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How a high working memory capacity can increase proactive interference

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ABSTRACT

Previous findings suggested that a high working memory capacity (WMC) is potentially associated with a higher susceptibility to proactive interference (PI) if the latter is measured under high cognitive load. To explain such a finding, we propose to consider susceptibility to PI as a net effect of individual executive processes and the intrinsic potential for PI. With the latter, we refer to the amount of information that is activated at a given time and that has the potential to exert PI subsequently. In two studies deploying generalized linear mixed models, susceptibility to PI was modeled as the decline of performance over trials of a complex span task. The results revealed that a higher WMC was associated with a higher susceptibility to PI. Moreover, the number of stimuli recalled in one trial as a proxy variable for the intrinsic potential for PI negatively affected memory performance in the subsequent trial.

1. Introduction

Proactive interference (PI) – the detrimental effect of information that was previously learned but has since become irrelevant – has been considered a major cause of forgetting (e.g., Underwood, 1957; Wixted & Rohrer, 1993). One common operationalization of PI is the decline of memory performance over two or more trials of a memory task, where several studies showed that individuals differ systematically in the extent of this decline (e.g., Friedman & Miyake, 2004b; Kane & Engle, 2000; May & Hasher, 1998). Different labels have been used for the respective inter-individually varying variable: resistance to PI (e.g., Friedman & Miyake, 2004b), and proneness or susceptibility to PI (e.g., Kane & Engle, 2000). In addition, these labels have been used with different theoretical connotations. Whereas Friedman and Miyake (2004b) used resistance to PI to denote a cognitive control function, Kane and Engle (2000) used susceptibility to PI more descriptively as a phenomenon the underlying mechanisms of which are yet to be explained. In the following, the term susceptibility to PI is used to draw on the interpretation of Kane and Engle (2000).

Individual differences in susceptibility to PI have been ascribed to individual differences in working memory capacity (WMC) in several theoretical frameworks (e.g., Braver, Gray, & Burgess, 2008; Hasher, Lustig, & Zacks, 2008; Kane & Engle, 2000; Lustig, May, & Hasher, 2001; Unsworth & Engle, 2007) sharing the common notion of working memory as "the ability to keep important information in mind while comprehending, thinking, and doing" (Conway, Jarrold, Kane, Miyake, & Towse, 2008, p. vii). This ability is closely related to cognitive control processes; in fact, in some theoretical accounts of working memory, individual differences in WMC are actually equated with individual differences in cognitive

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control – or executive – processes (cf. Kane et al., 2004, p. 190). Thus, when susceptibility to PI is related to WMC, one is usually referring to individual differences in the executive part of working memory.

Several previous studies reported a negative relation between indicators of WMC and susceptibility to PI, indicating that an increase in WMC is accompanied by a reduction in susceptibility to PI (e.g., Friedman & Miyake, 2004b; Kane & Engle, 2000; May, Hasher, & Kane, 1999). However, there are also some findings suggesting that in some situations, high WMC individuals are equally or even more susceptible to PI than low WMC individuals (Kaller et al., 2014; Kane & Engle, 2000). Thus, the relation between WMC and susceptibility to PI seems to be more complex than "the larger WMC, the lower susceptibility to PI".

1.1. The Relation between susceptibility to PI in working memory and WMC

In the present studies, we investigated susceptibility to PI in working memory, where susceptibility to PI is modeled as the decline of working memory performance over a sequence of trials of a complex span task. Complex span tasks are classical indicators of WMC (e.g., Conway et al., 2005; Oberauer, Lewandowsky, Farrell, Jarrold, & Greaves, 2012), in which a storage part (e.g., remembering a sequence of words) alternates with a processing part (e.g., solving arithmetic operations). It has been argued that complex span tasks are a closer approximation to everyday memory requirements than tasks without a processing part (i.e., simple span tasks; Friedman & Miyake, 2004a). Hence, it seems reasonable to model susceptibility to PI using these tasks in order to better approximate susceptibility to PI under everyday memory requirements.

