



## Distinct transfer effects of training different facets of working memory capacity

Claudia C. von Bastian<sup>a,b,\*</sup>, Klaus Oberauer<sup>a</sup>

<sup>a</sup> Department of Psychology, University of Zurich, Switzerland

<sup>b</sup> Faculty of Psychology, Distance Learning University Switzerland, Switzerland

### ARTICLE INFO

#### Article history:

Received 11 June 2012

revision received 31 January 2013

Available online 19 March 2013

#### Keywords:

Cognitive training

Mixed-effects modeling

Transfer

Working memory capacity

### ABSTRACT

The impact of working memory training on a broad set of transfer tasks was examined. Each of three groups of participants trained one specific functional category of working memory capacity: storage and processing, relational integration, and supervision. A battery comprising tests to measure working memory, task shifting, inhibition, and reasoning was administered before, immediately after, and 6 months after 4 weeks of computer-based training. Training groups were compared to an active control group practicing perceptual matching tasks. Data were analyzed with linear mixed-effects models that revealed distinct transfer profiles for the experimental groups: Storage-Processing training had an effect on working memory and reasoning, and Supervision training improved task shifting and reasoning. There was no such broad transfer of Relational Integration training. The degree of improvement in the training tasks correlated positively with the magnitude of transfer. Differential effects of training different functional categories of working memory and executive functions could explain why previous studies yielded mixed results: Training specific processes leads to transfer on specific cognitive constructs only.

© 2013 Elsevier Inc. All rights reserved.

### Introduction

**Distinct Transfer Effects of Training Different Facets of Working Memory Capacity** Working memory is a cognitive system providing temporary access to representations needed for complex cognition. The purpose of the present work is to investigate whether working memory capacity (WMC) can be improved by training. Our study builds on a model of the factorial structure of working-memory capacity, the facet model (Oberauer, Süß, Schulze, Wilhelm, & Wittmann, 2000; Oberauer, Süß, Wilhelm, & Wittmann, 2003; Süß, Oberauer, Wittmann, Wilhelm, & Schulze, 2002).

According to the facet model, WMC can be classified into three functional categories: simultaneous storage and processing, relational integration, and supervision. Storage and processing comprises the simultaneous main-

tenance and manipulation of information. Relational integration involves the coordination of information elements into new structures. The third functional category, supervision, refers to the selective activation of relevant information and inhibition of irrelevant information. In studies of the facet model of working memory (Oberauer et al., 2000, 2003), the concept of supervision has so far been measured through the efficiency of task switching, which is largely equivalent to the concept of shifting in Miyake et al.'s model of executive functions (2000). Miyake et al. (2000) distinguish shifting, inhibition, and working-memory updating as three lower-level factors of executive functions. Factor-analytic studies have shown that the constructs storage and processing and relational integration are closely correlated, and both are more weakly related to supervision (Buehner, Krumm, & Pick, 2005; Oberauer et al., 2003). Therefore, here we regard WMC (constituted by storage and processing and relational integration) and supervision (or shifting in the context of executive functions) as two related but distinct high-level constructs.

\* Corresponding author. Address: Department of Psychology, Binzmühlestasse 14/22, CH-8050 Zurich, Switzerland. Fax: +41 44 635 74 79.

E-mail address: [c.vonbastian@psychologie.uzh.ch](mailto:c.vonbastian@psychologie.uzh.ch) (C.C. von Bastian).

WMC is assumed to be a largely stable trait, which predicts other cognitive abilities such as fluid intelligence and reasoning (Conway, Kane, & Engle, 2003; Engle, Kane, & Tuholsky, 1999; Kyllonen & Christal, 1990; Oberauer, Süß, Wilhelm, & Wittmann, 2008; Süß et al., 2002). There is also a considerable number of published studies linking impairments of WMC to a wide range of neurological disorders, such as attention-deficit hyperactivity disorder (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005). Likewise, there is evidence that individual differences in supervision abilities (i.e., executive functions) are highly stable, and impact everyday behavior (Friedman et al., 2007; Mischel et al., 2011). Hence, it is an important question whether WMC and supervision can be improved by training, and whether this improvement affects related cognitive abilities.

