Chapter 11
The Redundancy Effect

The redundancy effect may appear on the surface to be related to the split-attention effect but in fact is quite unrelated. There are similarities because both effects deal with multiple sources of information such as visuals and text. As is the case for the split-attention effect, any combination of diagrams, pictures, animations and spoken or written verbal information can lead to the generation of extraneous cognitive load. Nevertheless, despite their surface similarities, the redundancy effect has very different characteristics to the split-attention effect. The two effects differ because the logical relations between the multiple sources of information required as essential pre-requisites to produce each effect differ; that difference is critical and should never be ignored.

As was discussed in Chapter 9, the split-attention effect occurs when learners must integrate in working memory multiple sources of related information presented independently but unintelligible in isolation. A set of geometry statements such as Angle ABC equals Angle XYZ cannot be fully comprehended without reference to a diagram. Both sources of information, the diagram and the statements, must be present and if presented in physically separate form, must be mentally integrated because they refer to each other. The working memory resources used to accomplish this integration become unavailable for learning and may exceed the available capacity of working memory.

This chapter describes a different logical relation between the multiple sources of information. The redundancy effect may occur when the multiple sources of information can be understood separately without the need for mental integration. Written or spoken text that simply re-describes a diagram that can be fully understood without the text provides an example. In this situation, the physical integration of, for example, the written text with the diagram is unlikely to be beneficial. There is no reason to suppose that learning will be enhanced by physically integrating within a diagram text superfluous to comprehension. Indeed, such conditions may be detrimental to learning by imposing an extraneous cognitive load. Accordingly, redundant information should be omitted to preclude an increase in extraneous cognitive load caused when learners inevitably focus attention on unnecessary information and physically integrate it with essential information.

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Using the example of a diagram and redundant text, rather than presenting a self-explanatory diagram and a verbal explanation that just re-describes the diagram (either as visual text, spoken text or both), it should be beneficial to present the diagram alone without any explanatory text.

The most common form of redundancy occurs when the same information is presented in different modalities. A diagram with text that re-describes the diagram, or text presented in both spoken and written form provide examples. Nevertheless, it needs to be noted that in cognitive load theory, any additional information not required for learning is classified as redundant. A cartoon associated with text does not re-describe the text but is still redundant if it is not required to understand the text, as is an explanation of sections of a procedure that learners already understand. Any information presented to learners that they may unnecessarily process is redundant. Cognitive load theory does not distinguish between types of redundant information because it is assumed that they have the same negative cognitive consequences that can be eliminated by the same instructional procedures, i.e. the omission of such redundant information.

The redundancy effect occurs when information that includes redundant material results in less learning than the same information minus the redundant material. The effect provides a clear example of extraneous, interacting elements. If essential information is provided along with unnecessary information, the elements associated with the unnecessary information are likely to be processed resulting in an extraneous working memory load. That extraneous working memory load violates the narrow limits of change principle that requires working memory load to be minimised. Less information will be transferred to the long-term memory information store resulting in less effective use of the environmental organising and linking principle, the critical principle used to generate action. It follows that only essential information should be presented to learners in order to maximise use of the borrowing and reorganising principle when acquiring information.

Some Empirical Evidence for the Redundancy Effect

Chandler and Sweller (1991) first demonstrated the redundancy effect within a cognitive load framework using learning materials consisting of text and diagrams that did not have to be mentally integrated in order to be understood. In several experiments with electrical engineering materials, learners who were not explicitly requested to integrate text and diagrams needed less time to learn but performed better than learners who were explicitly instructed to integrate text and diagrams. Furthermore, a single self-explanatory diagram was found to be superior to the text-and-diagram instructions in either a conventional or an integrated form.

