DOCUMENT SUMMARY

This paper presents a cognitive theory of multimedia learning based on three key assumptions: the dual-channel for processing verbal and visual information, limited capacity in each channel, and active processing for meaningful learning. The authors define cognitive overload and identify nine distinct, theory-based methods to reduce it in multimedia instruction. These methods, including off-loading, segmenting, pretraining, and eliminating redundancy, are supported by experimental research and provide a practical framework for designing more effective learning experiences.

FILENAME

mayer_2003_research_report_cognitive_load_multimedia

METADATA

Category: RESEARCH

Type: report

Relevance: Core

Update Frequency: Static

Tags: #cognitive-load #multimedia-learning #instructional-design #dual-channel #working-memory #e-learning #cognitive-theory

Related Docs: N/A

Supersedes: N/A

FORMATTED CONTENT

Nine Ways to Reduce Cognitive Load in Multimedia Learning

Richard E. Mayer, Roxana Moreno

Abstract

First, we propose a theory of multimedia learning based on the assumptions that humans possess separate systems for processing pictorial and verbal material (**dual-channel assumption**), each channel is limited in the amount of material that can be processed at one time (**limited-capacity assumption**), and meaningful learning involves cognitive processing including building connections between pictorial and verbal representations (**active-processing assumption**). Second, based on the cognitive theory of multimedia learning, we examine the concept of **cognitive overload** in which the learner's intended cognitive processing exceeds the learner's available

cognitive capacity. Third, we examine five overload scenarios. For each overload scenario, we offer one or two theory-based suggestions for reducing **cognitive load**, and we summarize our research results aimed at testing the effectiveness of each suggestion. Overall, our analysis shows that **cognitive load** is a central consideration in the design of multimedia instruction.

What is Multimedia Learning and Instruction?

We define **multimedia learning** as learning from words and pictures, and we define multimedia instruction as presenting words and pictures that are intended to foster learning. The words can be printed (e.g., on-screen text) or spoken (e.g., narration). The pictures can be static (e.g., illustrations, graphs, charts, photos, or maps) or dynamic (e.g., animation, video, or interactive illustrations).

We define **meaningful learning** as deep understanding of the material, which includes attending to important aspects of the presented material, mentally organizing it into a coherent cognitive structure, and integrating it with relevant existing knowledge.

> A central challenge facing designers of multimedia instruction is the potential for **cognitive overload**—in which the learner's intended cognitive processing exceeds the learner's available cognitive capacity.

How the Mind Works

We begin with three assumptions about how the human mind works based on research in cognitive science—the **dual channel assumption**, the **limited capacity assumption**, and the **active processing assumption**.

Assumption	**Definition**
Dual channel	Humans possess separate information processing channels for verbal and visual material.
Limited capacity	There is only a limited amount of processing capacity available in the verbal and visual channels.
Active processing	Learning requires substantial cognitive processing in the verbal and visual channels.

The Case of Cognitive Overload

A potential problem is that the processing demands evoked by the learning task may exceed the processing capacity of the cognitive system—a situation we call **cognitive overload**.

We distinguish among three kinds of cognitive demands: **essential processing**, **incidental processing**, and **representational holding**.

- **Essential processing** refers to cognitive processes that are required for making sense of the presented material.
- **Incidental processing** refers to cognitive processes that are not required for making sense of the presented material but are primed by the design of the learning task.
- **Representational holding** refers to cognitive processes aimed at holding a mental representation in working memory over a period of time.

The total processing intended for learning consists of **essential processing** plus **incidental processing** plus **representational holding**. **Cognitive overload** occurs when the total intended processing exceeds the learner's cognitive capacity. Reducing **cognitive load** can involve redistributing **essential processing**, reducing **incidental processing**, or reducing **representational holding**.