Previous research findings concerning training and transfer effects of WMC are inconsistent if not contradictory. Several recent studies indicate that adequate training can lead to an increase in WMC test performance and also to transfer to the performance in non-trained cognitive tasks (for a review see Klingberg, 2010). For example, Chein and Morrison (2010) examined the effectiveness of storage and processing training, operationalized by a complex span task. They found a generalization of the training effect to reading comprehension and inhibition in a subgroup of successfully trained participants. There is even evidence that fluid intelligence can be increased by computer-based training of WMC (for a review see Buschkuhl & Jaeggi, 2010; see also Borella, Carretti, Riboldi, & De Beni, 2010; Jaeggi, Buschkuhl, Jonides, & Perrig, 2008; Jaeggi et al., 2010; Karbach & Kray, 2009; Klingberg et al., 2005; Schmiedek, Lövdén, & Lindenberger, 2010). The work of Colom et al. (2010) suggests that such increases in intelligence are not only due to retest effects, since they found that retest gains in WMC tasks were not related to increases in intelligence test scores.

However, other studies do not reveal such convincing training and transfer effects. For example, Holmes, Gathercole, and Dunning (2009) found no transfer of working-memory training to fluid intelligence, although these authors used the same training paradigm and a sample comparable to Klingberg et al. (2005). Moreover, Owen et al. (2010) recently showed that an online cognitive training that led to large practice effects on the trained tasks induced no measurable generalization to other cognitive tasks. Contradictory results are also present in training studies focusing explicitly on executive processes. On the one hand, there are several studies supporting plasticity of executive processes (Dahlin, Nyberg, Bäckman, & Stigsdotter Neely, 2008; Karbach & Kray, 2009; Li et al., 2008). On the other hand, one study found no transfer of inhibition training for preschool children to cognitive control (Thorell, Lindqvist, Bergman, Bohlin, & Klingberg, 2008).

There are multiple possible reasons for the inconsistency in previous findings (cf. Conway & Getz, 2010; Moody, 2009; Shipstead, Redick, & Engle, 2012). First, it is problematic that many training regimens lack underlying theoretical models. Hence, it often remains unclear which cognitive processes, broadly defined as “inhibition” or “working memory”, were actually trained.

Second, previous studies vary widely regarding general training conditions such as intensity and number of training sessions. For example, in Owen et al.’s (2010) paradigm, training sessions were very short (only 10 min a day) and the number of completed sessions varied between participants from 2 to 188, whereas others who found transfer effects controlled very carefully how much training participants went through, showing increased transfer with larger amounts of training (Jaeggi et al., 2008). Moreover, it is important to control the quality of training and the commitment of participants. A plausible reason for the absence of transfer effects in the study by Owen et al. (2010) is the uncontrolled and anonymous setting of the training regimen. For instance, Smith et al. (2009) showed that in a more controlled setting, with face-to-face contact at pre and post training assessment, self-administered training interventions at home resulted in transfer effects.

Third, only few studies include an active control group that completes an alternative intervention. Implementing an active control group differentiates training and transfer effects not only from repetition effects (as a passive or waiting control group would do), but also from intervention effects (e.g., effects of sticking to a regular training schedule), and expectancy effects influencing cognitive performance (Oken et al., 2008). For the latter purpose it is important that the alternative training is perceived by participants as a potentially effective cognitive training. The importance of including an active rather than a passive control group was recently demonstrated by Redick et al.’s (in press) failure to replicate the findings of Jaeggi et al. (2008, 2010) when evaluating transfer effects in comparison to an active control group.

With the present study, we wanted to answer the following questions: (1) can WMC (with its two aspects, storage and processing, and relational integration) and supervision be improved by extensive training, (2) do training effects transfer to non-trained tasks measuring the same construct, and (3) does transfer to related cognitive abilities – such as inhibition and reasoning – occur?

In our study, we aimed to avoid the possible weaknesses occasionally observed in previous research. Therefore, our study was designed to meet the following four requirements. First, the choice of training tasks should be based on a theoretical model. Our training was based on the facet model of WMC (Oberauer et al., 2003), thus, we chose training tasks which are assumed to measure a particular functional category in that model (i.e., storage and processing, relational integration, and supervision). To distinguish training effects between the functional categories, each of three groups trained only one function.

Second, transfer should be measured by a broad test battery in order to reveal a fine-grained picture of transfer effects (Li et al., 2008; Shipstead, Redick, & Engle, 2010). It should consist of tests covering a broad range of transfer distances. Our test battery comprised several tasks measuring the same constructs as the trained tasks (i.e., the WMC-constructs storage and processing and relational integration, and the supervision construct of shifting), together with tasks measuring related constructs that were not trained but are assumed to correlate with the trained

متن کامل مقاله

دریافت فوری ←

**ISI**Articles

مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات