CHAPTER 8

The Split-Attention Principle in Multimedia Learning

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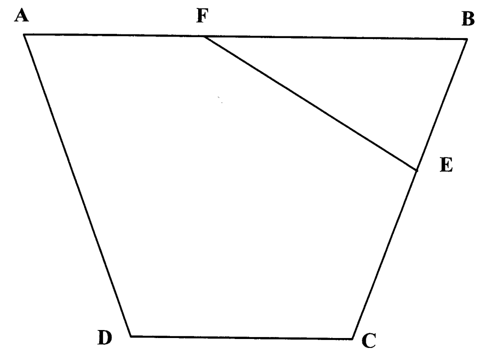
Abstract

The split-attention principle states that when designing instruction, including multimedia instruction, it is important to avoid formats that require learners to split their attention between, and mentally integrate, multiple sources of information. Instead, materials should be formatted so that disparate sources of information are physically and temporally integrated thus obviating the need for learners to engage in mental integration. By eliminating the need to mentally integrate multiple sources of information, extraneous working memory load is reduced, freeing resources for learning. This chapter provides the theoretical rationale, based on cognitive load theory, for the split-attention principle, describes the major experiments that establish the validity of the principle, and indicates the instructional design implications when dealing with multimedia materials.

Definition of Split-Attention

Instructional split-attention occurs when learners are required to split their attention between and mentally integrate several sources of physically or temporally disparate information, where each source of information is essential for understanding the material. Cognitive load is increased by the need to mentally integrate the multiple sources of information. This increase in extraneous cognitive load (see chapter 2) is likely to have a negative impact on learning compared to conditions where the information has been restructured to eliminate the need to split attention. Restructuring occurs by physically or temporally integrating disparate sources of information to eliminate the need for mental integration. The split-attention effect occurs when learners studying integrated information outperform learners studying the same information



Task: In the above diagram find the value of angle BFE when

line AB is parallel to line DC

Angle BCD = 110°

Angle BEF = 50°

Solution:

Angle FBE = 180 – 110 = 70° (Co-interior angles between parallel lines sum to 180°)

Angle BFE = 180 – 50 – 70 (Angles in a triangle sum to 180)

= 60°.

Figure 8.1. Split-attention in a geometry worked example.

presented in split-attention format. The split-attention principle flows from the split-attention effect. It states that when presenting disparate sources of information that must be mentally integrated in order for the information to be understood, those sources of information should be presented in integrated format.

Examples of the Split-Attention Effect

The different sources of information that cause split-attention vary. For example, the sources can be text and text, or text and mathematical equations, or different forms of multimedia. Using Mayer's definition of multimedia as "the presentation of materials using both words and pictures" (Mayer 2001, p. 1) it can be seen that split-attention will frequently occur using multimedia as there will always be at least two sources of information involved.

Figure 8.1 demonstrates an example of materials that include a requirement to split attention in the mathematical domain of geometry. In Figure 8.1 the diagram is separated from the solution that explains how the task (find Angle BFE) is completed. Neither source of information makes sense without the other. The diagram provides no solution information and the solution information is unintelligible without the diagram. To understand this worked example, a learner will be forced to integrate many pieces of information. Initially, learners will have to locate the given information (the parallel lines and the two angles) on the diagram. If the learner can write this information on the diagram then split-attention only occurs once at this stage. However, to follow the two steps to solution, learners have to mentally integrate these steps with specific angles and geometrical configurations in the diagram. This requirement to split attention between the diagram and text followed by mental integration is a classic example of split-attention. If the learner is a novice, possessing few developed schemas in this domain, it might be expected that substantial cognitive resources will need to be devoted to splitting attention between the disparate sources of information and mentally integrating them.

To avoid split-attention, researchers have successfully employed the strategy of physically integrating the various sources of information. Figure 8.2 demonstrates how the two parts (diagram and text) of the worked example in Figure 8.1 have been integrated. First, the given information on angles and parallel lines are drawn on the diagram. Parallel lines are represented by the universal symbol of the two arrows, and the two angles 110° and 50° are marked. Second, the two steps to solution are written on the diagram at the precise location where the values for the angles are calculated thus eliminating the need for the learner to keep refocusing attention from diagram to text and vice versa. Searching for referents in multiple sources of information is likely to be a major source of extraneous cognitive load. The order in which the solution steps are calculated, are also marked on the diagram and indicated by the numbers 1 and 2. As a consequence of this physical integration, the need for mental integration is reduced and extraneous cognitive load is kept to a minimum.

