The Effect of Presentation Mode on Cognitive Load: Teaching Cognitive Skills with Text and Pictures

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Whatever the subject matter or the underlying educational theory, instructional message design deals with the presentation of information. And if the main aim of a learning task is to optimize the learning process, the effect of presentation format on learning should be taken into account when constructing such a task. A theory that has produced some interesting research issues and yielded several practical guidelines for presenting information in instructional material is Cognitive Load Theory, largely developed by John Sweller (Sweller, 1988; Sweller, 1994; Sweller, van Merriënboer & Paas, 1998). According to this theory, limitations in working memory capacity are a central concern for instructional designers. A learning task for the teaching of cognitive skills has to be constructed in such a way that the student’s cognitive resources are directed to the learning process and not overloaded by irrelevant features of the instructional material.

One major issue in Cognitive Load Theory is the design of learning tasks in which both verbal and visual (pictorial or diagrammatic) information is presented. In those kind of learning tasks, the learner is often forced to switch between a text and a picture, and has to integrate them mentally, causing a high cognitive load. In their empirical research, Sweller and his associates discovered three ways in which this cognitive load could be decreased. First of all, they showed that physical integration of verbal and visual information can lower cognitive load and improve learning (Tarmizi & Sweller, 1988; Chandler & Sweller, 1991; Sweller, Chandler, Tierney & Cooper, 1990; Chandler & Sweller, 1992). By placing a textbox close to the part of the picture the text was referring to, time needed to keep the information active in working memory was diminished which resulted in less cognitive load. This is called the split-attention effect. An alternative way of decreasing cognitive load was found in three studies by Mayer & Moreno (1998), Mousavi, Low & Sweller (1995) and Tindall-Ford, Chandler & Sweller (1997), where text was replaced with spoken word. According to the authors, presenting the information in two sensory modalities (visual and auditory) increases the available working memory resources, and thus diminishes total cognitive load. This is known as the modality effect. Finally, Chandler and Sweller (1991), and Kalyuga, Chandler & Sweller (1998), demonstrated that in some cases leaving out verbal information is the best
way to decrease cognitive load. Especially when text doesn’t add any new information to what is shown in a picture, reading it only increases cognitive load and impedes learning. This is called the redundancy effect.

These findings on how presentation of verbal and visual information influences cognitive load are of great interest for instructional message design, especially in multimedia learning environments that offer various ways of presenting information. However, the three above-mentioned effects give different signals to the instructional designer. In what cases should verbal information be integrated with visual information, presented as spoken word, or left out, in order to keep cognitive load that is irrelevant to the learning process as low as possible? This article will try to address this question by having a closer look at the empirical evidence on all three effects and their mutual relationship. First however, a moment’s thought will be spent on the underlying concepts of working memory as they are applied in Cognitive Load Theory.

Working Memory Resources

In these constructivist days, a learning process can be seen as the construction of knowledge when a learner is confronted with instructions (Mayer, 1992). In the case of teaching cognitive skills this knowledge takes the shape of cognitive schemata that can be used for problem solving. Research into expertise has shown that the essential difference between a novice and a expert in a certain domain is in the quantity and organizational quality of available knowledge (see Chi, Glaser, & Rees, 1982). When confronted with a new problem an expert will use his or her schemata to categorize the problem on its deep, structural properties and follow the appropriate path to a solution. Novices however will only look at the superficial features of the problem and fall back on weak problem solving strategies like means-ends analysis. That implies that they will try to apply procedures that bring them closer to the solution, without knowing if the route is correct. For example, in a physics problem, instead of analyzing its structure, all formulas containing the givens will be tried in order to reach the required goal.

So one of the aims of teaching cognitive skills is getting schemata as effectively and efficiently as possible into the learner’s head. Or, to put it more friendly, to let the learners construct these schemata for themselves. However, that raises the question how this process of knowledge construction takes place. According to Mayer (1992) “…meaningful learning
occurs when the learner selects relevant information, organizes that information in a coherent whole, and integrates that information with appropriate existing knowledge.” (p.408).

Working memory plays an essential role in these processes of selecting, organizing and integrating information as it is the active part of memory where controlled processing takes place. What’s more, as working memory is the gateway between the external world and long term memory, it is the place where instructional message and prior knowledge meet. This places working memory at the heart of the learning process, and thus any instructional theory inevitably has to address its consequences in terms of memory processes. Cognitive Load Theory does exactly this, as it concentrates on capacity limits in working memory.