These results were replicated in experiments with biology materials using a self-contained diagram of blood flow through the human body. The diagram indicated, for example, that blood flowed from the left ventricle of the heart into the aorta. The corresponding statement said, ‘Blood is also forced from the left ventricle into the aorta’. The relation of this statement to the diagram should be carefully noted. It is very different to the relation of a statement such as, 'Angle ABC = Angle XYZ' associated with a geometry diagram. The diagram of the blood flow in the heart, lungs and body can be readily understood in isolation. The statements merely repeat information that is clear from the diagram. They do not say something that is essential to understand the solution to a problem as occurs in the case of a geometry problem solution. In the blood flow example, the additional, explanatory textual segments were redundant and interfered with learning.

Furthermore, an integrated format in which the statements were integrated with the diagram was even less effective than conventional instruction with separated diagrams and text. The diagram-only format resulted in the best learning outcomes. It was assumed that processing redundant text would impose an extraneous cognitive load and require additional working memory resources. In a conventional split-source format, learners can partially reduce this load by ignoring the text (Chandler & Sweller, 1991). It is more difficult to ignore the text when it is physically integrated with the diagram. Bobis, Sweller, and Cooper (1993) also replicated the redundancy effect using a paper-folding learning task with primary school students. In this study, diagrams were redundant and a text-only instructional format resulted in the best learning outcomes.

The redundancy effect is pervasive. It can be found in a wide variety of instructional contexts unrelated to diagrams and text. For example, traditional forms of instruction found in manuals or presented as on-screen instruction provided with software packages or technical equipment usually require using the actual hardware or equipment when following the instructions. As indicated in Chapter 9 on the split-attention effect, if such instructions are essential, they may cause learners to split their attention between the manuals, computer screen and keyboard, or the equipment, and so result in a heavy extraneous cognitive load. If the instructions replicate information obtained more readily in other forms, the redundancy effect may need to be considered. For example, presenting learners with diagrams of hardware as well as the hardware itself may lead to redundancy. There may be learning benefits in eliminating the computer hardware or equipment during the initial stages of instruction and using diagrams of the computer screen and keyboard or technical equipment with embedded textual instructions instead. Including both the hardware and the diagrams may lead to redundancy and a heavy extraneous cognitive load that interferes with learning.

In a series of experiments, such integrated diagram and text instructions placed in a manual without the hardware being available to learners were compared to manuals with hardware (Sweller & Chandler, 1994; Chandler & Sweller, 1996). Beneficial effects of the integrated manual only instructions without the presence of actual hardware were demonstrated in both written and practical skill tests despite reduced learning times and the absence of any practical experience using the hardware prior to the tests. The results suggested that the hardware was redundant and the manual only instructions were self-explanatory for the learners.

These results should not be interpreted as indicating that it is necessarily better to learn, for example, how to use software without access to functioning software. The results should be interpreted as indicating that it is better to learn either with access to the software (or hardware) or with diagrams and integrated text representing the software and hardware, but not both. Cerpa, Chandler, and Sweller (1996) found that presenting instructions on a screen alone was superior to presenting them on both a screen and in a manual. In combination with the results indicating that it is better to learn from a manual alone than a manual plus equipment, we can conclude that it does not matter whether instructions are presented on a screen or in a manual. The important point is that they should not be presented simultaneously in both forms. The extraneous cognitive load associated with redundancy will interfere with learning if students must process similar material on a screen and in a manual. Learning is enhanced if the material is presented in one or the other, but not both.

Pociask and Morrison (2008) demonstrated the effectiveness of eliminating redundant information in instructional materials used for teaching complex, orthopaedic, physiotherapy cognitive and psychomotor skills to first-year physiotherapy students in a realistic classroom setting. The performance measures that included written and psychomotor tests, ratings of cognitive load and task completion times indicated significantly increased learning outcomes and reduced levels of cognitive load for the modified, instructional format group.

