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Sequential congruency effects in implicit sequence learning

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ABSTRACT

We deal with situations incongruent with our automatic response tendencies much better right after having done so on a previous trial than after having reacted to a congruent trial. The nature of the mechanisms responsible for these sequential congruency effects is currently a hot topic of debate. According to the conflict monitoring model these effects depend on the adjustment of control triggered by the detection of conflict on the preceding situation. We tested whether these conflict monitoring processes can operate implicitly in an implicit learning procedure, modulating the expression of knowledge of which participants are not aware. We reanalyze recently published data, and present an experiment with a probabilistic sequence learning procedure, both showing consistent effects of implicit sequence learning. Despite being implicit, the expression of learning was reduced or completely eliminated right after trials incongruent with the learned sequence, thus showing that sequential congruency effects can be obtained even when the source of congruency itself remains implicit.

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1. Introduction

When an experienced driver corrects the trajectory of a vehicle upon perceiving the cues from a sudden wind gust, or a skater changes slightly her center of gravity in response to subtle irregularities on the floor surface, they are expressing their highly automated knowledge in flexible ways. Indeed, the mark of expertise is not just automatic responding to highly predictable environments, but also fast and flexible adaptations to unpredicted changes (Ericsson, 2006). Implicit learning has often been related with the processes leading to expertise (Cleeremans, Destrebecqz, & Boyer, 1998; Shanks, 2005). However, some researchers have suggested that, in contrast to explicit learning, implicit learning results in a relatively rigid knowledge base, which tends to be applied exclusively in the acquisition context (Abrahamse & Verwey, 2008; Berry & Dienes, 1993), and keeps affecting performance even when its utility decreases over a transfer phase (Jiménez, Vaquero, & Lupiáñez, 2006). According to that description of implicitly acquired knowledge, one may wonder whether it can sustain the flexibility required for expert performance, or whether other forms of knowledge should be responsible for these dynamic adaptation effects. The goal of this study is to assess whether the expression of implicit knowledge can be flexibly adapted to changes in its conditions of application, and precisely whether it can be sensitive to momentary changes in the usefulness of previously acquired tendencies.

2. Implicit sequence learning

Learning in serial reaction time (SRT) tasks has been taken as a lab model of skill acquisition. In the standard versions of this task, participants are required to respond as fast and accurately as possible to each trial by pressing on the key corre-

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sponding to the current location of a stimulus, which appears on each trial at one of a limited number of locations (see Fig. 1, panel A). Unbeknownst to participants, the series of locations follows a relatively complex spatial sequence (for instance, a sequence of 12 trials which is continuously recycled over training, such as those depicted in Fig. 1, panel B). Sequence learning is shown by a progressive improvement in responding to the structured trials (Nissen & Bullemer, 1987), as well as by a cost observed when the stimulus stops following the training sequence and is replaced either by a random trial (Cohen, Ivry, & Keele, 1990) or by a trial generated by a control sequence (Schvaneveldt & Gomez, 1998).

Learning about a sequence in these paradigms can be acquired without intention to learn, although intentional learning produces qualitatively different effects (Jiménez et al., 2006). On the one hand, intentional learning appears to result in more flexible knowledge, which can be successfully transferred over some surface changes not involving a change in the sequential structure. For instance, intentional learners trained in the standard SRT task, in which a single stimulus is presented on each trial, can use their sequence knowledge to respond to a transfer block in which distractors are presented in the non-target locations, thus requiring participants to discriminate target from distractors before responding to the target location. In contrast, incidental learning produces more specific knowledge, which can be applied over training with a single stimulus, but does not survive transfer to conditions requiring participants to discriminate targets from distractors. On the other hand, however, when the transfer conditions involve a decrease in the proportion of predictable trials, then incidental learners keep relying on their sequence knowledge, whereas intentional learners stop using it. For instance, when incidental learners trained with a continuously repeated sequence are transferred to a block in which only a few trials are consistent with that sequence, they keep responding faster to those few trials which still follow the training sequence. In contrast, when intentional learners are presented with the same conditions, they stop using their knowledge, so that the effect of learning is no longer observed over that transfer block. This pattern of results is consistent with the claim that only intentional participants become aware of the abrupt change in the proportion of predictable trials introduced over that transfer phase, and develop strategies oriented toward avoiding the use of knowledge that they experience as no longer valid. In contrast, incidental learners may simply be unable to notice such a change, and therefore they keep applying their knowledge regardless of the proportion of trials in which it is actually useful over a given block.

3. Conflict adaptation effects

The interpretation of these results in terms of the detection of a conflict between predicted and observed locations, and of the adoption of strategic adjustments in response to that conflict, resonates with a growing body of research concerning how the cognitive system deals with the competition arising on some tasks between the correct responses and some prepotent, but ultimately incorrect, response tendencies (Botvinick, 2007; Botvinick, Braver, Barch, Carter, & Cohen, 2001; Botvinick, Cohen, & Carter, 2004). This conflict has been investigated extensively using Eriksen's flanker tasks (Eriksen & Eriksen, 1974), Stroop tasks (Stroop, 1935) and Simon Tasks (Simon, 1969). In all these cases, conflict situations are built by asking participants to respond to one stimulus or stimulus' feature that is sometimes incongruent with another salient feature of the display. For instance, in the flanker paradigm participants may be told to respond to a central letter which is flanked by letters assigned to the opposite response, and in the Stroop paradigm participants are to name the color of the ink in which a word referring to a different color is written. In the Simon paradigm instead, participants are to respond to one stimulus' feature (e.g., color or shape) by pressing one of two keys (e.g., left or right) independently of the irrelevant left–right location of the stimulus. In all these cases, responding to a congruent trial (e.g., the red ink of the word "red") has been found to be faster than responding to an incongruent trial (i.e., the word "red" printed in blue), which is typically known as congruency effect. More important for the present purposes, it has also been shown that, despite the automatic and almost unavoidable nature of such congruency effects, the nature of the previous trial modulates the strength of the conflict, so that after congruent trials the congruency effect is larger than after incongruent trials (Gratton, Coles, & Donchin, 1992). The dependency of the congruency effect on previous congruency has been termed sequential congruency effects. The relative frequency of both congruent and incongruent trials has also been observed to affect the overall strength of the congruency effect (e.g., Lindsay & Jacoby, 1994).

Some authors have attempted to account for such effects in terms of the repetition of previous events (Hommel, Proctor, & Vu, 2004; Mayr, Awh, & Laurey, 2003). Thus, for example, on congruent trials preceded by congruent trials the exact stimulus and response can be presented (complete repetition), whereas on congruent trials preceded by incongruent trials some but not all features can repeat (partial repetition). As it is known that participants are faster in responding to complete than to partial repetitions, independently of congruency (Hommel, 2004), feature repetition priming might explain conflict adaptation effect. However, the sequential congruency effects have been found to survive even when the potential contributions from these episodic factors are taken into account (see Egner, 2007, for a review). Therefore, adaptation to conflict appears to be at least one of the factors accounting for these sequential congruency effects. Specifically, the conflict monitoring model put forward by Botvinick et al. (2001) and Botvinick et al. (2004) assumes that these effects depend on a running adjustment of control which is triggered by the detection of conflict over the previous trial. A dedicated system involving the dorsal anterior cingulate cortex (ACC) would register the conflict encountered over the last incongruent trial, and trigger the operation of prefrontal structures involved in increasing the control, thus decreasing the effect of congruency over the next trial. In contrast, a congruent trial will not be associated with any increase in control, and therefore will allow the activation of competing responses which hinder performance on successive incongruent trials.

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