Basic Research Into the Split-Attention Effect

The initial research into the split-attention effect was conducted by Tarmizi and Sweller (1988) who investigated the effectiveness of worked examples on learning geometry. Prior to this study, worked examples (see chapter 15) had proven to be highly effective for learning algebra (Cooper & Sweller, 1987; Sweller & Cooper, 1985) and in other mathematical domains (Zhu & Simon, 1987). However, in their initial experiments, Tarmizi and Sweller found that neither worked examples nor guided solutions (highly directed but not a full worked example) enhanced performance compared with conventional problem-solving strategies.

The failure of worked examples in geometry was initially perplexing. However Tarmizi and Sweller reasoned that the format of the worked examples, a diagram followed by the solution steps (Figure 8.1 provides an example), must increase

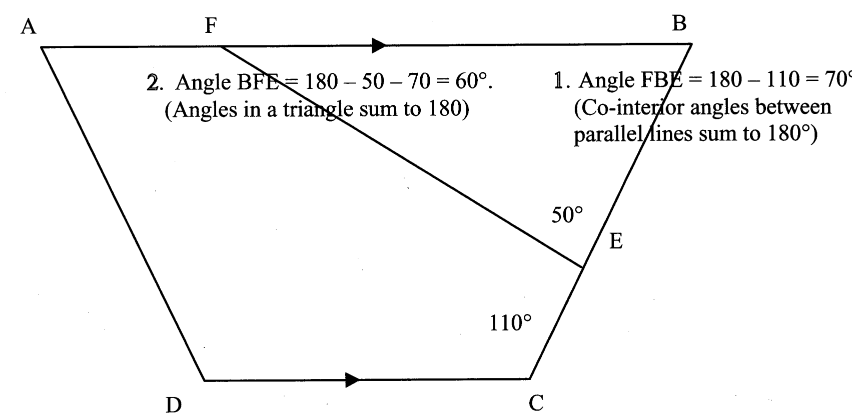


Figure 8.2. Integrated worked example of a geometry problem.

cognitive load. In particular, they argued that the source of increased cognitive load was the requirement for learners to mentally integrate the two sources of information (diagram and textual solutions) that had split their attention. They further hypothesised that if diagrams and texts were integrated, then split-attention would be avoided leading to effective worked examples. In the final two experiments of this study, Tarmizi and Sweller successfully showed that learners who studied integrated worked examples performed at a superior level (fewer errors and quicker solution times) compared to learners who followed a conventional problem-solving strategy during acquisition.

Researchers sought to test these findings in other domains following the identification of the split-attention effect and the success of integrated material in the geometry domain. Sweller, Chandler, Tierney, and Cooper (1990) reproduced the Tarmizi and Sweller findings using coordinate geometry materials. Again, traditionally structured worked examples in this domain have used a diagram associated with solution steps next to or under the diagram. Using this format, as indicated previously, learners are forced to search for the location of referents in either the diagram or the text and that search process requires working memory resources. Sweller et al. (1990) found that learners studied worked examples formatted in the traditional way performed no better than learners required to solve a conventional problem. In contrast, learners who studied an integrated worked example format where steps to the solution were written on the diagram at locations designed to reduce unnecessary search, performed significantly better than learners studying conventionally structured worked examples or solving problems. Furthermore, as might be expected, these results were not restricted to instruction using worked examples. In further experiments, Sweller et al. found that initial instructions presented in an integrated format were superior to the same instructions presented in a split-attention format.