The Effect of Simultaneously Presented Written and Spoken Text

As indicated in the previous section, the split-attention and redundancy effects appear to be related because they both feature multiple sources of information. For similar reasons, the modality effect described in the previous chapter and the multimedia redundancy effect described in this section appear to be related but are not. The relation between the sources of information determines whether a modality effect or a redundancy effect will be obtained. Whether material should be presented in audio-visual form or in visual form alone is determined by the relation between the multiple sources of information. If two or more sources of information refer to each other and can only be understood in conjunction, they should be presented in audio-visual form, if possible. In contrast, if the two sources of information can be understood in isolation, only one source, either the audio or the visual source should be used. If both are used, one source will be redundant and having to process both will lead to an extraneous cognitive load.

Thus, deciding whether both sources or only one source should be used depends on the relation between the two sources. Geometry statements that cannot be understood without reference to a diagram should be presented in spoken form, or physically integrated if they must be presented in written form. In contrast, descriptions of blood flow that merely re-describe a highly intelligible diagram should not be presented in spoken or indeed, written form. They should be eliminated. The logical relation between a diagram and text is important, not the existence of a diagram and text.

Many multimedia instructional materials use narrated explanations simultaneously with written text. From a cognitive load perspective, such duplications of essentially the same information in two different modalities may overload working memory and have negative rather than positive learning effects. When spoken explanations are used concurrently with the same written text, learners may also be required to relate and coordinate the corresponding elements of written and spoken information. This extraneous to learning processing may consume additional working memory resources. Therefore, eliminating a redundant source of information might be beneficial for learning.

Kalyuga, Chandler, and Sweller (1999) used computer-based instructions in mechanical engineering to compare three different forms of textual explanations presented together with an animated diagram: written text, spoken text and written plus spoken text. The results demonstrated a multimedia redundancy effect. The spoken text group outperformed the written text plus spoken text group with a higher posttest score, a lower number of re-attempts at interactive exercises and a lower subjective rating of cognitive load. Subjective ratings of cognitive load indicated that presenting on-screen textual explanations of the diagram together with the same auditory explanations actually resulted in additional cognitive load.

Using scientific explanations of animated visuals with instructions explaining the formation of lighting storms, Mayer, Heiser, and Lonn (2001) demonstrated in two experiments with university students that learners who studied narrations with concurrent animations performed better on retention and transfer posttests than learners who studied animations with concurrent narration and on-screen text that either summarised or duplicated the narration. Craig, Gholson, and Driscoll (2002) demonstrated a similar effect with animated pedagogical agents in which visual characters were enabled with speech, gestures, movements and other human-like behaviours.

This effect of superior learning following spoken rather than spoken and written text was clearly demonstrated by Kalyuga, Chandler, and Sweller (2004). Both in instructional and other contexts, identical or similar verbal information frequently is provided in simultaneous spoken and written form. This tendency has increased first with the advent of overhead projectors and then with the introduction of PowerPoint because both of these technologies facilitated the simultaneous presentation of spoken and written text. Based on the redundancy effect, we might expect learning to be inhibited by the concurrent presentation of the same information in both modalities. Using technical, text-based instructions without diagrams (Experiment 3), Kalyuga et al. (2004) obtained precisely this effect. Learning was facilitated when instructions were presented in spoken form alone rather than both spoken and written forms concurrently.

Jamet and Le Bohec (2007) tested the effect of presenting learners with information on the development of memory models. One group were presented diagrams along with spoken information. The other two groups were presented exactly the same diagrammatic and spoken information along with the equivalent written sentences presented either sequentially, sentence by sentence, or as a full-text group in which the sentences were displayed as a block next to the diagram. In a variety of subsequent tests, the spoken text alone group demonstrated superior learning to either of the spoken plus written text groups, demonstrating that the written text was redundant.

