

The multiple faces of working memory: Storage, processing, supervision, and coordination

Klaus Oberauer*, Heinz-Martin Süß, Oliver Wilhelm, Werner W. Wittman

University of Mannheim, Mannheim, Germany

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Abstract

Working memory capacity was differentiated along functional and content-related facets. Twenty-four tasks were constructed to operationalize the cells of the proposed taxonomy. We tested 133 university students with the new tasks, together with six working memory marker tasks. With structural equation models, three working memory functions could be distinguished: Simultaneous storage and processing, supervision, and coordination of elements into structures. Each function was further subdivided into distinct components of variance. On the content dimension, evidence for a dissociation between verbal–numerical working memory and spatial working memory was comparatively weak.

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1. Introduction

Once there was a short-term store—a system responsible for the memorization of a small number of chunks for the time one needs to walk from the phone book to the telephone. Over the past three decades, this system has evolved into the central stage of higher-order cognition. Now called working memory, it has been associated with an increasing number of basic cognitive functions, up to a point where it sometimes appears as a conceptual ragbag for everything that is needed for successful reasoning, decision making, and action planning.

* Corresponding author. Allgemeine Psychologie I, Universität Potsdam, Postfach 60 15 53, 14415 Potsdam, Germany. Tel.: +49-331-977-2833.

E-mail address: ko@rz.uni-potsdam.de (K. Oberauer).

At the same time, numerous proposals have been made to fractionate working memory, beginning with the three-component model of [Baddeley \(1986\)](#) and [Baddeley and Hitch \(1974\)](#), which continues to be differentiated into smaller units (e.g., the distinction of spatial and visual working memory by [Logie, 1995](#), the fractionation of the central executive discussed in [Baddeley, 1996](#)). On the other hand, some authors conceptualize working memory as a global cognitive resource that establishes a common limiting factor for a large set of different tasks (e.g., [Engle, Kane, & Tuholski, 1999](#); [Just & Carpenter, 1992](#); [Kyllonen & Christal, 1990](#)). Typically, those pointing out fine-grained differentiations base their views on experimental work and on neuropsychological data, while those highlighting the global character of working memory mainly draw on individual difference data.

This situation raises two questions. First, what is a reasonable scope for the concept of working memory—that is, which cognitive functions should be subsumed under it? And second, to what degree is working memory unitary—that is, which level of differentiation is most adequate? We will approach these questions from an individual difference perspective. Our working definition for working memory is of a set of limiting factors for performance in complex cognitive tasks. Looking at correlations between tasks that operationalize different aspects of working memory, we investigate the associations and dissociations between several of those limiting factors. Our guiding hypothesis is that working memory, like intelligence, will ultimately be described on different levels of generality, forming a hierarchy of related constructs.

2. A facet model of working memory

We assume that working memory can be differentiated according to two dimensions or facets in the sense of facet theory ([Canter, 1985](#); [Guttman, 1954](#)), one related to content domains, the other related to cognitive functions. On the content facet, we assume two broad categories: working memory for visuo-spatial material, and working memory for language and numerical material. This hypothesis matches the distinction of two domain-specific slave systems in [Baddeley's \(1986\)](#) model, and it is supported by individual differences research ([Oberauer, Süß, Schulze, Wilhelm, & Wittman, 2000](#); [Shah & Miyake, 1996](#)) as well as brain imaging data (e.g., [Smith & Jonides, 1997](#)). On the functional facet, we distinguish three categories that together cover most of the functions attributed to working memory in the literature: simultaneous storage and processing, supervision, and coordination. Since the three functional categories are not so well established, we discuss them in more detail below.

Until recently, *simultaneous storage and processing* was the leading definition of working memory as a whole (e.g., [Kyllonen and Christal, 1990](#), [Salthouse, 1991](#)). The concept of simultaneous storage and processing derives from the former notion of a short-term store. [Daneman and Carpenter \(1980\)](#) proposed to distinguish working memory from short-term memory by the addition of a processing component: Short-term memory only keeps information, working memory processes it. In order to make this differentiation meaningful, we have to adopt a narrow definition of the term *processing*, one that does not include, for example, rehearsal and grouping of items, because these processes are also involved in simple short-term

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