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Multiple priming instances increase the impact of practice-based but not verbal code-based stimulus-response associations☆

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ABSTRACT

Stimulus-response (S-R) associations, the basis of learning and behavioral automaticity, are formed by the (repeated) co-occurrence of stimuli and responses and render stimuli able to automatically trigger associated responses. The strength and behavioral impact of these S-R associations increases with the number of priming instances (i.e., practice). Here we investigated whether multiple priming instances of a special form of instruction, verbal coding, also lead to the formation of stronger S-R associations in comparison to a single instance of priming. Participants either actively classified stimuli or passively attended to verbal codes denoting responses once or four times before S-R associations were probed. We found that whereas S-R associations formed on the basis of active task execution (i.e., practice) were strengthened by multiple priming instances, S-R associations formed on the basis of verbal codes (i.e., instruction) did not benefit from additional priming instances. These findings indicate difference in the mechanisms underlying the encoding and/or retrieval of previously executed and verbally coded S-R associations.

1. Introduction

"What we learn to do, we learn by doing". This quote attributed to Thomas Jefferson exemplifies the notion that own action is necessary to learn. For a long time, psychologists have prevalently suggested that stimulus-response (S-R) associations, the basis of learning and behavioral automaticity, are formed by own action (i.e., practice). Repeated co-occurrence of stimuli and responses allows stimulus and response representations to bind together into S-R associations. These S-R associations subsequently render stimuli able to automatically trigger the retrieval of associated responses (e.g., Henson, Eckstein, Waszak, Frings, & Horner, 2014; Hommel, 1998; Logan, 1988, 1990). This automatic retrieval can even lead to erroneous responses when the currently required response does not match the response stored in the S-R association (e.g., Horner & Henson, 2011, 2012).

The formation and automatic retrieval of S-R associations can be inferred from repetition priming effects. That is, participants are faster to classify stimuli when repeatedly performing the same response rather than different responses upon them (e.g., Henson et al., 2014; Logan, 1990). Although a single priming instance is sufficient for automatic S-R associations to emerge (e.g., Horner & Henson, 2009; Hsu & Waszak, 2012; Moutsopoulou, Yang, Desantis, & Waszak, 2015; Waszak, 2010; Waszak, Hommel, & Allport, 2003), the behavioral impact of S-R associations typically increases with the number of priming instances (e.g., Horner & Henson, 2009; Logan, 1990; Moutsopoulou et al., 2015). For instance, Horner and Henson (2009) had their participants classify various everyday objects according to their size relative to a reference object. Participants either classified objects once or thrice with the same S-R mapping before the resulting S-R associations were probed. During probe trials, the size referent could either remain the same, so that participants still had to perform the same responses as during primes, or the size referent and with it the required response for a stimulus could switch. Analyzing probe trial performance, Horner and Henson (2009) found that repetition priming effects – that is, differences in the reaction times (RTs) and/or error rates (PEs; percentages of error) between item-specific response repetitions and response switches – were more pronounced when stimuli had been primed multiple times. That is, the more often participants had practiced responses, the stronger the behavioral impact of the resulting S-R associations was.

According to instance theory (e.g., Logan, 1990), repetition priming effects emerge as S-R instances, formed by previous pairings of stimuli and responses, race against an algorithmic process that computes

☆ The data of the reported experiments as well as experiment files and syntaxes are available via the Open Science Framework: https://osf.io/w548e/; DOI: 10.17605/OSF.IO/W548E.

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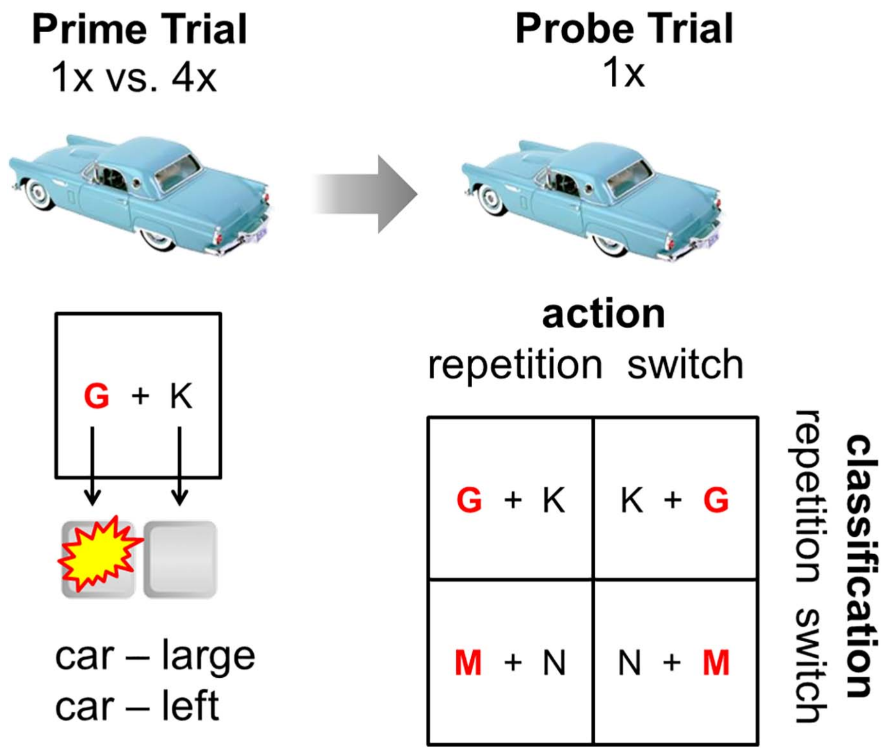