Gerjets, Scheiter, Opfermann, Hess, and Eysink (2009) obtained a multimedia redundancy effect in hypermedia learning. Hypermedia consists of multimedia learning environments with elements of information interconnected by a network of hyperlinks to increase levels of learner interactivity. Gerjets et al. (2009) demonstrated that arithmetical information supplemented with spoken and written explanations resulted in less efficient instruction than providing written only text. Also, in this study, spoken only explanations did not result in better learning than the dual-modality redundant format. These results may indicate that lengthy spoken text is unlikely to improve learning in any combination – with diagrams, written text, or both – as lengthy, complex, spoken information may generate a heavy working memory load in its own right (see Chapter 17 on the transient information effect). The role of the length of instructional segments is discussed below in the section on conditions of applicability of the redundancy effect.

The Redundancy Effect in Second/Foreign Language Learning

The negative effects on learning of presenting the same information in spoken and written form can be expected to have particular relevance when learning a second language. The redundancy effect has been mostly investigated in technical domains (e.g. mathematics, science, or engineering) with relatively well-structured problems. It was important to replicate these results and investigate the conditions of applicability of the effect in relatively poorly specified task areas that are typical of the social sciences and humanities. Foreign or second language acquisition is an important domain for the extension of cognitive load research. There have been a number of recent studies of cognitive load theory implications for instructional design in this area. For example, Moussa, Ayres and Sweller (in preparation) reported a redundancy effect in learning English as a foreign language. They established that a simultaneous presentation of oral and written material could inhibit learning and, paradoxically, students could learn to listen more efficiently by reading alone rather than by reading and listening at the same time. This result is only likely to be obtainable using learners with some degree of proficiency in listening. Plass, Chun, Mayer, and Leutner (2003) found that pictorial annotations were redundant for second language learners' reading comprehension.

Using first-year tertiary students as participants, Diao, Chandler, and Sweller (2007) and Diao and Sweller (2007) investigated whether the redundancy effect would apply to reading comprehension in learning English as a foreign language by comparing written presentations only and written presentations concurrent with verbatim spoken presentations. They suggested that for learners who had not achieved a sufficiently high level of foreign language proficiency, the listening rate could lag far behind the reading rate (Hirai, 1999) resulting in poor audio-visual correspondence. When the same text is presented in different modalities, learners must process these two sources of information simultaneously and build referential relations between them. Because decoding text presented even in a single modality may impose a heavy working memory load for beginner foreign language learners, they may have no available working memory capacity to read and listen at the same time, resulting in a redundancy effect.

Results demonstrated that the presence of a concurrent spoken presentation rendered reading comprehension less effective compared with written only instructions. At the lexical level, the concurrent presentation group gained less lexical knowledge than the read only group. At the level of text comprehension, the concurrent presentation group reported a higher cognitive load and demonstrated a lower level of main/general idea understanding and recall. Also, as can be expected from the element interactivity effect (Chapter 15), the interference of a concurrent spoken presentation was more evident for a textual passage with more complex syntax and text structures and, accordingly, a higher level of intrinsic cognitive load.

These results contradict the common practice of teachers to read out a text while students follow their words in a textbook. It needs to be noted that there is extensive evidence in the literature on second/foreign language comprehension suggesting a positive effect of presentations consisting of concurrent written and spoken text (e.g. Borrás & Lafayette, 1994; Garza, 1991; Markham, 1999). Almost without exception, these results are due to a common, specific flaw in the experimental designs used. There is a difference between comprehension and learning. If learners are presented text and then given a comprehension test, they will almost always score more highly on that test if the information is presented in dual-modality rather than single-modality form because they can choose to concentrate on reading or listening, whichever they feel will most increase comprehension. Nevertheless, in instructional contexts, an increase in comprehension is less important than an increase in what has been learned and an increase in comprehension does not mean more has been learned. To determine whether more has been learned, learners must be presented with new material following the phase in which dual- or single-modality material has been presented. They should be tested for their comprehension on that new material rather than the original material. If they have learned more following a single- or dual-modality presentation of the original material, then comprehension of the new material should be improved and a comprehension test of the new (not the old) material should demonstrate the extent to which learning has occurred during the original presentation of the old material under single- or dual-modality conditions. Using this experimental design, the common result suggests that single-modality presentations result in more learning than dual-modality presentations (Diao & Sweller, 2007; Diao, Chandler, & Sweller, 2007; Moussa, Ayres, & Sweller, in preparation).