The issue of limitations in memory has had a long history that traces back to the influential article by Miller (1956), in which the author discusses a limited span of processing capacity in the human mind. Interestingly, Miller distinguishes between two mechanisms, immediate memory and absolute judgement, that have different attributes. Firstly, immediate memory can be seen as a predecessor of short-term memory as its only function is retaining information, and according to Miller its span is “a fixed number of chunks” (p.93). This number refers to “the magical number seven plus or minus two” in the title of the article, and ever since it has been quoted in psychological literature as a shining example of the limitations in processing capacity. The “chunks” however can contain seemingly unlimited amounts of information items that are assembled by recoding procedures. The other capacity limitation that Miller discerns is the span of absolute judgements. He refers to this as “the amount of information that an observer can transmit” (p.91) when trying to tell apart different stimuli, and it is measured in information units called bits. An interesting point he makes is that this “channel capacity” seems to have several perceptual dimensions, so that adding different features like colour, spatial location and size increases the information processing capacity.

Recent theories of working memory combine the retaining and processing functions (Baddeley, 1992), and, fairly in line with Miller’s multidimensional channel capacity, presuppose separate memory resources for different input modalities (Shah & Miyake, 1996). Cognitive Load Theory as described by Sweller et al. (1998) draws heavily on the multiple components theory of working memory developed by Baddeley (1992). In Baddeley’s model, working memory consists of a Central Executive and two subsystems, the VisuoSpatial SketchPad and the Phonological Loop. As the latter two are both concerned with modality-specific input of information, the Central Executive is supposed to be modality neutral, one of
its main functions being the coordination of information from and to both subsystems as well as from and to long-term memory. The VisuoSpatial SketchPad is the main entrance for visual and spatial information and the Phonological Loop for acoustic and verbal information, so the use of both input systems can increase the available memory resources. Further evidence for this claim comes from Penney (1989), who gives a review of studies on memory capacity for verbal information. Most of them show that recall is better when words are presented in two sensory modalities rather than one. She explains this as a consequence of the working of the phonological store, a subsystem of the Phonological Loop, that can preserve an acoustical memory code for at least a minute. According to her “separate streams”-hypothesis, written words are represented in a phonological or visual code, while spoken words are represented in an acoustic as well as a phonological code. That means that there are different processing streams in working memory for visually and auditorily presented information.

These assumptions are taken by Sweller et al. (1998) as ground for the claim that a bimodal presentation can lead to a lower cognitive load than unimodal presentation of the same information, as in the former case more working memory capacity is available for the actual learning process. One problem with the claim of superior learning by bimodal presentation is that most empirical evidence for the modality-specific subprocessors is based on research on immediate recall. However, it was stated before that the learning of cognitive skills consists of selecting, organizing and integrating information, and in Baddeley’s model these processes take place in the modality-neutral Central Executive. So it is at least doubtful that subsystems like the VisuoSpatial SketchPad and the Phonological Loop are able to explain any substantial learning effects resulting from a bimodal presentation.

The working memory model of Shah and Miyake (1996) offers a way out of this dilemma by claiming a more central role for subsystems like the VisuoSpatial SketchPad and the Phonological Loop. In their view, working memory consists of different modality-specific memory resources for both the processing and the retaining of information. Although they do acknowledge the existence of some sort of Central Executive responsible for the integration of information from different sources, their model differs from Baddeley’s multimodal model of working memory in that it draws the different modality-specific elements out of the periphery into the centre of the memory system. In two experiments they give their theoretical claims some empirical solidity, showing that spatial ability and reading ability draw on different working memory resources. Not only have they tried to measure the recall span for
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In summary, it seems that more working memory resources become available when information consists of visual as well as verbal elements, and these resources can even be extended, at least at the level of subsystems, by presenting verbal information auditorily. However, when there is no necessity to integrate text and image, the different resources will not be used simultaneously, and gains in total processing capacity are not to be expected. On the other hand, when verbal and visual information do refer to each other, the main question is how to present this information so that the available working memory resources are used as efficiently as possible. This question is addressed by Cognitive Load Theory.