Additional evidence of the split-attention effect and how it could be avoided was provided by Ward and Sweller (1990) in the area of physics. Using mechanics problems based on the formulae associated with constant acceleration, Ward and Sweller found that worked examples compared poorly with a problem-solving strategy. Following on from the earlier research of Tarmizi and Sweller, Ward and Sweller reasoned that the worked examples were structured using a format that promoted split-attention. Figure 8.3a depicts a worked example in dynamics following the traditional textbook format. The problem statement and the initial given states are presented first followed by the appropriate formulae and the solution steps. Using this structure, the learner has to mentally integrate the problem statement, the initial givens, the formula, and the solution steps at various points. In contrast Figure 8.3b demonstrates how this information can be integrated physically to reduce split-attention. The key to this integration is to place the algebraic variables (e.g., v) immediately next to their numeric values to reduce search for the appropriate referents and to complete the algebraic manipulation and substitution before the question is stated to reduce the problem-solving search associated with a problem goal. Employing this integration strategy, Ward and Sweller successfully showed that integrated worked examples were superior to both a problem-solving strategy and to studying conventionally structured worked examples.

The three studies described all contained problems that required mathematical solutions. However, during this early period of research into the split-attention effect, evidence was also collected in nonmathematical domains. Chandler and Sweller (1991) found that instructional materials designed for electrical apprentices contained many cases of split-attention. For example, in learning about the installation of electrical wiring, instructions invariably included diagrams of electrical circuits separated from written explanations on how the circuits worked. By integrating texts and diagrams, Chandler and Sweller demonstrated that the

a)

A car moves from rest to a speed of 40m/s in 20 seconds. What is the acceleration of the car?

$u = 0$ m/s, $v = 40$ m/s, $t = 20$ s

$v = u + at$

$v - u = at$

$a = (v - u)/t$

$a = (40-0)/20$

$a = 2$ m/s^2

b)

A car moves from rest ($u = 0$) to a speed ($v = 40$m/s) in 20 seconds ($t = 20$): $v = u + at$, $v - u = at$, $a = (v - u)/t$, $a = (40-0)/20$, $a = 2$ m/s^2. What is the acceleration of the car?

Figure 8.3. Split-attention and integrated dynamics problem.

split-attention effect could be avoided, resulting in superior performance by the integrated design group.

As part of this study, Chandler and Sweller also conducted an experiment using a topic in biology. Students were required to learn how blood flowed through the heart and lungs. In this experiment instructions that integrated both diagrams and text were not found to be superior to instructions that kept diagrams and text separate. In this experiment, a third group that received their instructions in the form of a diagram only, learned the most. In this case, information on the diagram and in the text relayed the same information, although presented in a different form. Consequently, information was redundant in one form or the other – both were not needed to understand the materials. *Redundancy* is discussed in detail in chapters 10 and 12. The diagram-only treatment used in the biology experiment by Chandler and Sweller (1991) was superior to the integrated format because redundant material was excluded.

It must be strongly emphasised that the logical relation between sources of information is critical for the split-attention effect. The effect can only be obtained when multiple sources of information are essential for understanding and so cannot be understood in isolation. If multiple sources of information provide the same information in different forms and so are redundant, integrating them is not beneficial (see chapter 10).

Substantial work on multimedia associated with the split-attention principle has been carried out by Richard E. Mayer. Although Mayer has focused more generally on how illustrations and animations facilitate learning, his research has also extended the knowledge base on split-attention and other cognitive load theory phenomena particularly in the computer domain.

Early work by Mayer (1989) indicated that including illustrations in expository scientific text has clear advantages. In two experiments, Mayer demonstrated that labelled illustrations during instruction were particularly effective. Mayer found that providing pictures without labels or labels without pictures were inferior to providing both together. Mayer concluded: "... without a coherent diagram that integrated the information, students performed relatively poorly on problem solving" (p. 244). It is notable in this study that Mayer identified the importance of integrated information. While this work was not directly concerned with the split-attention effect, inspection of Mayer's diagrams clearly shows that both the labels and the text are presented in a fashion so as to avoid split-attention.

Although Mayer (1989) did not compare integrated with nonintegrated information directly, a later study did. In developing a generative theory of textbook design, Mayer, Steinhoff, Bower, and Mars (1995) argued that an important step for meaningful learning to occur was to build connections between pictorial and verbal representations. Furthermore they argued that this was more likely to occur when text and illustrations were presented *contiguously* (p. 33) on the page rather than separately. To test this hypothesis, a series of experiments was designed around instruction on how lightning worked. In this study, undergraduates with varying knowledge about lightning were randomly assigned to either an integrated group or a separated group. Students in the integrated group received a 600-word text on one page and five illustrations about how lightning worked on a facing page in the same booklet. Each illustration, which also contained labels and a caption, was placed next to the corresponding paragraph that described it. In contrast, the separated group received the same 600-word text and illustrations (without labels and captions) in separate booklets. The results from this study showed that students who received the integrated materials performed at a higher level on problem-solving tasks than students who received separated materials. However, this difference was only observed using students with a low knowledge base prior to commencing the trial. For students with a greater understanding of meteorology, no difference was found between the two groups.