Thus, cognitive load theory suggests that when teaching novice second/foreign language learners to read or to listen, the common procedure of presenting both written and spoken text simultaneously may not be appropriate. If the aim of instruction is to teach novice learners to read, involving them in listening together with reading instruction could interfere with rather than facilitate learning. Furthermore, beyond the novice level, learning to listen is facilitated more by reading than by listening and reading.

Evidence for the Redundancy Effect in Pre-Cognitive Load Theory Research

Several examples of phenomena that can readily be related to the redundancy effect were demonstrated before cognitive load theory was developed and applied to redundancy. These examples are notable in that in a very wide variety of disciplines and procedures, they provide evidence of the redundancy effect but have no consistency in their theoretical explanations. None were explained in terms of a working memory load.

Reder and Anderson (1980, 1982), in a particularly interesting example of redundancy, found that students could learn more from summaries of textbooks than from the full chapters. Most textbook writers take the traditional view that providing learners with additional information is at worst neutral in its effects and could be beneficial. Not only is information frequently presented at considerable length, redundant material such as cartoons and other irrelevant pictorial information is often included. All require scarce working memory resources to process. From a cognitive load theory perspective, it is not surprising that more can be learned from a summary than a full textbook chapter, consistent with the result obtained by Reder and Anderson.

Schooler and Engstler-Schooler (1990) found that the requirement to verbalise a visual stimulus could impair its subsequent recognition. Verbalising visual information can be difficult and may place a considerable load on working memory. Furthermore, that load may add little to the ability to subsequently recognise the visual material, explaining the Schooler and Engstler-Schooler results in terms of redundancy and cognitive load.

Lesh, Behr, and Post (1987) found that mathematical word problems could become more difficult to solve if additional concrete information is included in the problem statements. Many mathematics educators have suggested that the difficulty students have in learning to solve word problems could be ameliorated by the inclusion of concrete, physical representations of the problems. Some of these suggestions can be sourced to a Piagetian view of the distinction between concrete and formal operational thought. Piagetian stage theory suggests that we learn to manipulate concrete objects prior to learning to manipulate more abstract, formal entities. In fact, whether or not we know how to manipulate concrete objects, we still need to be able to process the abstract representations of objects incorporated in many word problems. If working memory resources are devoted to manipulating the concrete objects, we may have insufficient resources left to learn how to deal with their abstract equivalents. Seeing the objects is merely likely to interfere with learning how to manipulate the abstract representations, leading to redundancy.

Using a flow diagram of the nitrogen, water, oxygen and carbon dioxide cycles, Holliday (1976) demonstrated that high school students who studied a diagram only achieved better comprehension than two groups that studied the diagrams alongside a text that presented the same material, or the text alone. Students who were presented with text and diagrams performed no better than those who studied the text only.

The diagram alone was all that was needed to learn the material. Adding text to the diagram was redundant while text alone either did not include sufficient information or else provided the information in a form that was difficult to process.

Miller (1937) demonstrated that presenting children with a word associated with a picture was less effective than the word alone in teaching children to read. In order to learn to read, working memory resources must be devoted to the graphics that constitute text. Based on cognitive load theory and the redundancy effect, nothing is gained by devoting working memory resources to pictures as well as the text. Most beginning readers know what a cat looks like and do not need to see a picture of a cat. Their working memory resources need to be concentrated on the graphics that constitute the written word 'cat'. Miller's results were replicated by Saunders and Solman (1984) who demonstrated that adding pictures to words interfered with learning.