Cognitive Load Theory

In Sweller’s (1988) article on cognitive load during problem solving he describes an experiment in which goal-directed and goal-free problem solving are compared as instructional methods. In this experiment he asks his subjects not only to solve some trigonometry problems but also to memorize the givens and solutions. The results show that goal-directed problem solving interferes with this secondary task. Although Sweller frankly admits that schema acquisition includes more than memorizing solution steps, he concludes that goal-directedness seems to hinder the learning process. This is accounted for by stating that this kind of problem solving forces the learner to keep more information available in working memory than in a goal-free situation. After all, in the former case the learner has to consider the problem states as well as the intermediate and goal states, while in a goal-free situation the only active production rule is “Can I calculate a value?”. The main point however is that Sweller showed that the cognitive load caused by the format of the instructions can influence the learning process.

This idea has been elaborated in Cognitive Load Theory (Sweller, 1994; Sweller et al., 1998). In the theory a distinction is made between intrinsic and extraneous working memory load brought about by instructions. The first can be seen as the result of the intrinsic
complexity of the learning task, as it is the basic amount of processing required to understand
the information, whereas extraneous load can be seen as the result of the presentation format
of the instructions. That means that intrinsic load is dependent on the learner’s expertise, but
that extraneous load can be influenced by instructional message design. Because the aim of
instructional message design is to direct the available cognitive resources to the learning
process itself and not to any irrelevant feature of the instructional material, extraneous load
has to be kept as low as possible, especially in the case where intrinsic load is high and there
is reason to expect that the learning process can seriously be hindered by the presentation
format.

The Split-Attention Effect

One possible cause of high extraneous load is information that is presented in different
modes (e.g. verbal and visual). This came about in some experiments in which Tarmizzi and
Sweller (1988) compared worked examples with problem solving as instructional method.
Although Cognitive Load Theory predicted better learning results for worked examples as a
consequence of less extraneous cognitive load, this didn’t show in the experiments. The
worked examples consisted of verbal as well as visual information, for example in a
gemetric task where a picture of a triangle was accompanied by information on how to
calculate the value of one of the angles. The authors reasoned that the mental integration of
both textual and pictorial elements had been cognitively demanding and had led to a high
extraneous cognitive load. Therefore no difference in learning results had been found between
worked examples and problem solving. This hypothesis was subsequently tested by means of
placing the text inside the pictures instead of underneath it. This way the learner didn’t have
to split his or her attention between both sources of information, as the physical distance
between interrelated verbal and visual information was minimized. These integrated worked
examples resulted in superior learning when compared to a non-integrated format, as well as
to a problem solving format. Sweller et al. (1994; 1998) call the detrimental effect of
switching between different information sources on cognitive load the split-attention effect,
which can be undone by physically integrating information. It should be noted that the split-
attention effect is not limited to situations in which different modes are used (e.g. visual vs.
verbal), but also applies to situations in which different information sources are used. For
example, Sweller & Chandler (1994), Chandler & Sweller (1996), and Cerpa, Chandler &
Sweller (1996), showed that learning a computer programming language by either a written manual or an on-screen tutorial was superior to a mixed mode of learning, in which a combination of paper-based and on-screen information was used.

The split-attention effect in the case where instructions consist of verbal as well as visual information has been demonstrated in many experiments, in areas such as geometry (Tarmizzi & Sweller, 1988), computer programming (Chandler & Sweller, 1992; Sweller et al., 1990), electrical engineering (Chandler & Sweller, 1991) and biology (Chandler & Sweller, 1991). In most experiments the learning task consisted of worked examples, or contained pictures of a model or machine in combination with a textual explanation on its functioning. In the split-attention conditions text was placed underneath or next to the picture, while in the integrated conditions text was placed inside the picture, with numbers indicating the order in which textlines had to be read. The fact that all experiments showed superior learning results for the integrated conditions warrants a closer look at the exact conditions under which the results were obtained.

First of all, when thinking of the generalizability of the results, it is remarkable that the learning tasks used in the above-mentioned experiments all dealt with subjects from the exact sciences. Theoretically there is no need for this, because Cognitive Load Theory doesn’t exclude any domain as long as the instructions consist of pictorial and verbal information. For example, one can think of teaching all sorts of models in the social sciences, which also implies presenting a combination of pictorial and verbal information. One possible explanation for the dominance of the exact learning domains is the necessity to measure learning effects as objectively as possible. By keeping the domain formal, learning gains are most conveniently recorded. However, extension to less well-defined learning domains would strengthen the generalizability of the results on the split-attention effect.

