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Cognitive Load Factors Moderating the Redundancy Effect in Multimedia Learning

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Abstract: According to the redundancy effect in cognitive load theory, if two or more sources of information could be understood separately without the need for mental integration (e.g., when the same information is presented in different formats or modalities), redundant sources of information should be omitted rather than presented. Within a cognitive load framework, the redundancy effect is explained by a more efficient use of the available working memory resources: by reducing cognitive load wasted on unnecessary integration of redundant sources of information, more resources become available for meaningful learning. However, some studies failed to replicate the redundancy effect and in some cases, found significant differences opposite to those expected. This paper reviews and systematizes a set of factors moderating the redundancy effect in multimedia learning.

Keywords: multimedia learning, cognitive load, redundancy effect, audiovisual redundancy.

Introduction

Working memory is our major information processor which is very limited in its capacity and duration when dealing with new information [1]. In addition, contemporary models of human cognition assume that we have two different, partially independent, processors for dealing with visual and auditory information both of which have capacity and duration limitations [2, 3]. These characteristics and limitations should be taken into account when designing instructional presentations. Firstly, the presentation formats should be designed in a way that can help learners to avoid an unnecessary overload in either of the processors. Secondly, by using both, rather than a single processor, the processing load can be spread over both processors thus reducing the load on a single processor, and dual modality presentations could be superior to visual only presentations (modality effect, [3, 4]).

The redundancy effect generally occurs when two or more sources of information can be understood separately without the need for mental integration, for example, when written or spoken text that simply re-describes a diagram that can be fully understood without the text. Under these conditions, processing the text and mentally integrating it with the diagram may result in an increased cognitive load and inhibit learning by unnecessarily diverting cognitive resources. Accordingly, redundant sources of information should be omitted rather than presented.

In multimedia learning, 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. In cognitive load theory [4], any information that is not required for learning but is presented to learners is regarded as redundant as it may result in wasteful (extraneous) cognitive load. However, some studies failed to replicate the redundancy effect and on few occasions even found differences opposite to those expected. Therefore, establishing clear boundaries and moderating factors for the effect is an important research issue. This paper reviews and systematizes a set of factors moderating the redundancy effect in multimedia learning.

1. Concurrent Presentations of Written and Spoken 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 learning effects. When spoken explanations are used concurrently with the same written text, learners may be required to relate and coordinate the corresponding elements of written and spoken information. This extraneous to learning processing may unnecessarily consume additional working memory resources.

For example, computer-based instructions in mechanical engineering were used to compare written text, spoken text, and written plus spoken text that explained an animated diagram [5]. The results demonstrated that the spoken text group outperformed the written text plus spoken text group. Subjective ratings of cognitive load indicated that presenting on-screen textual explanations of the diagram together with the same auditory explanations resulted in additional load. Two experiments with university students [6] demonstrated that learners who studied narrations with concurrent animations performed better on posttests than learners who studied animations with concurrent narration and on-screen text that either summarized or duplicated the narration. A similar effect was demonstrated with animated pedagogical agents [7]. Diagrams with spoken text were also compared with exactly the same information along with the equivalent written sentences presented either sequentially, sentence by sentence, or as a full-text displayed next to the diagram [8]. The spoken text format resulted in superior learning compared to both written text groups.

With the increased popularity of PowerPoint presentations, the same verbal information is often provided in both spoken and written forms simultaneously. Based on the redundancy effect, learning might be inhibited by such concurrent presentations. This effect was also obtained using technical, text-based instructions without any diagrams [9]. Learning was facilitated when instructions were presented in a spoken form alone rather than concurrently.

Audiovisual redundancy effect was also demonstrated in hypermedia learning [10]. Arithmetical information supplemented with lengthy spoken and written explanations was less efficient than written only text. In this study, spoken only explanations did not result in better learning than the dual-modality explanations. Lengthy spoken text may cause cognitive overload due to the transiency of spoken information (some elements of information become unavailable before they are mentally integrated with related follow-up elements). The role of the length of instructional segments will be discussed later.

2. Moderating Factors

2.1 Independence of Sources of Information

The redundancy effect was always demonstrated under conditions when sources of information were intelligible in isolation. An example is textual information that merely re-describes a diagram, a table, or another section of text. 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.

2.2 Levels of Information Complexity

Sufficiently high levels of interactivity or interconnectedness between elements of information represent an essential moderating factor for the redundancy effect. Instructional materials with low levels of complexity are unlikely to demonstrate benefits from eliminating redundant information as it may still be within working memory limits and not interfere with learning. In contrast, if materials are characterized by high levels of complexity, an additional load caused by processing redundant information can be harmful. For example, studying a self-contained manual without actual hardware was beneficial at initial stages of learning compared to the manual plus the hardware, but only for relatively complex tasks [11]. No redundancy effect was demonstrated for low complexity materials. Measures of cognitive load confirmed the importance of internal complexity of materials to the redundancy effect. Significantly better test results associated with a lower cognitive load favored an integrated manual only group compared to the manual and hardware group in areas of high complexity. No effects were found in areas of low complexity.