It might be noted that this picture-word effect equally applies to learning to read whole sentences as well as individual words. Torcasio and Sweller (2010) extended this work to learning to read phrases and sentences. They found that the picture books commonly used to teach young children to read and consisting of sentences on one page and corresponding pictures on the opposite page resulted in less learning than the same sentences without the pictures. For young children, learning to read requires them to attend to a sentence such as 'Mrs. Smith lived in the house on the hill'. If they see a picture of Mrs. Smith and the house on the hill, working memory resources are likely to be devoted to the picture rather than the text resulting in less textual learning compared to learners who only see the text, a classic redundancy effect.

It can be seen that there is a wealth of data demonstrating the redundancy effect. Until the advent of cognitive load theory, most of these results had little influence because they were treated as individual, unrelated findings. Hopefully, the advent of cognitive load theory and knowledge of the redundancy effect will result in a reconsideration of these important findings.

Factors Moderating the Redundancy Effect

Investigating specific boundaries for the redundancy effect is an important research issue. Some established conditions required for the redundancy effect are described below.

Independence of Information Sources

We have emphasised above and in previous chapters that the split-attention and modality effects are obtainable only when the related sources of information are unintelligible in isolation. In contrast, this chapter is concerned with conditions under which sources of information are intelligible in isolation. An example is textual information presented in written and/or spoken form that merely re-describes a diagram, a table or another section of text. If a diagram, table or text is intelligible in isolation and contains all of the required information, its spoken and/or written re-description should be eliminated rather than included. We have emphasised these points because they frequently are ignored in the literature.

For the redundancy effect to occur, either source of information must be intelligible separately. If a source of information (textual or graphical) is fully intelligible on its own, then any additional redundant sources of information should be removed from the instructional materials rather than integrated into them.

Levels of Element Interactivity

As with other cognitive load effects, sufficiently high levels of element interactivity for the learning material are an essential moderating factor if the redundancy effect is to be observed. According to the element interactivity effect (see Chapter 15), instructional materials with low levels of element interactivity and consequently, a low intrinsic cognitive load, are unlikely to demonstrate noticeable benefits from eliminating redundant elements of information. Even relatively high levels of extraneous cognitive load may still be within working memory limits and not interfere with learning. In contrast, if learning materials are characterised by high levels of element interactivity and therefore generate a heavy intrinsic cognitive load, an additional extraneous cognitive load caused by processing redundant information can be harmful to learning.

For example, a modified, self-contained manual without a requirement to refer to actual hardware can be beneficial compared to the manual plus the hardware, but only for tasks characterised by high levels of element interactivity (Chandler & Sweller, 1996). No redundancy effect was demonstrated by Chandler and Sweller (1996) for low element interactivity material. Measures of cognitive load confirmed the importance of element interactivity to the redundancy effect. Significantly better test results associated with a lower cognitive load favoured an integrated, modified manual only group compared to the manual and hardware group in areas of high element interactivity. No effects were found in areas of low element interactivity.

At the other end of this spectrum, when dealing with excessively complex materials for which learners do not have sufficient prior knowledge, very high levels of intrinsic cognitive load may be experienced. Even eliminating redundant sources of information for such materials may not alleviate the experienced cognitive overload, resulting in a failure to demonstrate a redundancy effect.

Pacing of Presentations

In most audio-visual learning experiments that have demonstrated multimedia redundancy effects, system-controlled pacing was used, and the fixed instruction time was determined by the pace of the narration. In such conditions, learners presented with visual text in addition to its auditory form need to engage in visual search by switching their attention back and forth between on-screen text and pictorial elements while under strict time constraints imposed by the system. These processes may result in a high extraneous cognitive load. In learner-paced presentations, students may review the material at their own pace with extra time available for managing potential overload, thus reducing the benefits of non-redundant presentations. Of course, when narration is used, learner-paced presentations, while feasible, can be difficult to implement and difficult for students to use.

