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Contingency learning is not affected by conflict experience: Evidence from a task conflict-free, item-specific Stroop paradigm

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ABSTRACT

A contingency learning account of the item-specific proportion congruent effect has been described as an associative stimulus–response learning process that has nothing to do with controlling the Stroop conflict. As supportive evidence, contingency learning has been demonstrated with *response conflict*-free stimuli, such as neutral words. However, what gives rise to response conflict and to Stroop interference in general is *task conflict*. The present study investigated whether task conflict can constitute a trigger or, alternatively, a booster to the contingency learning process. This was done by employing a "task conflict-free" condition (i.e., geometric shapes) and comparing it with a "task conflict" condition (i.e., neutral words). The results showed a significant contingency learning effect in both conditions, refuting the possibility that contingency learning is triggered by the presence of a task conflict. Contingency learning was also not enhanced by the task conflict experience, indicating its complete insensitivity to Stroop conflict(s). Thus, the results showed no evidence that performance optimization as a result of contingency learning is greater under conflict, implying that contingency learning is not recruited to assist the control system to overcome conflict.

1. Introduction

Reading is an acquired human ability to decode and interpret visual lexical symbols. In adults, this ability is known to be automatic, that is, it occurs whenever a lexical stimulus is encountered. The most dramatic demonstration of the automaticity of the reading process is an *interference effect* obtained in the Stroop task (Stroop, 1935). In this task, participants have to name the color of visually presented words (e.g., blue for the stimulus RED presented in blue ink) while ignoring their meaning (e.g., the word RED). There is no need to read the words to accomplish the task and yet reading occurs, as evidenced by slower response times for incongruent stimuli (e.g., RED in blue ink) than for neutral letter strings (e.g., XXXX in blue ink). The fact that reading takes place in spite of the fact that it is not required, and even interferes with performance, demonstrates its automaticity (Perlman & Tzelgov, 2006).

The interference, or conflict, produced by the automatic performance of the irrelevant reading task has been shown to be a target of cognitive control. That is, when a conflict becomes too strong, cognitive control is able to reduce it. Much evidence for that ability of the cognitive system came from a bulk of studies that manipulated the proportion of congruent vs. incongruent stimuli to control the Stroop effect (e.g. Logan, 1985; Logan & Zbrodoff, 1979). The main finding of these studies, or what is known as the "list-wide proportion-congruent effect", was that the magnitude of the observed interference effect was smaller when the experienced conflict was too strong (i.e., large proportion of incongruent trials in the list).

Several models have been proposed to explain the mechanism by which conflict is reduced in the Stroop task (a conflict-monitoring framework; Blais, Robidoux, Risko, & Besner, 2007; Botvinick, Braver, Barch, Carter, & Cohen, 2001; Botvinick, Cohen, & Carter, 2004; De Pisapia & Braver, 2006). According to Botvinick et al.'s (2001); Botvinick et al.'s (2004) conflict-monitoring architecture, increasing the proportion of incongruent trials raises the amount of (response) conflict (i.e., stronger competition between the response activated by the color-naming process and the irrelevant response activated by reading). The elevation in conflict is detected by the conflict-monitoring unit, which in turn signals units responsible for control exertion. The control is achieved through focusing attention on the relevant task. This way the irrelevant reading task does not get much attention and the conflict it produces is considerably reduced.

It has also been proposed that the control system is not just able to reduce the conflict accumulated at the list level, but is also flexible enough to reduce the conflict produced by specific items in the list (Bugg, Jacoby, & Chanani, 2011; Bugg, Jacoby, & Toth, 2008; see also Blais et al., 2007). The "item-specific proportion-congruent" effect (Jacoby, Lindsay, & Hessels, 2003; Jacoby, McElree, & Trainham, 1999) demonstrates that when the proportion of incongruent stimuli is

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manipulated at the level of specific words, the words mostly presented as incongruent stimuli tend to produce less interference than those mostly presented as congruent stimuli.

1.1. Cognitive control, learning and what is in between

The process of cognitive control is assumed to proceed in a way that can be described as "automatic", that is, without assuming any hidden agency deciding when, where and how to intervene. As such, for the last couple of decades there has been some tension in this research field to differentiate between the "automatic control" and simple learning mechanisms, or to define how much the former may be relying on the latter.

According to the proposal of Verguts and Notebaert (2008, 2009), a simple learning process may be in fact "in service of control". Specifically, their proposal holds that the goal of control (i.e., conflict reduction) can be achieved through associative (Hebbian) learning that binds together all currently active (i.e., task-relevant) representations. That is, according to this account the control is actually based on a learning process. It is important for the present discussion to note that except for extending the general conflict-monitoring theory (Botvinick et al., 2001, 2004) by explaining how the system knows "where" to intervene, it shares most of its other features. Thus, when the conflict is sufficiently reduced, less learning occurs, which means learning in this situation is dependent on and guided by the magnitude of the experienced conflict.

