

## Attention and Long-Term Memory in System and Process Theories of Working Memory: A Reply to Soemer's (2015) Comment on Schweppe and Rummer (2014)

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Published online: 30 July 2015

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Recently, Soemer (2015) criticized our theoretical review paper published in this journal (Schweppe and Rummer 2014). In our article, we argued for a new perspective on (working) memory within theories of multimedia learning. Our main idea was that a theory that focuses on interactions between attention and long-term memory (as does Cowan's 1999, embedded-processes model) provides a more unitary account of the multi-faceted principles associated with working memory in multimedia research than those models currently incorporated in multimedia theories. Even though many of the recommendations for how to design multimedia learning materials relate to reducing cognitive load in working memory, they refer to attention and long-term memory at least as much.

Our article had two core messages: (1) Based on a description of the multicomponent model of working memory (e.g., Baddeley 2000; Baddeley & Hitch 1974) and how it is adapted in theories of multimedia learning,<sup>1</sup> we concluded that the most important principles for multimedia learning are neither clearly attributable to the basic model (i.e., the multicomponent model) nor to the applied models (i.e., the cognitive theory of multimedia learning, e.g., Mayer 2009, and the cognitive load theory, e.g., Sweller 1999). (2) As an alternative, we suggested incorporating a different model that conceives of working memory as the interplay of attentional processes and long-term memory and thus allows for explaining principles related to attention, working memory, and long-term memory in a unitary manner (i.e., the embedded-processes model by Cowan 1999).

Soemer's (2015) comment mainly concerned our description of the multicomponent model of working memory. More specifically, he criticized that, unlike suggested in our article, the current version of the multicomponent model of working memory (Baddeley 2000, and later) does not postulate *structurally* independent working and long-term memory systems but rather

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<sup>1</sup>It is important to note that current theories of multimedia learning do not incorporate one of the recent versions of the multicomponent model (Baddeley 2000, or later).

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*functionally* independent systems. He concluded that this misunderstanding makes the entire argument in favor of a different perspective on working memory invalid because, when interpreted correctly, the difference between the two approaches is only minimal. If this were the case, the two accounts would not contradict each other but rather look at working memory from different angles and complement each other. According to Soemer (2015), there is, thus, no need for multimedia theories to refer to alternative models of working memory.

There are, however, three major issues regarding this criticism: (1) It is not clear what exactly is meant by the distinction between a *structural* separation of working memory and long-term memory on the one hand and a *functional* one on the other. Similarly, it is not clear which distinction is made in the multicomponent model. (2) We doubt that the question whether working memory and long-term memory are structurally or solely functionally independent is relevant for multimedia learning. (3) It is particularly the different *focus* of the embedded-processes model that makes it a promising alternative for integrating the diverse findings regarding cognitive constraints and their implications for the design of multimedia learning environments.

Ad 1: According to Soemer's (2015) interpretation of the multicomponent model, working memory is distinct from long-term memory only in that it fulfills distinct cognitive functions. The argument is based on a quotation from Baddeley and Logie (1999, p. 47), which states that "working memory and LTM comprise two functionally separable cognitive systems." However, this statement does not say anything about whether the distinction between working memory and long-term memory is functional *only* or functional *and* structural. The crucial question is what the difference between a functional separation and a structural separation means in this context. We spoke of "structural" in terms of models that distinguish *separate cognitive systems* or components (like the multicomponent model, Baddeley & Hitch 1974, or the multi-store model, Atkinson and Shiffrin 1968) as opposed to models whose main focus is the distinction between *processes* (like the embedded-processes model, Cowan 1999). In this sense, the separation between working memory and long-term memory can be interpreted as both functional and structural in Baddeley's model. For instance, Baddeley (2000, p. 422), made clear that even the recent version of the model "differs from many current models of WM in its continued emphasis on a multicomponent nature, and in its rejection of the suggestion that working memory simply represents the activated portions of LTM." Even more explicitly, Baddeley (2010, p. 139) clarified with respect to the phonological loop, the verbal subsystem of working memory: "Other critics argue that the phonological loop should be regarded simply as part of the language processing system, rather than regarding it as a supplementary store. However, while the loop has almost certainly evolved from mechanisms for speech perception and production, the fact that patients with grossly impaired phonological short-term memory may have normal speech perception and production argues for a *separate system* [emphasis added by authors], although this is strongly linked to language processing." It is, however, under discussion whether the multicomponent model indeed assumes separate "boxes" or solely separate mechanisms, that is, whether the distinction is structural as well as functional (Miyake and Shah 1999). In trying to carve out the differences between the multicomponent model and the embedded-processes approach, we may have been somewhat misleading with regard to the question of how working memory and long-term memory are regarded as separable. It is therefore important to clarify the argument.