Another issue is that the time available for learning in the experiments varied from a few minutes to a whole week. In some cases, worked examples were studied for a short time, mostly in combination with a few problems to solve. On the other hand, in three experiments conducted by Chandler and Sweller (1991; 1992), students got an instructional manual in combination with practical training in numerical programming or electrical engineering. After a whole week of instruction, differences in learning results due to presentation format in the manual were recorded. The setting of these experiments was true to life, as the instructions were given as part of a training program of an engineering company. This makes the results less easy to interpret, since many external factors can have influenced the learning results. On
the other hand, the results of the experiments that were conducted in more artificial circumstances may have less practical relevance. However, the fact that the results in both experimental and real-life settings were pointing in the same direction gives empirical body to the claim that the split-attention effect is a relevant issue for instructional message design.

As the evidence for a split-attention effect seems quite strong, a critical look at the learning results obtained in the experiments is justified. When physically integrating information, Cognitive Load Theory claims that learning gains are to be expected as a result of lowering extraneous cognitive load. So putting text inside a picture frees working memory space to be used for the construction of proper schemata. In the experiments by Tarmizi and Sweller (1988) and Sweller et al. (1990), testing of the learning results was mainly done by presenting the subjects new problems in the same domain. Overall, these were solved faster and with less errors by learners who had studied the integrated instructions, than by learners who had studied the conventional split-attention instructions. However, a closer look reveals that while in the Tarmizi and Sweller (1988) experiments this applied mainly to transfer problems, these results were not replicated in the Sweller et al. (1990) study. In the latter experiments, hardly any significant transfer effects were found, although integrated instructions did have a positive impact on solving problems that were similar to those studied in the acquisition phase. In the other two studies by Chandler and Sweller (1991;1992), testing of learning gains comprised mostly reproduction of the processes described in the instructions, with the exception of one experiment (described in Chandler & Sweller, 1991) in which two practical tests had to be performed by the students. Here, the results were in favour of subjects who had received integrated instructions, although this difference was not significant for one of the tests. Another interesting finding in this particular experiment was that the effects of the presentation format lasted for a long time, as tests were again administered three months later with exactly the same results.

So although evidence on transfer isn’t as straightforward as hoped for, most results seem to support the split-attention effect. By integrating verbal and visual information, extraneous cognitive load is decreased, resulting in more efficient and effective learning processes. At least, this is the account given by Cognitive Load Theory. With no viable alternatives available at the moment, it seems to be a reasonable explanation. However, as Chandler and Sweller (1992) justly remark when discussing their empirical work: “It should again be emphasised that we were not engaged in a theory validation exercise (…) The theory has been used as a generative tool which has provided new and viable methods of
instructional design in a wide variety of areas.” In fact, in none of the above-mentioned experiments cognitive load itself has been measured, which means that they give no substantial evidence for the split-attention effect in terms of decreasing cognitive load apart from the explanation in terms of the resulting learning benefits. Other researchers conducting experiments based on cognitive load theory do have used measurements of cognitive load. For example, Paas has done quite some research on the measurement of cognitive load in instructions (Paas, 1992; Paas & van Merriënboer, 1993; Paas & van Merriënboer, 1994; Paas, van Merriënboer & Adam, 1994). In a range of experiments, a subjective rating scale of perceived task difficulty was used to get at least an estimation of the cognitive load imposed by different instructional formats (e.g. worked examples vs. problem solving). Unfortunately, this scale hasn’t been used extensively when comparing integrated with non-integrated instructions. Two exceptions are experiments by Tindall-Ford et al. (1998) and Kalyuga et al. (1998). Although their main interest was not on split-attention but on modality and redundancy effects, their cognitive load measures do indicate a lower load for integrated instructions. Further research on the split-attention effect should include measurements of cognitive load, in order to investigate more thoroughly the theoretical claims of Cognitive Load Theory.

The Modality Effect: A special case of Split-Attention?

