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Working memory tasks train working memory but not reasoning: A material- and operation-specific investigation of transfer from working memory practice

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ABSTRACT

A sample of $N = 216$ university students was divided into six experimental groups and an active control group. Three experimental groups were trained on the working memory operations *Storage and Processing* and three groups on *Relational Integration*, both derived from Oberauer, Süß, Wilhelm, and Weittman's (2003) model. The training material was divided into verbal, numerical, and figural content, resulting in six groups trained on one type of material within one of the two operations. Transfer was observed between verbal and numerical working memory material within the same operation, yet no transfer showed for figural material. Also, no transfer was observed between the two working memory operations. In addition, working memory training had no effect on performance in verbal, numerical, and figural reasoning tasks, regardless of the trained material or operation.

1. Introduction

1.1. Cognitive training

Increasing cognitive performance has been the goal of a plethora of studies throughout the last century and drug- (e.g., Kimberg, D'Esposito, & Farah, 1997) as well as training-related approaches (see Morrison & Chein, 2011, for an overview) have shown encouraging results; even changes in neural activity after training with cognitive tasks could be detected (Olesen, Westerberg, & Klingberg, 2004). Working memory, in particular, has been the subject of various training studies, which is not surprising: working memory performance has been related to – inter alia– mathematical ability WM (Gathercole, Pickering, Knight, & Stegmann, 2004), reading comprehension (see Carretti, Borella, Cornoldi, & De Beni, 2009), and even decisions under stress, such as police shooting behavior (Kleider, Parrott, & King, 2010). As a result, working memory training programs, such as Cogmed, (see Roche & Johnson, 2014, for a review), have gained remarkable popularity. The idea of these programs is to improve is basic cognitive skills cognitive skills, such as working memory (Andersson, 2010), and – if possible – other cognitive functions in the process.

An enormous amount of different paradigms has been applied for cognitive training in order to distinguish training-related gains in performance that are due to familiarization with the trained material from actual enhancement of a trained skill, which would transfer to non-trained material or even different cognitive skills (see Owen et al., 2010). In this flourishing field of research, the most heatedly debated topic is the extent to which the training transfers to different cognitive tasks and – if that – what aspects of the training and the trained material are responsible for it. A meta-analysis by Schwaighofer, Fischer, and Bühner (2015) suggests that the extent and the durability of training effects for working memory may depend on the training conditions, such as supervision and the duration of the sessions. This may explain why the picture of results in the present literature is rather mixed regarding the effectiveness of training for increasing performance in other cognitive skills. Nevertheless, working memory training has been reported to increase – among various others – performance in executive function tasks (Salminen, Strobach, & Schubert, 2012), episodic memory (Rudebeck, Bor, Ormond, O'Reilly, & Lee, 2012), and academic

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achievement (Titz & Karbach, 2014). Notably, working memory training can also result in decreases in episodic memory. These decreases may be ascribed to worse strategies after working memory training (Matzen et al., 2016). However, especially the possibility of increasing (fluid) reasoning through working memory training has resulted in a large number of primary studies as well as literature reviews and meta-analyses on this topic (see, e.g., Bogg & Lasecki, 2015; von Bastian & Oberauer, 2014; Schwaighofer et al., 2015, for three recent ones).

1.2. Transfer between working memory and reasoning

The reason for the extensive research on the transfer between working memory and reasoning, in particular, is only consequential, as the two skills are closely related constructs: working memory and reasoning are known to be highly related regarding behavioral performance (e.g., Kyllonen & Christal, 1990; Süß, Oberauer, Wittmann, Wilhelm, & Schulze, 2002) and even show a functional overlap in neuroimaging studies (Burgess, Gray, Conway, & Braver, 2011).