Cognitive load theory can explain the Mayer et al. (1995) results in terms of the split-attention effect. All students in the separated group were forced to integrate information from two physically separated sources, which was cognitively demanding. Students with little knowledge in the domain were unable to access schemas that could help reduce these demands, resulting in a poorer performance than students who followed the less demanding format (information already integrated). However, students with more knowledge, had readily available schemas that reduced the demands made by split-attention.

Further evidence of the beneficial effects of presenting verbal and visual materials in an integrated format came from Moreno and Mayer (1999). In a computer-based environment using meteorological tasks, Mayer and Moreno showed that the separation of text and diagram didn't have to be on different pages or substantially removed from each other to produce a split-attention effect. Differences could be quite subtle. On tests of verbal recall and transfer, an integrated format group outperformed a separated format group. Although the text was short and the diagrams were straightforward, the separated group was forced to expend more cognitive resources than the integrated group to assimilate the information. A further finding in this study was that students who received illustrations with no written text at all, but with a concurrent narration, performed at a higher level than the other two groups. This is an example of the modality effect (discussed in chapters 9 and 11).

Over a number of studies, Mayer and his colleagues have collected evidence that integrating words and pictures leads to superior learning compared with a more spatially remote multimedia design. These findings have led Mayer (2001) to formulate the *spatial contiguity principle*: "Students learn better when corresponding words and pictures are presented near rather than far from each other on the page or screen" (p. 81). This principle is one of seven that constitutes Mayer's cognitive theory of multimedia learning (for more detail see Mayer, 2001, p. 184). The results found by Mayer are also in accord with cognitive load theory. If learners are forced to engage in a search for referents because words are separated from pictures or diagrams in a book or on a page or screen, then cognitive resources may be diverted from learning. Search processes will increase extraneous cognitive load. The need to search is reduced by integrating words and pictures, thus decreasing load and increasing learning.

E-Learning and the Split-Attention Effect

The basic research into the split-attention effect identified many learning environments where integrated rather than split-source information should be used. Potentially, any instructional material that contained more than one source of information was a candidate for integrating split-source information. However, the initial research focused on materials that were presented solely using paper-based media. When researchers turned their attention to learning in a computer environment (e-learning) the research base was significantly expanded.

In the initial days of the computer revolution, learning how to use computer and/or computer applications relied heavily on an accompanying computer manual. Such manuals are still common although largely for economic reasons, screen-based information is now increasingly popular. Typically, computer manuals contain instructions that the reader must follow while attending to information on the computer screen while using a keyboard and mouse. In these situations, split-attention between the manual, computer, and keyboard seems inevitable.

The first to demonstrate the split-attention effect caused by the simultaneous use of both manual and computer-based information were Sweller and Chandler (1994) and Chandler and Sweller (1996). In the 1994 study, Sweller and Chandler tested a conventional method of learning a computer application against an integrated approach designed to reduce split-attention. For the conventional method, students were required to learn a computer-aided design/computer-aided manufacture (CAD/CAM) package using both a manual and a computer. This conventional procedure required a number of mental integrations among the instructions in the manual, use of the keyboard, and displays on the computer. To reduce split-attention, the integrated group received all their instructions in a modified manual. No computers or their keyboards were used, instead, the screen and keyboard were replaced by diagrams in the manual. Furthermore, to reduce split-attention within this medium, text and diagrams were fully integrated, requiring students to follow a number of ordered steps. In a direct comparison based on a postacquisition test that included use of the hardware, the group following the integrated approach using no hardware was found to be superior to the conventional group, suggesting that the simultaneous use of a manual and computer created a split-attention effect. That effect resulted in students who had had practice using the hardware demonstrating less proficiency in hardware use than students who had learned without direct access to the relevant equipment.