Nine Ways to Reduce Cognitive Load

Overload Scenario	**Problem**	**Load-Reduction Method**	**Principle**
Type 1	One channel is overloaded with essential processing	**Off-loading:** Present words as narration rather than on-screen text	Modality Effect
Type 2	Both channels are overloaded with essential processing	**Segmenting:** Break lesson into learner-paced segments	Segmentation Effect
		Pretraining: Present names and characteristics of main concepts before the lesson	Pretraining Effect
Type 3	System is overloaded by incidental processing due to	**Weeding:** Exclude interesting but extraneous	Coherence Effect

	extraneous material	material	
		Signaling: Add cues that highlight the organization of the essential material	Signaling Effect
Type 4	System is overloaded by incidental processing due to confusing layout	**Aligning words and pictures:** Place printed words near corresponding parts of graphics	Spatial Contiguity Effect
		Eliminating redundancy: Avoid presenting identical streams of information simultaneously	Redundancy Effect
Type 5	System is overloaded by need to hold representations in working memory	**Synchronizing:** Present corresponding narration and animation at the same time	Temporal Contiguity Effect
		Individualizing: Consider differences in learners' prior knowledge or abilities	Spatial Ability Effect

Type 1 Overload: Off-Loading

- **Problem:** One channel is overloaded with essential processing demands. This occurs in a "split-attention effect" where a learner must switch between viewing an animation and reading on-screen text.
- **Solution: Off-loading.** Present words as narration. This reassigns some processing from the visual channel to the verbal channel. This is the **Modality Effect**: Students understand a multimedia explanation better when the words are presented as narration rather than as on-screen text.

Type 2 Overload: Segmenting and Pretraining

- **Problem:** Both channels are overloaded with essential processing demands, often when material is complex and the pace is fast.

- **Solution: Segmenting.** Break the presentation into bite-size, learner-controlled segments. This is the **Segmentation Effect**: Students understand a multimedia explanation better when it is presented in learner-controlled segments rather than as a continuous presentation.
- **Solution: Pretraining.** Provide prior instruction on the names and behaviors of the system's components before presenting the full causal model. This is the **Pretraining Effect**: Students understand a multimedia presentation better when they know the names and behaviors of the components in the system.

Type 3 Overload: Weeding and Signaling

- **Problem:** The system is overloaded by **incidental processing** demands caused by extraneous material (e.g., background music, irrelevant video clips).
- **Solution: Weeding.** Eliminate interesting but extraneous material. This is the **Coherence Effect**: Students understand a multimedia explanation better when interesting but extraneous material is excluded rather than included.
- **Solution: Signaling.** When extraneous material cannot be removed, provide cues (e.g., stressed keywords, arrows, outlines) to guide the learner's attention to essential information. This is the **Signaling Effect**: Students understand a multimedia presentation better when it contains signals concerning how to process the material.

Type 4 Overload: Aligning and Eliminating Redundancy

- **Problem:** The system is overloaded by **incidental processing** demands caused by a confusing presentation of essential material.
- **Solution: Aligning words and pictures.** Place printed text near the corresponding parts of the graphic to reduce visual scanning. This is the **Spatial Contiguity Effect**: Students understand a multimedia presentation better when printed words are placed near rather than far from corresponding portions of the animation.
- **Solution: Eliminating redundancy.** Avoid presenting the same information simultaneously as narration and on-screen text alongside an animation. This is the **Redundancy Effect**: Students understand a multimedia presentation better when words are presented as narration rather than as narration and on-screen text.

Type 5 Overload: Synchronizing and Individualizing

- **Problem:** The system is overloaded by the need for **representational holding**—holding information (e.g., narration) in working memory while waiting for the corresponding visual information to be presented.
- **Solution: Synchronizing.** Present corresponding visual and auditory material at the same time. This is the **Temporal Contiguity Effect**: Students understand a multimedia presentation better when animation and narration are presented simultaneously rather than successively.
- **Solution: Individualizing.** Match the multimedia design to the learner's abilities. For example, learners with high spatial ability benefit more from synchronized

presentations because they can hold and manipulate mental images with less effort. This is the **Spatial Ability Effect**.

Conclusion

A major challenge for instructional designers is that meaningful learning can require a heavy amount of essential cognitive processing, but the cognitive resources of the learner's information processing system are severely limited. Therefore, multimedia instruction should be designed in ways that minimize any unnecessary **cognitive load**.

Our research program convinces us that effective instructional design depends on sensitivity to **cognitive load** which, in turn, depends on an understanding of how the human mind works. The seemingly practical search for load-reducing methods of multimedia instruction has contributed to theoretical advances in cognitive science—a well-supported theory of how people learn from words and pictures.