Fig. 1. Schematic overview of the item-specific repetitions/switches in S-A and S-C mapping (i.e., action and classification mapping) between the prime instance(s) of a stimulus and its probe instance as indicated by the task cues (size task: "K + G" and "G + K" – K = "klein"/small, G = "groß"/large; mechanism task: "M + N" and "N + M" – M = "mechanisch"/mechanic, N = "nicht-mechanisch"/non-mechanic). S-A and S-C repeated across prime instances, but varied orthogonally between the item-specific prime instance(s) and probe instance. Each combination of classification and action mapping occurred equally frequently for the two prime types (executed and verbally coded) and the two numbers of prime instances (1 vs. 4). Correct classifications are marked as red and bold. Correct actions are indicated by the spatial position of the letter corresponding to the correct classification. Adapted from Pfeuffer, Moutsopoulou et al. (2017).

responses anew. When the currently required response matches the response stored in the S-R instance, reactions are faster on those trials on which instance retrieval wins the race. Thus, on average reactions are faster when S-R mappings repeat rather than switch. Instance theory explains the increased impact of prior S-R mappings with more priming instances (i.e., the increased performance differences between response repetitions and response switches) by suggesting that separate instances are created each time a stimulus and a response are paired. The more identical instances are generated, the more often instance retrieval wins the race and the larger the performance benefit of response repetitions is in comparison to response switches.

A pattern of results similar to that observed by Horner and Henson (2009) emerged when both the classification task participants were to perform upon stimuli and participants´ action could independently repeat or switch between the prime instance(s) of a stimulus and its probe instances (Moutsopoulou et al., 2015; see also Fig. 1). Participants were to classify everyday objects either according to their size in relation to a reference box or according to whether they were mechanic or not by pressing a left or right key. Moutsopoulou et al. (2015) used task cues (e.g., "S + L" for "small vs. large") to indicate both the classification task participants should perform on a subsequent stimulus as well as the classification-action mapping of a trial. Stimuli were primed with the same classification-action mapping either once or four times before they were probed (see Fig. 2, upper panel). Both switches in action mapping and switches in classification mapping (i.e., switches between classification tasks) between the prime instance(s) and probe instance of a specific stimulus led to longer RTs and increased error rates in comparison to repetitions of the respective mappings. Importantly, however, performance differences between repetitions and switches were more pronounced when stimuli had been primed multiple times. As the behavioral effects of switches in stimulus-action mapping and stimulus-classification mapping did not interact, Moutsopoulou et al. (2015) concluded that S-R associations consist of two distinct components, Stimulus-Action (S-A) and Stimulus-Classification (S-C) associations, that can each be strengthened by multiple priming instances (see also Koch & Allport, 2006, for evidence of stimulus-task or S-C associations in task switching).[1])

This interpretation is in line with the idea of an associative mechanism (see also Horner & Henson, 2009). Rather than creating several identical S-R instances, having participants repeatedly respond to stimuli with the same S-R mapping may also strengthen the initially formed S-R association and thus yield a stronger influence on performance. Regardless of whether practice benefits are explained by a race of an automatic instance retrieval against an algorithmic processing route or by an associative mechanism, theories agreed that S-R associations are formed by active task execution (i.e., practice).

Yet, in recent years the notion that S-R associations, and with them behavioral automaticity, can only be achieved through own action has been questioned. Various authors suggested that not only own action, but also mere instruction may bind stimuli and responses together (e.g., Brass, Wenke, Spengler, & Waszak, 2009; Cohen-Kdoshay & Meiran, 2007, 2009; Meiran, Kessler, Cole, & Braver, 2015; Liefooghe, Wenke, & De Houwer, 2012; Waszak, Wenke, & Brass, 2008; Wenke, De Houwer, De Winne, & Liefooghe, 2015; Wenke & Frensch, 2005; Wenke, Gaschler, & Nattkemper, 2007; Waszak, Pfister, & Kiesel,

[1] Prior research on S-R associations (e.g., Allenmark, Moutsopoulou, & Waszak, 2015; Horner & Henson, 2009, 2011; Moutsopoulou et al., 2015) has consistently regarded S-A and S-C associations (or their equivalents) as sub-components of a generic concept of S-R associations. This terminology was originally introduced, as many preceding (and also later) studies that used the term S-R associations did not differentiate S-A and S-C associations and it is therefore in some cases not possible to infer, whether S-A and/or S-C associations were assessed in these studies. We will therefore speak of S-A and S-C associations when refering to our work and speak of S-R associations when discussing other studies that did not differentiate between the S-A and S-C component.