In two experiments with technical apprentices, Kalyuga, Chandler, and Sweller (2004) compared simultaneously presented written and auditory forms of the same information with an instructional format in which these sources of information were temporally separated with the redundant written text presented only after the narration ended. The experiments demonstrated that the sequential presentation of auditory and visual explanations of a diagram resulted in superior posttest scores and lower ratings of cognitive load than the concurrent presentation of the same explanations. However, this effect was obtained only when instruction time was constrained in a system-controlled condition (Experiment 2). There were no differences in a learner-controlled condition (Experiment 1). The unrestricted instruction time might have partially compensated for the unavailable processing resources that were used to deal with the increased extraneous load during concurrent presentation compared with sequential presentation. In contrast, in the restricted condition, simultaneous presentations may have overloaded working memory with neither visual nor auditory text processed adequately. The delayed presentation of the visual text could have effectively served as a repetition of the presentation, thus enhancing the positive effects of the earlier auditory text.

The Length of Instructional Segments

As was the case for the modality effect, the length of textual segments may also be a factor influencing the redundancy effect. When simultaneously processing uninterrupted, long textual descriptions presented in visual and auditory modalities, learners may have to relate and reconcile too many elements of information within a limited time frame. Segmenting the text may eliminate negative effects of verbal redundancy.

Experiment 3 of Kalyuga et al. (2004) used lengthy, technical textual materials without diagrams and demonstrated a redundancy effect through concurrent presentation of auditory and visual material compared with the auditory-only text. Possible influences of visual split attention were excluded in this experiment as no diagrams were involved. However, Moreno and Mayer (2002) demonstrated that when no visual diagrams were involved, concurrent presentations of the same auditory and visual text produced better results than auditory-only text, indicating a reverse redundancy effect. This difference in results could be due to the length of textual segments that were processed continuously. In the Kalyuga et al. (2004) study, the text was presented to participants continuously as a single large chunk of around 350 words without breaks. In contrast, Moreno and Mayer (2002) presented the text in several consecutive small segments with appropriate breaks between them. Such breaks may have allowed the learners to consolidate their partial mental models constructed from each segment of the text before moving to the next one.

Thus, if text is partitioned into logically complete and easily managed sequential segments with time breaks between them, a narration with concurrent, visual text may not only eliminate negative effects of verbal redundancy, but actually improve learning. For example, such formats could be effective for learners for whom the language of instruction is a second language and who may have problems with understanding auditory text without a written back-up. On the other hand, continuously presenting long textual descriptions may contribute to the intrinsic complexity of instructional materials by forcing learners to relate and reconcile many elements of auditory and visual information within a limited time frame.

Thus, while demonstrating a modality effect may require relatively brief and simple textual information, the multimedia redundancy effect usually occurs if the textual information is lengthy and complex. Presenting this information in spoken form, especially concurrently with the same information in visual form, may cause a cognitive overload and have negative learning consequences similar to the reverse modality effect (Chapters 10 and 17). Lengthy sections of spoken text that is transitory in nature may exceed working memory capacity limits. Similar to the modality effect, the length of textual segments may override pacing of the presentation as a factor influencing the conditions of applicability of the multimedia redundancy effect.

Summary of Conditions of Applicability

Several conditions that are essential for occurrence of the redundancy effect have been identified:

(a) Different sources of information must be intelligible independently with no requirement for mental integration and simultaneous processing.
(b) Element interactivity of learning materials must be high.
(c) For the multimedia redundancy effect, the text must be presented concurrently in written and spoken forms and be sufficiently lengthy and complex to cause high levels of working memory load.

It is also plausible that levels of learner expertise could influence the effect as the notion of redundancy may be affected by learner levels of expertise. Information that is essential and non-redundant for novices may become redundant for experts. The expertise reversal effect observed in such situations depends on the redundancy effect and will be considered in detail in the next chapter.