Contrary to the majority of studies, we hypothesize that if susceptibility to PI is assessed over a sequence of trials of a complex span task, high WMC individuals are equally or even more susceptible to PI than low WMC individuals.

The reason for this deviating expectation are the results from Kane and Engle (2000): In their experiments, participants were screened for their scores in a complex span task, and those scoring in the top quartile ("high-span group") were compared to those scoring in the bottom quartile ("low-span group") with respect to their susceptibility to PI. The latter was assessed using three consecutive trials of a simple span task. This PI task was either completed under no or minimal cognitive load (imposed by a simple finger tapping task), or under high cognitive load (imposed by a complex finger tapping task) during encoding, retrieval, or both. The main results revealed that if no or minimal cognitive load was imposed, the high-span group was less susceptible to PI than the low-span group. If a high cognitive load was imposed during encoding, retrieval, or both, the high-span and the low-span group did no longer differ regarding their susceptibility to PI.

For predicting the relation between WMC and susceptibility to PI in working memory as assessed by complex span tasks, the results obtained by Kane and Engle (2000) under high cognitive load during encoding are most revealing. This is because in complex span tasks, the presentation of the to-be-remembered stimuli alternates with a processing part, while no additional cognitive load is imposed during recall. Thus, to-be-remembered stimuli have to be encoded and maintained under (conditions of) interference from the processing part, which is most similar to the condition in Kane and Engle (2000) in which a simple span task was completed under high cognitive load during encoding. Thus, the main results from Kane and Engle (2000) suggest that high and low WMC individuals do not differ in their susceptibility to PI if susceptibility to PI is assessed using a sequence of trials of a complex span task.

Kane and Engle (2000) proposed the following general account for their results: Under no cognitive load, high-span individuals were able to engage executive processes (controlled attention) to counteract PI, whereas low-span individuals were not. Therefore, increasing cognitive load resulted in an increase of susceptibility to PI in the high-span group, whereas the low-span group, who were not assumed to have been using executive processes to counteract PI anyway, was unaffected. In fact, Kane and Engle (2000) assumed that under high cognitive load, the capability to engage executive processes in counteracting PI was leveled between the low and high-span groups.

From our point of view, there are three potential shortcomings of the account of Kane and Engle (2000). First, they assume that low-spans were unable to engage executive processes to counteract PI even under no or low cognitive load. Given that their sample consisted of university students, this seems to be a very strong assumption. The authors themselves qualified this assumption by making recourse to the specificities of their materials. Second, Kane and Engle (2000) assumed that a high cognitive load leveled the low and high-spans' ability to engage executive processes in counteracting PI. However, it remains unclear why a high cognitive load should specifically affect these executive processes while leaving others unaffected. For example, the high-span group outperformed the low-span group under high load in the first trial, indicating that high-spans and low-spans were not equal with regard to their ability to engage executive processes to counteract interference from a concurrent task. Third, the account offered by Kane and Engle (2000) cannot explain the results of their additional analyses: The results reported above were based on proportional PI effects, whereby the number of words in the second (or third, resp.) trial was subtracted from the number of words in the first trial and divided by the number of words in the first trial. If, however, data from the experiments were collapsed and analyses were based on raw recall data instead of proportional PI effects, the high-span group would tend to be more susceptible to PI than the low-span group under high cognitive load. Although this effect was only marginally significant, we attach value to it because it was potentially underestimated: Working memory performance was operationalized by a sequence of consecutive trials of a complex span task, which by now is known to be highly sensitive to the build-up of PI (e.g., Bunting, 2006; May et al., 1999). Thus, individuals scoring high in the complex span task did so at least in part because they were less susceptible to PI than individuals scoring low in the complex span task. Accordingly, there might have been a spurious negative correlation between the indicator of