In a second study Chandler and Sweller (1996) reproduced this result, again demonstrating that fully integrated instructions on a computer application presented on paper alone were superior to simultaneously using a computer. Practice using the computer was far less important than properly formatted instructions presented on paper. Over the two studies, Chandler and Sweller demonstrated the effect using a number of different materials. However, these studies also identified the critical importance played by element interactivity (see chapter 2). Element interactivity refers to the number of elements that must be simultaneously processed in working memory in order to understand the information. Materials low in element interactivity are easy to learn because they keep working memory demands to a minimum. In contrast, materials high in element interactivity are more complex and place more demanding loads on working memory. Element interactivity affects intrinsic cognitive load, whereas the split-attention effect is considered extraneous cognitive load because it is created by the format of the instructional materials (chapter 2).

In two studies, Chandler and Sweller found that the split-attention effect only occurred when the materials were high in element interactivity. Secondary tasks were used to measure cognitive load where a secondary task consists of, for example, responding to a sound while engaged in the primary task, in this case learning the computer application. A high cognitive load on a primary task should depress performance on a secondary task (e.g., see Brünken, Plass, & Leutner, 2003). Measures of cognitive load using secondary tasks clearly indicated that the split-attention effect was first, caused by cognitive load effects and second, only obtainable under conditions of high intrinsic cognitive load caused by high levels of element interactivity. Clearly, in these computer environments, the interaction between intrinsic and extraneous cognitive load is extremely important. For very simple tasks, such as adding data to a spreadsheet cell using the computer and manual simultaneously, split-attention may have little effect because of low element interactivity. An inadequate instructional format may not overload working memory if the intrinsic cognitive load associated with the task is low. For tasks high in element interactivity, such as completing a complicated spreadsheet formula, a split-attention format will have a negative impact on learning. The addition of a heavy working memory load due to high element interactivity and due to split-attention may be overwhelming.

The Chandler and Sweller results described so far may appear controversial or counterintuitive, as they appear to suggest that the best way to learn about computers is not to use one. However, as these authors argued, the integrated noncomputer approach was best suited to learning computer skills at the very early stages. Obviously, we need to use computers at some stage and indeed, Chandler and Sweller (1996) made the following point about the strategy: "It can be suggested that, under some circumstances, the removal of computing equipment during critical phases of learning may provide considerable benefit" (p. 168).

Following the success of the integrated manual approach, Cerpa, Chandler, and Sweller (1996) reasoned that its effectiveness could plausibly be caused by differences in the media rather than split-attention; that is, paper-based material enhances learning compared with electronic versions, although there were no theoretical grounds for this explanation. Consequently, Cerpa et al. devised a study to test this possibility. Instead of integrating the materials on paper, a fully integrated package was constructed on the computer. Working in the domain of spreadsheet learning, students were required to acquire a number of skills ranging from selecting cells, rows, and columns to using functions and entering formulae. An integrated design was constructed by inserting all the instructions into the software at the appropriate points, thus reducing the effects of split-attention. One group of students received instructions in this integrated mode and were compared with a second group who received a traditional instructional package of manual and computer.

On test questions following the instructions, the integrated (computer-only) group significantly outperformed the split-attention group (computer plus manual). However, this difference was only found on test questions tapping knowledge that was high in element interactivity, such as creating a formula. On low element interactivity tasks such as selecting a row, no differences were found between groups. The results from this study eliminated the possibility that print media were superior to an electronic medium, and provided further evidence to support the split-attention effect and the role played by element interactivity. The study also demonstrated that computers could be used effectively provided the split-attention effect was avoided. It is also worth noting at this point that Cerpa et al. employed a third group in the study that received both a computer-based instructional package and a manual. This group also proved to be inferior to the computer-based-only group because of redundancy (see chapter 10).

Temporal Versions of the Split-Attention Principle

The split-attention examples described all have one thing in common: The various sources are physically separate. Regardless whether the cause of split-attention is text and a diagram, or computers and a manual, the two different sources of information are physically separate in a manner that requires search in order to locate relevant referents. It is that act of search that imposes an extraneous cognitive load.