An alternative way of decreasing cognitive load when presenting verbal as well as visual information is to offer the verbal information as spoken word. In line with the multiple components theory of Baddeley (1992) and the separate streams hypothesis of Penney (1989), Sweller et al. (1998) claim that presenting a picture visually and a text auditorally will make more working memory space available for the learning process. Since the modality-specific components of working memory are addressed at the same time, the total available capacity will increase. As a result, extraneous load will be lower compared to the situation in which the verbal information is presented visually. This modality effect has been tested in several experiments, in the domain of geometry (Mousavi, Low & Sweller, 1995), electrical engineering (Tindall-Ford, Chandler & Sweller, 1998) and scientific reasoning (Mayer & Moreno, 1998).

All authors compared audio-visual with visual-only instructions. Mousavi et al. (1995) gave their students geometrical worked examples; Tindall Ford et al (1998) concentrated on
teaching how to perform an electrical test and Mayer and Moreno (1998) showed their students how lightning develops. In all three studies, audio-visual presentation of information appeared to be superior, as could be inferred from the learning results. However, there were differences in the way in which this improvement in learning was demonstrated. Whereas Mayer and Moreno found better retention as well as better problem solving transfer, Mousavi et al. did not obtain any significant results on transfer tests in their first two experiments. On the other hand, Tindall-Ford et al. obtained their learning effects in transfer questions and practical tests but not in reproduction questions. Furthermore, it is interesting to note that in their second experiment, Tindall-Ford et al. did not only test learning results but also recorded subjective measures of cognitive load during instructions. The outcome of these measures clearly favoured the audio-visual instructions, as a significantly lower load was reported in the audio-visual than in the visual-only conditions. So these results seem to give a strong basis for an explanation of the modality effect in terms of cognitive load.

It was shown before that extraneous cognitive load could also be lowered by physically integrating verbal and visual information, as a result of the split-attention effect. This raises the question how the modality effect and the split-attention effect are related to one another. In their first experiment, Tindall-Ford et al. compared audio-visual instructions with integrated as well as non-integrated visual-only instructions. The latter presentation format led to inferior learning results as was predicted. But no differences were found between audio-visual and integrated visual-only instructions, which had been expected as a result of the increase in available memory capacity in the former case. Unfortunately, in this specific experiment no subjective load measures were taken. Furthermore, in all other experiments on the modality effect, audio-visual instructions were only compared to non-integrated visual instructions. As argued before, the latter presentation format causes a high extraneous load as the learner has to switch between picture and text. However, the learner who receives the text as spoken word doesn’t need to, because he or she can look at the picture and listen to the accompanying narration at the same time. So the presentation of information in two sensory modalities leads to an optimal use of the available memory resources because text and picture are processed simultaneously. So an alternative explanation for the modality effect is offered us by Cognitive Load Theory itself, as the superior results audio-visual instructions can also be accounted for as the result of preventing split-attention.
On the other hand, Mousavi et al. (1997) provided some evidence for a modality effect that occurred separately from the split-attention effect. In two of their experiments they compared audio-visual and visual-only instructions in which picture and text were presented simultaneously, with visual and visual-only instructions in which picture and text were presented sequentially. In either case they found audio-visual instructions to give better learning results than visual-only instructions. Supposing that the sequential presentation of verbal and pictorial information had caused a split-attention effect (as in Mayer & Anderson, 1992), the superior results for the audio-visual instructions in the sequential condition can only be explained by an increase in memory resources. Unfortunately, the split-attention effect had not been demonstrated convincingly, because no differences in learning were found between the sequential and simultaneous presentation modes.

A study by Jeung, Chandler and Sweller (1997) showed that there can be a split-attention effect in audio-visual instructions. They offered their subjects worked examples in a computerized geometry task, and distinguished between pictures that were low and high in visual search as the pictures differed in complexity. For worked examples that contained pictures high in visual search, no differences in learning results were obtained between audio-visual and visual-only instructions. According to the authors, subjects who were listening to the narration in the audio-visual condition had to keep the textual information active in working memory while searching for the part of the picture the text was referring to, which led to a higher cognitive load. In other words, a split-attention effect was demonstrated that was just as strong as the split-attention effect in the non-integrated visual-only condition. Jeung et al. further showed how to counteract this effect, by adding visual cues to the audio-visual instructions. With electronic flashing, those parts of the picture were highlighted that the accompanying text was dealing with. This way, the attention of the learner was guided to the right part of the picture and unnecessary visual search was prevented. The results showed that this visual cueing restored the better learning results that could have been expected from audio-visual instructions as a result of the modality effect. However, just like in the experiments by Tindall-Ford et al. (1998) and Mayer and Moreno (1998), this improvement in learning can also be explained in terms of preventing split-attention, especially since no “cued” visual-only instruction was used for comparison.

