A meta-analysis of how signaling affects learning with media

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ABSTRACT
The signaling effect states that learners profit from cues that highlight the organization of specific relevant information within materials. This meta-analysis includes 103 studies and N = 12,201 participants. 139 retention and 70 transfer performance measures were used to determine separate mean effect sizes. Cognitive load, motivation/affect, learning time, and eye-tracking data were included as dependent variables to explain possible effect mechanisms. Additionally, nine possible moderators (e.g., type of signaling) were identified. The retention (g+ = 0.53, 95% CI [0.42, 0.64]) and transfer (g+ = 0.33, 95% CI [0.22, 0.43]) sizes support the positive effect of signaling on motivation/affect, learning time, and learning-relevant fixations. Cognitive load was significantly reduced. In contrast to the expertise reversal effect hypothesis, prior knowledge was not identified as a moderator of the signaling effect. The results were interpreted using media learning theories. Recommendations for future studies are included herein.

1. Introduction

Almost every learning situation involves media that include verbal and visual information, such as texts and pictures that must be continuously analyzed and processed by learners. Moreover, in order to reach a learning goal, this information needs to be integrated into a coherent mental model and stored in long-term memory (Mayer, 2014a). However, prior to the storage of this information, its relevance must be determined (Awh & Jonides, 2001). This is a challenging task, as instructional environments increase in fidelity and visual richness (e.g., Chen, Liu, & Hwang, 2015). Therefore, instructional designers use different methods to attract the learners’ attention and highlight important information (e.g., underlining) in order to improve learning outcomes. This principle is generally referred to as signaling – the attempt to highlight organizational structures (e.g., main aspects or learning-relevant information) to foster goal-oriented learning (Van Gog, 2014). This study summarized experimental studies on the advantages and disadvantages of signaling features through a theoretical and meta-analytical review.

2. Theoretical background

2.1. The signaling principle and media design theories

The signaling principle, also known as the cueing principle, is based on the finding that people learn better when instructional materials include cues that highlight relevant elements or the organization of the material (for reviews, see Corkill, 1992; De Koning, Tabbers, Rikers, & Paas, 2007; Dodd & Antonenko, 2012; Richter, Scheiter, & Eitel, 2016; Spyridakis, 1989; and Van Gog, 2014). This is...
principle is also referred to as the attention-guiding principle because most cues highlight information to attract attention. According to Van Gog (2014), two main signaling modes can be distinguished: signals within texts and signals within pictures (including other forms of graphics, like diagrams, videos, or animations). Textual signaling can be distinguished into five subtypes: organizational signals (e.g., headings or summaries), colors (e.g., font colors), text-picture references (e.g., “see the picture”), intonation (e.g., in auditory texts), or a mixture of types (e.g., coloring and text-picture referencing). Graphical signals can be subdivided into pointing gestures (e.g., arrows or gestures of pedagogical agents), colors (e.g., parts of a picture), labels (e.g., naming parts of an animation), flashing, spotlights (also called anti-cueing; e.g., greying out parts of an illustration), graphic organizers, or, again, a mixture of two or more types (e.g., pointing gestures and labels). A graphical overview of signaling types is shown in Fig. 1.

Research on the signaling principle is based on a long tradition of experimental studies. First studies occurred in the early 1970s (e.g., Cashen & Leicht, 1970), but the debate about new forms of signaling is ongoing (e.g., Gordon, Tindall-Ford, Agostinho, & Paas, 2016). Earlier studies focused on cues within texts (e.g., outlines; Glynn & Di Vesta, 1977), while the latest studies generally focus on new signaling methods in, for example, video-based materials (e.g., Ouwehand, van Gog, & Paas, 2015a), in connection with pedagogical agents (e.g., Johnson, Ozogul, & Reisslein, 2015), or in virtual reality environments (e.g., Dodd & Antonenko, 2012).

The signaling principle can be based on two media design theories. According to the Cognitive Theory of Multimedia Learning (CTML; Mayer, 2014a), learning is based on three assumptions about meaningful cognitive processes: (1) humans process information via two channels (visual/pictorial & auditory/verbal), (2) each channel has a limited information processing capacity, and (3) learning only takes place if cognitive processes are coordinated (active processing). Moreover, learning-relevant information needs to be selected, organized and integrated into long-term memory (SOI-assumption of CTML). Since not all learning situations involve teachers who monitor the learning progress, the selection of relevant information must be coordinated using attention-guiding features (signals) within the learning material. However, not every signaling attempt is helpful; some guiding features actually distract learners or fail to effectively convey meaning. In this case, signaling leads to additional cognitive processes that do not contribute to goal-oriented learning. Within CTML, this is referred to as extraneous processing. In contrast, essential processing defines the cognitive processes needed to represent a mental model of the instructional material, while generative processing sums up all processes that try to make sense of and store information. In conclusion, CTML is not limited to multimedia instructional materials, since even simple instructional materials like a learning text might evoke verbal and nonverbal mental models and can be transferred via mental conversions (Mayer, 2014a).

The separation of cognitive processes postulated in the CTML, however, was based on the Cognitive Load Theory (CLT; e.g., Paas &
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