Instructional Implications

The major instructional implication that flows from the redundancy effect is that in many instructional situations, there may be more costs than benefits in concurrently presenting essentially the same information in different forms such as different modalities, or presenting any unnecessary information. The most important conditions for the redundancy effect to occur, all of which flow directly from cognitive load theory, are that the sources of information must not rely on each other for intelligibility, element interactivity should be high, and where different verbal modalities are involved, the audio component needs to be sufficiently complex to impose high processing demands on working memory.

There are many instructional situations that meet these conditions. For example, the effect may often occur during PowerPoint presentations when large amounts of textual information are presented on the screen and simultaneously narrated by the presenters. In this situation, the audience needs to relate the on-screen text with the presenter's oral explanations, often also needing to pay attention to additional graphical information presented on the screen. These processes may require excessive working memory resources that become unavailable for comprehending and learning essential information. Reducing the on-screen text to a short list of the most important points and explaining them in detail orally may provide a better presentation technique.

Repeatedly occurring examples of redundancy can be found in maps, street directories, pie-charts and other diagrams complemented with textual explanations. When a diagram is self-contained, any additional verbal explanations can unnecessarily distract learner attention and generate an extraneous cognitive load irrespective of whether they are presented in an integrated visual form, auditory form or both.

Many traditional manuals instructing people how to use various software applications or technical devices require learners to simultaneously pay attention to explanations in the manual, in many cases, illustrated by screenshots or pictures, to the actual computer screen or equipment, and also enter data or commands using the computer keyboard. In addition to the common occurrence of split-attention, these types of instruction may also contain redundant sources of information, most notably, the computer or device itself. These sources of redundancy may contribute to high levels of extraneous cognitive load. As was noted above, temporarily eliminating computers or redundant hardware at the initial stages of learning should facilitate learning. Such self-contained manuals, dealing with highly interactive components of instruction, have proved to be effective for novice computer users (Sweller & Chandler, 1994; Chandler & Sweller, 1996). Eliminating the manual and placing all information on the screen also may be effective from a cognitive load perspective. In this case, the only role of the computer during the initial stages of learning would be to turn on-screen pages. After learners acquire some knowledge of the application or hardware, they will be able to handle higher levels of cognitive load because the effective capacity of working memory increases significantly when dealing with familiar information (see Chapter 4). Therefore, in the following stages of learning, the computer may be used for more interactive modes of learning. However, in areas where motor components and spatial-motor coordination are essential (e.g. typing), extensive practice with real equipment from initial learning is likely to remain essential.

Conclusions

For many of us, a common sense perspective often suggests that by presenting the same information in multiple forms such as presenting verbal information in both auditory and visual modalities will enhance student learning. Counter to this intuition, the available experimental evidence obtained within a cognitive load framework indicates that this perspective may contain a basic fallacy and instructional presentations involving redundant information more often inhibit rather than enhance learning. This chapter reviewed the theory and empirical evidence, outlining the conditions under which the redundancy effect might occur.

Within a cognitive load framework, the redundancy effect is explained by the increases in extraneous cognitive load generated by the need to process redundant information. Learners who are presented with several sources of essentially the same information simultaneously such as written and spoken text may need to attempt to coordinate them. Randomly searching for connections between elements from different sources of information that are not related to the learning goal can produce heavy demands on working memory and thus be detrimental to learning. Even when additional sources of information are unrelated to the major source such as background music, talk or movement, they are likely to capture attention and so divert working memory resources away from the task at hand, resulting in a reduction in learning due to redundancy. Irrelevant, unnecessary information can easily capture working memory resources and reduce learning. It should be eliminated.

The notion of redundancy may depend on levels of learner expertise. Information that is essential and non-redundant for novices may become redundant for experts. Therefore, as learners acquire more expertise in a domain, the information that has been previously essential and non-redundant may become redundant and cause increased levels of extraneous cognitive load for these learners. The associated expertise reversal effect will be considered in detail in the following chapter.