Overlooking the experimental evidence concerning the modality effect, it may be concluded that definite conclusions cannot be drawn yet. Although the evidence on the Phonological Loop provided by Baddeley (1992) and Penney (1989) gives reason to believe
that an increase in memory capacity can be achieved by an audio-visual presentation format, this has yet to be proven by comparing integrated and audio-visual instructions and by measuring the accompanying cognitive load. Until then, most of the obtained results can still be explained as a consequence of preventing split-attention rather than of increasing working memory capacity.

The Interference of the Redundancy Effect

From the preceding it has become clear that changing the way in which verbal and pictorial or diagrammatic information are presented influences the cognitive load imposed on the learner, and thereby influences the learning process. In the experiments mentioned before instructions were given in which text and picture were referring to each other and could not be processed separately in order to be understood. In cases where separate processing is possible however, Cognitive Load Theory does not predict any positive effects of integrating text and picture. For example, in some experiments by Chandler and Sweller (1991), they presented their subjects a diagram from an electric circuit that could be understood without referring to the accompanying text. Comparing a non-integrated with an integrated presentation format yielded no difference in performance on a subsequent test, so no split-attention effect was found. When the subjects were explicitly asked to read the textual information, they obtained even worse results than subjects who could ignore the text, showing a detrimental effect of presenting redundant information. This was confirmed by comparing a condition in which only a diagram was presented with a condition in which both verbal and pictorial information were given. Subsequent results showed that the subjects in the diagram-only condition obtained better learning results than the other subjects, even when the latter had received their instructions in an integrated format. This redundancy effect can also be accounted for by Cognitive Load Theory. Sweller et al. (1998) state that the adding of superfluous information will lead to a higher extraneous cognitive load, because part of the total working memory capacity is used for the processing of unnecessary information and not for learning processes. When designing instructional messages, this effect should be prevented by removing redundant information.

So before integrating verbal and pictorial information in order to lower the extraneous load inflicted on the learner, the question must be raised if the textual information is redundant or not. If it is, leaving the text out is a better option than trying to fit it into the
picture or offer it auditorally. However, if information is redundant will be partly dependent on the prior knowledge of the learner as has been demonstrated by Kalyuga, Chandler & Sweller (1998). In their experiments they showed that over time, the textual part of their instructional material became redundant as their subjects progressed from novices to experts. The instructional material used in their study consisted of a diagram of an electrical circuit that was accompanied by a text on its functioning. In two of their experiments, instructions in a conventional split-attention format were compared to an integrated and a diagram-only format. In the first experiment, subjects who had received the integrated instructions were reporting significantly lower subjective load and achieved better learning results than the subjects in the other two conditions, indicating a strong split-attention effect. After two months of training the first experiment was repeated, but no differences were found between the three conditions in either cognitive load or learning results, indicating that the split-attention effect had disappeared completely. The authors claimed that this was caused by the fact that subjects in the integrated condition were less able to ignore the now partly redundant textual information, undoing the positive effect of integration on cognitive load. This effect was even stronger in the third experiment conducted again one month later, in which an audio-visual instruction was compared to a diagram-only instruction. Now the subjects in the latter condition showed superior learning results and significantly lower cognitive load, which pointed at a strong redundancy effect. Kalyuga et al. concluded that the verbal information had become superfluous with the acquisition of expertise, and that the diagram could now be understood by itself. Their last experiment however does raise the question if the positive effect of removing redundant text is equally strong for visual-only instructions. In the reported experiments, only the audio-visual presentation format showed to be inferior to the diagram-only conditions.