Ad 2: Nonetheless, the question whether working memory and long-term memory are functionally and structurally or solely functionally separable is only a peripheral point in our argument, specifically when it comes to applying working memory theories to multimedia

research. We therefore doubt that this clarification obviates our argument in favor of a process-based perspective of working memory that integrates attentional processes and long-term memory. As Soemer (2015) pointed out, a crucial implication of research inspired by the multicomponent model concerns domain-specific interference in that two visuo-spatial or two verbal cognitive operations interfere more strongly than a visuo-spatial and a verbal one. This finding, which the embedded-processes model attributes to similarity-based interference (Cowan 1999), can even be regarded as the basis of multimedia learning because it emphasizes the benefit due to combining pictorial and verbal information. It has also influenced multimedia theories in that they emphasized the difference between presenting verbal materials in visual versus auditory modality—a modality-specific distinction which, notably, is not equivalent to Baddeley and Hitch's (1974) domain-specific distinction. However, as we argued (Schweppe and Rummer 2014), most of the recommendations for multimedia design that are currently investigated and that are attributed to working memory are only loosely connected to this central assumption of the multicomponent model.

Ad 3: We further argued that many of the multimedia principles either refer to attention (e.g., the coherence principle, Mayer, Heiser, and Lonn 2001, the signaling principle, Mautone and Mayer 2001), or to the influence of prior knowledge in long-term memory (e.g., the expertise reversal principle, Kalyuga, Ayres, Chandler, and Sweller 2003). It is a common assumption of working memory models that attention and long-term memory interact with working memory in some way. Yet a multimedia learning theory would benefit the most from a basic framework that already provides a *unified* account of all these processes and/or components, that is, of attention, working memory, and long-term memory. Instead of reiterating the entire argument of Schweppe and Rummer (2014), we want to explicate one point that we regard as particularly promising, that is, the distinction between the voluntary and involuntary allocation of attention in Cowan's (1999) framework (see also Posner 1980). The involuntary allocation of attention is driven by characteristics of the stimuli (their saliency or novelty), a fact that is employed in the signaling principle, which aims at making important aspects of the multimedia presentation particularly salient. It also plays a role in the coherence principle, in which designers are told to avoid seductive details, that is, less important information that involuntarily attracts attention. Attention is further assumed to be allocated voluntarily via the central executive, based on the learners' interests or on the demands of the current task. The split attention principle, for instance, aims at facilitating learners' search for relevant and corresponding information in graphics and text and, thus, their voluntary allocation of attention. Therefore, a theoretical framework that distinguishes between voluntary and involuntary attentional processes is desirable. Such a differentiation is provided by the embedded-processes approach but not by the multicomponent model.

In sum, we agree with Soemer (2015) that the question whether working memory and long-term memory are solely functionally separable or functionally and structurally separable is relevant for theories of working memory. However, we disagree that this question has important implications for theories of multimedia learning. The main point of our article was that the *focus* of the embedded-processes model can be productive for multimedia research in that it provides an integrated account of the cognitive processes that are most relevant for learning with text and pictures (attention and long-term memory) and their interaction. This is not to say that the multicomponent model does not include attention and long-term memory or that it should be rejected. Yet, in our view, a framework such as Cowan's (1999) that unifies different types of attention, working memory, and long-term memory, provides the opportunity to explain the theoretically almost disintegrated effects in an integrally connected way.

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