Physical separation is not the only form of separation generating unnecessary search. Multiple sources of information that must be integrated before they can be understood can also be separated in time, resulting in temporal separation. It is reasonable to suppose that temporal separation also generates an extraneous cognitive load for exactly the same reasons as physical separation. Learners must unnecessarily find referents between separated sources of information, in this case temporal separation, and that requirement to mentally coordinate multiple sources of information requires working memory resources. Temporal integration, that is, simultaneously presenting multiple sources of information that must otherwise be mentally integrated before they can be understood, should reduce the need for mental integration and so reduce extraneous cognitive load. A comparison of temporally separate and integrated instruction should yield evidence of superior learning under integrated conditions yielding a temporal version of the split-attention effect. As indicated previously, Mayer and his colleagues have researched the phenomena associated with presenting diagrams and text together during instruction but in addition, have considered the consequences of temporal rather than spatial versions of the split-attention effect.

Mayer (2001) called this principle the *temporal contiguity principle*: "Students learn better when corresponding words and pictures are presented simultaneously rather than successively" (p. 96). So far, all instructional materials reported in this chapter, have engaged the learner in the visual medium only. However, the temporal contiguity principle extends the split-attention theory to include sound. Since the invention of the modern cinema, pictures and the spoken word have been presented together to provide instruction on a film screen, a television screen, and more recently, on a computer screen (although we must not forget that teachers have been reading to their students, while simultaneously presenting pictures or demonstrating skills for considerably longer). Consequently, how sounds and pictures should be presented is also an important consideration.

Mayer (2001) argued that because of the limitations of working memory, words and pictures should not be separated temporally. For example, consider the case of a computer-based multimedia presentation where a narration episode is followed by an animation episode, which depicts the content of the narration. To understand fully what both episodes mean, the learner must hold some or all of the narration in working memory and then integrate this narration with the animation. Furthermore, if the narration is long, then information may be lost without constant rehearsal, or even be too large to assimilate in the first instance.

Mayer developed the temporal contiguity principle based on the results of a number of studies conducted using animation in a computer-based environment. An initial influence was a study by Baggett (1984). Baggett designed an experiment in which a film was shown to college students where the visual and auditory components (voice-over) were presented in seven different conditions. Three conditions presented the visual material either 7, 14, or 21 seconds before the auditory component, and three conditions presented the visual material either 7, 14, or 21 seconds after the auditory components. The final condition presented both the visual and auditory materials simultaneously. On recall tests students who received the concurrent mode or the visuals 7 seconds before the voice-over performed at a superior level to the other five groups. This experiment demonstrated the importance of presenting both media together in close proximity.

Initial research by Mayer and Anderson (1991) compared the effect of receiving instruction that presented words before pictures with instructions that presented both words and pictures simultaneously. In the first experiment of this study, students studied an animation that showed how a bicycle tyre pump worked. A words-before-picture group received a narrative description of how the pump worked before the animation (silent) was presented. The words-with-pictures-together group received both sound and pictures simultaneously. The group that received the simultaneous presentation scored higher on problem-solving tasks.

In a second study, Mayer and Anderson (1992) extended this research. The number of presentations was increased, and the impact of varying the order of narration and animation was examined. On problem-solving tasks, a concurrent group outperformed all other groups and notably, groups who received narration before animation, or vice versa, performed at the same level as a control group with no instruction.

Mayer and Sims (1994) also found evidence that a concurrent presentation of narration and animation was superior to a sequential presentation of either narration followed by animation or animation followed by narration on problem-solving tasks. The study domains were the human respiratory system and bicycle pumps. In addition, this study also examined the influence of spatial ability on these presentation modes. For high spatial-ability learners there was a significant temporal contiguity effect. However, for low spatial-ability learners the concurrent group performed at the same level as the sequential group. Mayer and Sims explained this finding by arguing that students with low spatial ability had to devote relatively more cognitive resources to connecting the two sources of information compared with students with high spatial abilities. In particular high spatial awareness was particularly advantageous in building visual representations.

The preceding studies demonstrated that students who received information simultaneously (integrated narration and animation) outperformed students who received nonintegrated instructions (narration and animation separated temporally). These differences were found consistently on transfer (problem-solving) tests and less frequently on retention tests. The results support Mayer's temporal contiguity principle (Mayer, 2001).