The close relationship between reasoning and working memory, naturally, resulted in various studies, analyzing the effect of training in one of the two on performance in the other: Zinke et al. (2014), for example, present encouraging findings with respect to transfer effects of working memory training to fluid intelligence in older adults. Yet, their findings are a based on comparisons between a training group and a passive control group, which received no intervention. Training and passive group may differ on several variables such as amount of computer contact, expectancy effects and motivation (Redick, Shipstead, Wiemers, Melby-Lervåg, & Hulme, 2015). These variables may influence observed differences between trained and control groups. Therefore, causal interpretations regarding the effectiveness of working memory trainings are not permissible. In addition Zinke et al. used only one task to measure transfer of working memory training to reasoning. Thus, only one aspect of the construct is captured and other methodological concerns are not ruled out (Shipstead, Redick, & Engle, 2012). Jaeggi, Buschkuehl, Jonides, and Perrig (2008) used an adaptive working memory training task to increase working memory performance and reported transfer to reasoning performance. The study, however, evoked criticism due to the tasks used for the assessment of reasoning (see Moody, 2009; Shipstead et al., 2012). Apart from the study by Jaeggi et al., many other investigations on transfer effects from working memory training, assessed reasoning using single measures with figural material (see Schwaighofer et al., 2015) and, thus, task specific influences on transfer effects cannot be ruled out. The same holds for various other investigations that reported evidence from working memory training to reasoning, some for children (Alloway, 2012) or elderly participants (Zinke et al., 2014), but were criticized due to several statistical and methodological issues (see Redick et al., 2012a; Redick, Unsworth, Kelly, & Engle, 2012b; Redick et al., 2015). In a recent meta-analysis, Melby-Lervåg, Redick, and Hulme (2016) found that improvements in working memory are not related to improvements to reasoning. The authors note that repeatedly practicing a working memory task may not be sufficient to improve all processes shared by working memory and reasoning. Training-related improvements in working memory may just reflect stimulus-specific overlap between trained and transfer tasks or the development of task-specific strategies (e.g., Dunning & Holmes, 2014; Harrison et al., 2013). Hence, working memory training may even not genuinely improve working memory capacity (Melby-Lervåg et al., 2016).

Taken together, it remains unclear which aspects of working memory training are responsible for possible transfer between working memory and reasoning and to which degree the different functions of working memory or the task material are responsible for observed transfer effects. In particular, no study has thus far systematically analyzed the influence of training of different working memory operations in combination with varying stimulus material (in terms of verbal, numerical, or figural stimuli). The same holds for the stimulus material in post-training reasoning tests, which – as noted before – mostly comprised only single measures and consequently one type of stimulus material.

1.3. Facets of working memory

Unlike the blurry picture regarding transfer from working memory training to reasoning, transfer between different aspects of working memory has gathered far more support (see Shinaver, Entwistle, & Söderqvist, 2014, for an overview). One reason may be the extensive use of the term working memory, which has led to the inclusion of various functions and content domains in the concept (see Oberauer, Süß, Schulze, Wilhelm, & Wittmann, 2000). Consequently, various models have been developed to describe the construct of working memory (see e.g., Miyake & Shah, 1999), including different aspects of attention, cognitive control, and other constructs, based on evenly different operationalizations through cognitive tasks.

To obtain a structured view of the concept of working memory, Oberauer et al. (2000), developed a facet model from 23 tasks, sampled from the literature. The so derived model of working memory distinguishes between the two facets of the working memory construct, namely operations and materials (function and content), each divided into subcategories. The model was later refined (Oberauer, Süß, Wilhelm, & Wittman, 2003) to comprise verbal-numerical and figural material on the content facet and the operations storage and processing, coordination of elements into structures (relational integration), fast processing of information, and supervision of cognitive operations. Oberauer et al. defined the first two as the main operations of working memory and the latter two as only loosely related to the first two primary operations. A few studies investigated transfer effects of training different or all facets of working memory from the model by Oberauer et al. (2003). Von Bastian and Oberauer (2013) had three groups each training only one facet (storage and processing, relational integration, or supervision) but with different materials. Storage and processing training showed a marginally significant transfer effect to working memory capacity and a significant transfer effect to reasoning. Supervision training resulted in transfer to task switching and reasoning. von Bastian and Oberauer (2013) had younger and older adults practicing all three facets of working memory with only one task per facet (i.e., not distinguishing among different content or material). The authors found improvements in working memory for both age groups but no transfer to reasoning.

1.4. Rationale

Most training studies did not distinguish between the stimulus materials used for the training, which may well be a fundamental factor for observed transfer (von Bastian & Oberauer, 2013, trained different working memory operations with verbal, numerical, and figural material, yet did not use separate training groups for different materials and did not distinguish between the trained material in their analysis. Also, they did not distinguish between varying stimulus materials in the reasoning tests). The present investigation therefore aims at analyzing the influence of training two different working memory operations (storage and processing and relational integration within the framework of Oberauer et al., 2003) with three different materials (verbal, numerical, and figural), resulting in a 2×3 matrix comprising all six possible combinations, on the performance in the same six working memory tasks after training.

In addition, possible transfer from working memory training to gains in reasoning performance is investigated. However, in order to more specifically investigate the role of the task material, reasoning is also tested with tasks comprising the same three types of material used for working memory training (i.e. verbal, numerical, and figural). The present study is therefore the first to systematically investigate the influence of operations and material with respect to all possible combinations of

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