results can emerge (as Mayer, 1995, himself anticipated).

In all three experiments, differences in bandaging performance tended to be reflected in differences in performance on the post task questions, suggesting that participants learned the task in a relatively explicit manner (e.g. Berry and Broadbent, 1984; Berry, 1994). Although we expected to find different patterns of performance on the text and line drawing questions as a function of learning presentation condition, none were apparent.

In Experiment 1, there was no significant advantage of the realistic and dynamic video presentation condition over the text and line drawings condition, nor was there any advantage of realistic video stills over simple line drawings. These findings suggest that technically simple methods can be very effective when training people to perform simple procedural tasks, and that it is not always necessary to use advanced technology for such purposes. The findings have important implications for systems designers, as training systems which incorporate video are both expensive to produce and require more sophisticated delivery platforms.

The advantage of enhanced over simple line drawings in Experiment 2 clearly supports the view that the content and quality of pictures influences their effectiveness (Molitor *et al.*, 1989; Scaife and Rogers, 1996; Winn, 1989). According to Winn (1989), the use of symbols, such as arrows, can help to make temporal and spatial relationships within graphical representations clearer, and thus strengthen the visual argument. In the present study, the addition of arrows to the line drawings appeared to better convey information about how to get from one step of the procedure to the next.

The findings from Experiment 2 are also in agreement with the relatively few studies (e.g. Ellis *et al.*, 1996; Mayer and Gallini, 1990) which have examined the effect of adding different types of text to pictures (as opposed to looking at how different types of pictures lead to better understanding of text). For example, Ellis *et al.* (1996) found better performance on an assembly task when pictorial information was combined with *functional* rather than with *structural* explanations. According to Ellis *et al.*,

functional explanations provide information about cause–effect relationships within systems portrayed and tend to be action-oriented, while structural explanations provide static descriptions of the components of a picture and how they interconnect. Similarly, Mayer and Gallini (1990) report an advantage of the combination of pictures with explanatory text which labels the system components and describes their behaviour at different stages in the operation of the system. Although the *standard* text of Experiment 2 did not provide labels (these, we could assume, would not be of much benefit given the familiar nature of the task components), it did elucidate the successive steps in the procedure, and so could be considered similar to Mayer and Gallini's effective explanatory text. Moreover, it could be considered to be a *functional* explanation, according to Ellis *et al*.'s definition, whilst our *reduced* text is more like a *structural* explanation.

The fact that performance on the bandaging task for the combined text plus line drawings condition was relatively good in all three experiments suggests that the requirement to split attention across the two types of learning material did not cause major problems for participants. Other studies (e.g. Chandler and Sweller, 1991) have shown reduced performance (known as split attention effects) when people are required to attend to multiple sources of information which they need to integrate mentally in order to understand the material. Improvements in performance on a variety of problem-solving tasks have been demonstrated when split attention effects are reduced, either by the physical integration of text and pictorial information (i.e. by presenting the information closer together), or by presenting verbal information auditorily rather than visually (e.g. Chandler and Sweller, 1991; Tindall-Ford *et al*., 1997). Using our bandaging task, it would not be easy to integrate the text and pictures any more closely than they are at present in the combined (simultaneous) presentation conditions. However, experiments in progress are examining whether there is any advantage to a combined narration and line drawings presentation over the standard combined text and line drawings presentation. Experiments in progress are also investigating whether the lack of contiguity effects obtained in Experiment 3 applies to procedural learning tasks in general or just to the bandaging task used in the present study.

Finally, the results of the present set of experiments have implications for the design of multimedia learning systems. First, they show that a combination of text and pictures is usually better than the presentation of either medium alone, but only when the two media convey complementary rather than redundant information. However, with simple procedural tasks, it is possible to design the visual information so that it is equally as effective as the combined presentation. Second, multimedia displays which clearly convey action information seem to be the most effective for training procedural tasks. Finally, unlike explanatory information (such as that used by Mayer and colleagues), for simple procedural tasks, sequential presentation of text and pictures can be as effective as their simultaneous presentation, even if the distance between the corresponding text and pictures is considerable.

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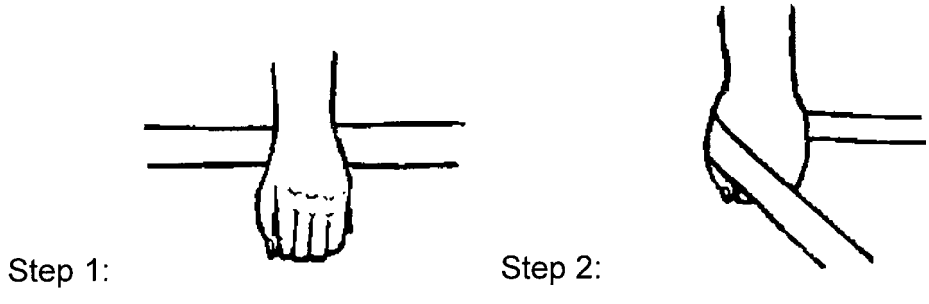
APPENDIX A: EXAMPLES OF MATERIALS USED IN EXPERIMENT 1

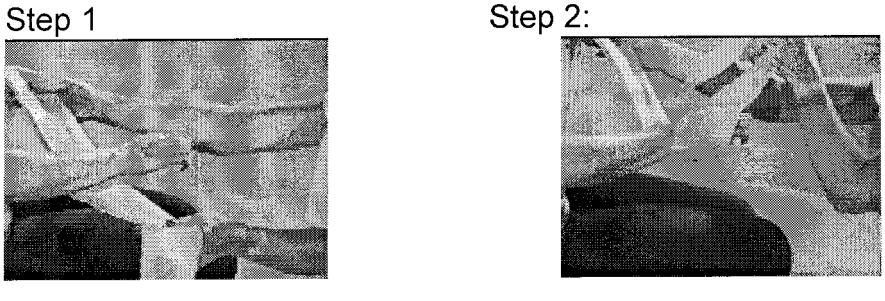
Text

Step 1: To begin, the hand should be in a fist, with the palm facing downwards. Holding the ends of the bandage in each hand, place the centre of the bandage under the wrist.
Step 2: Wrap one end of the bandage around the back of the hand.

Line drawings only



Video stills



APPENDIX B: EXAMPLES OF MATERIALS USED IN EXPERIMENT 2

Reduced text

Step 1: The hand is in a fist with the palm facing downwards. The centre of the bandage is under the wrist.
Step 2: One end of the bandage lies diagonally over the back of the hand.

Enhanced line drawings