In contrast, there are suggestions that learning does not represent a mechanism "in-service-of control", but separate cognitive phenomena that sometimes might "mimic" the effects of control. That is, learning is assumed to produce an independent (confounding) effect on reaction time (RT) that happens to look like the effect of conflict reduction attributed to cognitive control. In the context of the Stroop task, Schmidt, Crump, Cheesman, and Besner (2007) proposed that the item-specific proportion-congruent effect might be driven by such learning that has nothing to do with (controlling the) conflict. This *contingency learning* account of the item-specific proportion-congruent effect is based on the fact that in the original study of Jacoby et al.'s (2003), as well as in the recent replications (Hazeltine & Mordkoff, 2014), faster responses were also observed for congruent items in a mostly congruent condition, as compared to the condition where the probability of an item appearing in a congruent or incongruent color was equal.[1] This result cannot be accounted for by assuming the intervention of cognitive control, since congruent items do not produce response conflict, and therefore are not able to engage control (see also Levin & Tzelgov, 2014). According to the *contingency learning* account (Schmidt, 2013a, 2013b; Schmidt & Besner, 2008; Schmidt et al., 2007; for contrasting views see Bugg & Hutchison, 2013; Bugg et al., 2011; Hutchison, 2011; see also Abrahamse, Duthoo, Notebaert, & Risko, 2013; Atalay & Misirlisoy, 2012; Bugg, 2014), the item-specific proportion-congruent effect is better described as a speeding-up observed for the words frequently appearing in a specific (be it congruent or incongruent) color, and is due to the fact that manipulation of proportions at the item level creates contingencies between specific words and responses. These contingencies are learned and subsequently used to predict responses. For example, if RED frequently appears in blue ink, the learned association would be "if the word is RED then push the 'blue' button". Note, in contrast to the learning-based control view (Verguts & Notebaert, 2008, 2009), contingency learning is not assumed to be aided by response conflict, but rather to represent a general ability to bind stimuli and responses on the basis of their existing correlations. The mechanism of contingency learning as implemented in the parallel-episodic processing model (Schmidt, 2013a) has no feature that is able to measure the response conflict, nor has it a property allowing for allocation of attention in an adaptive manner, and yet it successfully simulates the pattern of the item-specific proportion-congruent effect.

However, according to recently reported data, which will be discussed shortly, there might be a third type of control–learning relationship that comes right in between the two aforementioned proposals and which is at the focus of the present study. Recent studies showed that implicit learning processes might not be completely independent of conflict as suggested by Schmidt et al. (2007) for contingency learning. However, the way they depend on conflict does not fit the learning-based control put forward by Verguts and Notebaert (2008, 2009) (i.e., conflict-monitoring framework) either. Deroost, Vandenbossche, Zeischka, Coomans, and Soetens (2012) presented a probabilistic sequence of the colors in the Stroop task, which was implicitly learned by the participants. They found that sequence learning did not help to reduce the conflict (i.e., the Stroop effect). Stroop conflict however, was shown to enhance the expression[2] of learning: the acquired sequence knowledge was used more under conflict (i.e., incongruent) conditions than under conflict-free (i.e., congruent and neutral) conditions. Boosting effects of conflict on implicit learning have also been reported in other studies. Deroost and Soetens (2006) observed a larger sequence learning effect for participants who were trained with incompatible (i.e., conflicting) than compatible stimulus–response mappings. Similarly, Zhao, Ngo, McKendrick, and Turk-Browne (2011) found that engaging in a secondary (i.e., interfering) task during the training phase, as opposed to passive viewing, improved statistical learning. Finally, Vandenbossche, Coomans, Homble, and Deroost (2014) reported a larger sequence learning effect for aged adults under high-interference (i.e., a dual task performed in the same modality) than under low-interference (i.e., a cross-modal dual task) training condition.

To summarize, the implicit sequence learning was not found "to serve control" by *reducing the conflict* (Deroost et al., 2012) as assumed for learning-based control (Verguts & Notebaert, 2008, 2009). Yet, the observed enhancement and stronger reliance on implicit learning in conflict environments (Vandenbossche et al., 2014; Zhao et al., 2011; see also Deroost & Soetens, 2006; Koch, 2007, Exp. 1) speaks for the possibility that implicit learning processes might nevertheless contribute to cognitive control. However, this may happen not by reducing the conflict but according to Deroost et al. (2012), through *optimization of the task performance*: "Optimization of task performance was accomplished by an increased reliance on implicit sequence knowledge under high conflict. This indicates that implicit learning processes can be flexibly recruited to support cognitive control" (p. 15). This idea might seem novel in the domain of cognitive control, since the latter is traditionally described as the process that is sensitive to the amount of conflict and that aims to minimize this conflict when it gets too strong. However, considering the control process more broadly makes it is perfectly clear that the reduction of the conflict is only needed to ensure a good level of performance in the ongoing task. Stated otherwise, the final goal of the control process is to protect the performance from the conflict-related decline. Bugg's (2014) study provides empirical support for such a view of cognitive control. It was shown in a series of experiments that in a high-conflict context, cognitive control was only engaged as a "last resource", when stimulus–response associations did not allow maintaining a sufficient level of performance. Thus, the magnitude of the conflict seems only to matter when it has a detrimental effect on performance. This emphasizes the importance of the performance rather than conflict per se in the context of control engagement.

One way to preserve the required performance when conflict arises, as suggested by the conflict-monitoring theory, is by reducing the

[1] A 50/50 condition in Jacoby et al.'s (2003) study.

[2] As opposed to *acquisition* of learning that was not affected by the amount of conflict (manipulated by the proportion of congruent trials) at the training phase.