2.3 Levels of Learner Control

In most experiments that demonstrated audiovisual 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, needed to engage in cognitively taxing visual search between on-screen text and pictorial elements while under strict time constraints. In learner-paced presentations, students may review the material at their own pace with extra time available for managing cognitive load, thus reducing the benefits of non-redundant presentations.

In two experiments with technical apprentices, simultaneously presented written and auditory explanations of a diagram were compared with an instructional format in which these two forms of verbal information were temporally separated (written text presented only after the narration ended) [9]. The experiments demonstrated superiority of the sequential presentation of auditory and visual explanations over their concurrent presentation, but only when instruction time was constrained in a system-controlled condition. There were no differences in a learner-controlled condition.

2.4 The Length of Instructional Segments

The length of textual segments may also influence 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. This may contribute to the intrinsic complexity of such materials in addition to dealing with the transient nature of spoken information.

For example, a concurrent presentation of auditory and visual forms of the same technical text (without diagrams present) resulted in less learning than the auditory-only text [9]. However, another study 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 [12]. This difference in results could be explained by the length of textual segments. In the first study, the text was presented to participants continuously as a single large chunk without breaks [9]. In contrast, in the second study, the text was presented in several consecutive small segments with appropriate breaks between them [12]. Such breaks might have allowed the learners to consolidate their partial knowledge structures constructed from each segment of the text before moving to the next one. If text is partitioned into easily managed sequential segments with time breaks, 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 benefit from a written back-up.

Thus, the audiovisual redundancy effect most likely occurs when 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. Lengthy sections of spoken text that is transitory in nature may exceed working memory capacity limits. The length of textual segments may override pacing of the presentation as a moderating factor for the audiovisual redundancy effect.

2.5 Levels of Learner Prior Knowledge

Most studies reviewed in this paper were conducted with novice learners. At the same time, the notion of redundancy may depend on levels of learner prior knowledge. Information that is non-redundant for novices may become redundant for more knowledgeable learners. Therefore, as learners acquire more knowledge in a domain, the information that has been previously essential may become redundant and cause increased levels of unnecessary cognitive load for these learners. For example, auditory explanations of technical diagrams became redundant after a series of training sessions intentionally designed to increase levels of learner expertise in using similar types of diagrams [13]. Similar results (referred as the expertise reversal effect) have been demonstrated on many occasions in relation to different instructional techniques, formats of information presentation, and levels of instructional guidance (see [4, 14] for comprehensive overviews of the expertise reversal effect).

3. Instructional Implications

The major instructional implication of the redundancy effect is that in many instructional situations, there may be no benefits in concurrently presenting the same sources of information in different forms. The most important conditions for the effect to occur are that the sources of information must not rely on each other for intelligibility, information should be sufficiently complex, and (if involved) the spoken text should to be sufficiently lengthy to cause high levels of working memory load. The levels of learner prior knowledge could also influence the effect as the notion of redundancy depends on levels of learner expertise in a domain.

There are many instructional situations in multimedia learning where these conditions are in place. A simple example is provided by many PowerPoint presentations during which large amounts of textual information are often presented on the screen and simultaneously narrated by the presenters thus generating a potential cognitive overload. Reducing the on-screen text to a short list of the most important points and explaining details orally may be a better technique.

Many computer-based multimedia manuals instructing people how to use complex software applications or technical equipment require learners to simultaneously pay attention to explanations in the illustrated manual, to the actual computer software on the screen or equipment, and also enter data or commands using the keyboard. From a cognitive load perspective, the actual computer software or equipment may be redundant at the initial stages of learning (e.g., for novice users) and their temporarily elimination may facilitate learning [11, 15]. In the following stages of instruction, when learners acquire some knowledge of the application or hardware and are able to handle high levels of cognitive load, more interactive modes of learning with actual hardware could be used.

Conclusion

It is a common belief that by presenting the same information in multiple forms may enhance student learning. Counter to this intuition, the available evidence obtained within a cognitive load framework indicates that this perspective may be wrong and instructional presentations involving redundant information more often inhibit rather than enhance learning. This paper reviewed the theory and empirical evidence, outlining the factors that may influence the redundancy effect in multimedia learning.

Within a cognitive load framework, the redundancy effect is explained by the increases in unnecessary, wasteful cognitive load generated by the need to process redundant information. Learners who are presented with several sources of essentially the same information (e.g., written and spoken text) must coordinate them and search for connections between elements from different sources of information. These activities are not directly related to learning but may generate a heavy cognitive load and thus inhibit learning.

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