Further research by Moreno and Mayer (1999) into temporal contiguity investigated the impact of using smaller segments in computer-based episodes of narration and animation. In this study, the large instructional episodes on the formation of lightning used in previously described experiments were divided into 16 smaller segments. Groups of students were presented with either 16 successive alternations of mini narrations and animation in that order, or vice-versa. These groups were compared with students who received the whole episode in an integrated fashion described previously. As few differences were found between groups on retention and transfer tests (results marginally favoured the integrated whole episode approach), Moreno and Mayer (see also Mayer, 2001) concluded that students who received the smaller segment episodes were not subjected to high working memory loads because successive presentations were very short (one or two lines at a time). Consequently, learners were able to successfully integrate the two sources of information themselves and performed at a level comparable to the fully integrated approach.

Implications for Instructional Design

The split-attention effect is a robust, easily demonstrated effect leading to the split-attention principle: Where instruction includes multiple sources of information that must be mentally integrated in order to be intelligible, those sources of information should be both physically and temporally integrated in order to reduce unnecessary search for referents and to reduce extraneous cognitive load. Now there are many studies demonstrating that substantial learning gains can be achieved by physically integrating disparate sources of information rather than requiring learners to use mental resources in mentally integrating the same information. Those studies use a wide variety of materials and participants under many conditions.

Notwithstanding the strength of the split-attention effect, considerable care must be taken when physically integrating disparate sources of information. Simply placing, for example, all text onto a diagram, is no substitute for an understanding of the split-attention principle. There are many conditions under which the principle does not apply or worse, where attempts to apply the principle will have negative rather than positive effects on learning. We would like to emphasise the following points:

1. The principle only applies when multiple sources of information are unintelligible in isolation. For example, physically integrating a diagram with statements that merely redescribe the diagram has negative, not positive effects on learning due to the redundancy effect (see chapter 10). If all sources of information are intelligible in isolation and redundant, elimination of redundancy rather than physical integration should be pursued. Thus, analysing the relation between multiple sources of information prior to physical integration is critical.
2. The split-attention principle only applies to high element interactivity material. If intrinsic cognitive load is not high, whether or not an extraneous cognitive load is added due to split-attention is likely to be irrelevant (see chapter 2). A diagram and related text that have few interacting elements and so are easily understood are unlikely to be rendered more intelligible by physically integrating them. They can be easily learned even when presented in split-source format.
3. Whether sources of information are intelligible in isolation and whether the information is high in element interactivity not only depends on the instructional material, it also depends on learner characteristics. Material that is unintelligible in isolation and high in element interactivity for low knowledge learners may be intelligible in isolation and low in element interactivity for learners with more knowledge. For high knowledge individuals, physical integration may be deleterious, resulting in the expertise reversal effect (see chapter 21). Alternative instructional techniques are required under such circumstances with the elimination of redundant information being the most common technique.

These limitations under which the split-attention effect can be observed strengthen its scientific validity in that they clearly indicate the experimental conditions that lead to the effect. Nevertheless, from an instructional perspective, they require instructional designers to take many factors into account. A simple recommendation such as "eliminate split-attention between diagrams and text" is not sufficient. To adequately understand the split-attention effect, instructional designers may require considerably more training in cognitive theory and its instructional implications than is currently the norm.

Conclusions

Split-attention is pervasive. The format of much instruction is determined by tradition, economic factors, or the whim of the instructor. Cognitive factors are rarely considered resulting in instructional designs in which split-attention is common. Cognitive load theory, which gave rise to the split-attention principle and which is based on an understanding of human cognitive architecture, especially the relations between working and long-term memory, is able to provide theory-based and experimentally tested instructional guidelines. Those guidelines that are associated with the split-attention effect and that have been discussed in this chapter have the potential to substantially improve multimedia instruction.

Glossary

Integrated instructions. Instructions in which multiple sources of information are physically integrated so that working memory resources do not need to be used for mental integration. Can be contrasted with split-attention instructions.

Split-attention instructions. Instructions in which multiple sources of information are not physically or temporally integrated so that working memory resources need to be used for mental integration. Can be contrasted with integrated instructions.

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