Yeung, Jin and Sweller (1997) on the other hand investigated the relationship between visual-only instructions and the redundancy effect. Although they presented only verbal information in their experiments, their findings are of interest as they showed the combined effects of expertise and integration of information sources on learning. It turned out that the use of the same instructional material can lead to different learning results, depending on the subjects’ expertise. For example, in one of their experiments a text had to be read with the help of a vocabulary list of difficult words that was integrated in the text or added at the end of the text. When the vocabulary list was integrated, less skilled readers scored higher on a subsequent comprehension test than when it was put at the end of the text. So preventing
split-attention seemed to lower extraneous cognitive load, as could be expected. However, when the same conditions were used with skilled readers, the effect was reversed. The subjects in the integrated condition were not able to ignore the meaning of the difficult words which led to a higher cognitive load as a consequence of the redundancy effect, and comprehension was partly prevented. However, they did score higher on a vocabulary test when compared to expert subjects in the non-integrated condition who had received the meaning of difficult words at the end of the text. Apparently, the latter subjects didn’t need to know the exact meaning of some of the words in order to comprehend the presented text, and had ignored the vocabulary list. So if the aim of the learning task had not been comprehension but knowing the exact meaning of some difficult words, an integrated presentation would have given the best results.

From the above it proves that the relationship between split-attention and modality effects on the one hand, and redundancy effects and expertise on the other hand is a complex one. The former two effects stress the importance of integrating verbal and pictorial material in instructional message design, whereas the redundancy effect shows that this strategy will not automatically result in the optimal learning results when some parts of the information is superfluous for the target learners. In fact, differences in the design of the instructional message not only influence the quality of the learning results, but also seem to lead to different learning outcomes. Not only has the learner’s expertise to be taken into account when looking at the consequences of integrating verbal and visual information, but also the kind of learning that is aimed at.

Discussion

The main question was whether verbal information should be integrated with visual information, be presented as spoken word, or be left out, in order to keep cognitive load that is irrelevant to the learning process as low as possible. Generally speaking, the way to reduce extraneous cognitive load is by using the available working memory resources as efficiently as possible. According to Cognitive Load Theory, there are three ways to achieve this goal when verbal and visual information is used in instructions.

First of all, by reducing the physical distance between interconnected verbal and visual information, the learner doesn’t have to split his or her attention and extraneous load is decreased. This split-attention effect has been demonstrated convincingly in several
experiments. At least, in terms of an improvement in learning results. Until now, there hasn’t been much validation in terms of cognitive load measures.

Secondly, by presenting the verbal information as spoken word, working memory resources are increased and extraneous load is lowered. When a picture has a high complexity, this modality effect will only occur when the verbal information is supported with visual cues, otherwise unnecessary visual search will undo the positive effect of audio-visual presentation. Until now, this modality effect has only been convincingly shown when comparing audio-visual instructions with non-integrated visual-only instructions.

Finally, by removing the verbal information that is not necessary for understanding the visual information, it is prevented that the available memory resources are used for the processing of redundant information. Experiments have shown that it depends on the learner’s expertise if the visual information is understandable by itself and if verbal information is redundant or not.

Overlooking the empirical evidence thus far, no straightforward answer can be given to the question how to present our verbal and visual information. The only clear guideline that Cognitive Load Theory seems to produce is that redundant information should be removed. However, if learners need the verbal information in order to understand the verbal information, it is unclear when text and picture should be physically integrated, and when text should be presented auditorally. Both methods seem to have a positive effect on learning as a result of decreasing cognitive load, but the mechanism behind it is not fully clear yet. For example, although there is some experimental support for the modality effect, the results can just as well be accounted for by the split-attention effect, as offering the information through two different senses will get both verbal and pictorial information in working memory at the same time. This would imply that a bimodal presentation mode is the most efficient way of addressing the available working memory resources.

On the other hand, when one cannot know the expertise of the learners in advance, or when there are great differences in expertise, the redundancy effect might also influence the choice between an integrated or bimodal presentation mode. Especially because visually presented text is easier to ignore than spoken text, its effects on cognitive load might be less detrimental. That would plead for an integrated instruction, or even for a non-integrated presentation of information, because it is harder to ignore text that is inside a picture than text that is standing underneath it.
These issues however can only be resolved by empirically investigating the relationships between the split-attention, the modality and the redundancy effect. Especially by using cognitive load measures, a further understanding can be obtained of the way in which the presentation mode of visual and verbal information influences the learning process, resulting in guidelines for instructional message design.
References


