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Implementing flexibility in automaticity: Evidence from context-specific implicit sequence learning

Maria C. D'Angelo [a,*], Bruce Milliken [a], Luis Jiménez [b], Juan Lupiáñez [c]

[a] Department of Psychology, Neuroscience & Behaviour, McMaster University, 1280 Main St. W., Hamilton, Ontario, Canada L8S 4K1
[b] Facultad de Psicología, Universidad de Santiago de Compostela, 15782 Santiago de Compostela, Spain
[c] Facultad de Psicología, Universidad de Granada, Campus de Cartuja, 18071 Granada, Spain

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ABSTRACT

Attention is often dichotomized into controlled vs. automatic processing, where controlled processing is slow, flexible, and intentional, and automatic processing is fast, inflexible, and unintentional. In contrast to this strict dichotomy, there is mounting evidence for context-specific processes that are engaged rapidly yet are also flexible. In the present study we extend this idea to the domain of implicit learning to examine whether flexibility in automatic processes can be implemented through the reliance on contextual features. Across three experiments we show that participants can learn implicitly two complementary sequences that are associated with distinct contexts, and that transfer of learning when the two contexts are randomly intermixed depends on the distinctiveness of the two contexts. Our results point to the role of context-specific processes in the acquisition and expression of implicit sequence knowledge, and also suggest that episodic details can be represented in sequence knowledge.

1. Introduction

From brushing our teeth to typing on a computer or reading, there are countless situations in which our behaviors are guided by seemingly automatic processes. In the domain of cognitive psychology, automatic processes are typically thought of as fast, effortless, and unintentional, but also somewhat rigid (Posner & Snyder, 1975; Shiffrin & Schneider, 1977). The notion that automatic processes are rigid stems from findings indicating that these processes can be activated and interfere with behavior when they are at odds with current goals (e.g., Stroop, 1935). A key issue for researchers is to understand how automaticity serves us so well in such a wide range of contexts in spite of its apparent rigidity. One potential answer to this question, which is the broad focus of the current paper, is that in fact automaticity gains its flexibility through sensitivity to contextual cues.

The specific focus of this paper is the role of contextual factors in the expression of automaticity in an implicit learning task. Implicit learning has often been defined as learning that occurs without intention or conscious effort, and in the absence of awareness of knowledge that has been acquired (Reber, 1993). As a consequence of this definition, implicit learning effects have largely been thought to reflect the engagement of automatic processes (Cleeremans & Jiménez, 1998; Frensch, 1998; Perruchet & Gallego, 1997). If the traditional view of automatic processes is correct, and if implicit learning effects indeed reflect the engagement of automatic processes, then the expression of implicit learning should be quite rigid. This conclusion is consistent with previous work showing patterns of rigid expression of sequence knowledge in incidental but not

* Corresponding author.
E-mail addresses: dangelmc@mcmaster.ca (M.C. D'Angelo), millike@mcmaster.ca (B. Milliken), luis.jimenez@usc.es (L. Jiménez), jlupiane@ugr.es (J. Lupiáñez).

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intentional learners (e.g. Jiménez, Vaquero, & Lupiáñez, 2006), as well as with claims that there is no control in implicit sequence learning (Abrahamse, Jiménez, Verwey, & Clegg, 2010; Destrebecqz & Cleeremans, 2001, 2003). A primary aim of the present study was to examine whether the presumed rigidity of automaticity can be overcome by reliance on contextual cues in an implicit sequence learning task.

In the laboratory, sequence learning is typically studied through the use of the serial reaction time (SRT) task. In the standard version of this task, a target appears on every trial at one of four marked locations. Participants respond to the location of the target as quickly and accurately as possible by pressing a key corresponding to the location of the target. Unbeknownst to participants, the location at which the target stimulus appears is predicted by a relatively complex sequence. Sequence learning is assessed by examining whether participants show a gradual improvement in responding to trials generated by a training sequence (Nissen & Bullemer, 1987), as well as by examining whether there is a cost to performance on trials in which the location of the target is either randomly generated (Cohen, Ivry, & Keele, 1990), or is generated by a control sequence (Schvaneveldt & Gomez, 1998).

2. Using context to implement flexibility

The goal of the current study was to determine whether contextual factors can be used to control the acquisition and expression of implicit sequence learning, by training participants on two complementary sequences that were each associated with distinct contexts. Recently, Abrahamse and Verwey (2008) examined the role of contextual factors in implicit sequence learning, and demonstrated the dependence of implicit sequence learning on static contextual factors. More specifically, Abrahamse and Verwey used a modified version of the SRT task to train participants on a second-order conditional (SOC) sequence in a training context. In this experiment, context was defined based on the shape of placeholders (triangle or rectangle), the background color (white or grey), and the vertical location of the row of placeholders (top or bottom of screen). After a series of training blocks, participants completed a transfer block in which the location of the target continued to be selected based on the training sequence, but the context was switched (e.g., participants were trained using triangles at the top of a white screen during training, and completed a transfer block using rectangles at the bottom of a grey screen). Importantly, performance was impaired in this transfer block, suggesting that sequence knowledge was bound to the contextual factors present in the training blocks.

The context dependent sequence learning effect demonstrated by Abrahamse and Verwey (2008) provides some initial evidence that task-irrelevant contextual factors can be represented together with sequence knowledge. The goal of the current study was to extend the study of context-dependent learning to the broader question of whether context can control both the acquisition and expression of sequence knowledge. In Abrahamse and Verwey's study participants were trained on only one sequence, and were only briefly exposed to the secondary context, which was presented in isolation. In addition, participants were trained using a deterministic presentation of the training sequence, meaning that learning was only measured by the gradual improvement in performance across the training blocks, and by the impairment in performance in the transfer block, but not by an online difference between training and control trials. Given our broader goal of testing context-specificity in sequence learning, we developed a new procedure to assess whether context can indeed be used to implement flexibility in both the acquisition and expression of implicit sequence learning. Our new procedure allowed us to have an online measure of the acquisition of context-specific learning in a series of training blocks, and also allowed us to examine the specificity of the expression of learning in a series of transfer blocks where two contexts were randomly intermixed.

3. The present study

To examine whether reliance on contextual factors can lead to flexibility in the acquisition and expression of implicit sequence learning, we trained participants on two complementary sequences that were each associated with a distinct context. For the present set of experiments, we use the term context to refer to features that can aid participants in distinguishing between different sources of information, which are associated with different situations containing different statistical structures. In contrast to the procedure employed by Abrahamse and Verwey (2008), we used a probabilistic design using a trial-by-trial substitution method (Schvaneveldt & Gomez, 1998) to obtain an online measure of learning, which allows us to differentiate the acquisition from the expression of learning. Furthermore, and more important, we included transfer blocks in which the two contexts were randomly intermixed. These transfer blocks allowed us to examine whether sequence knowledge was indeed bound to the contextual features, as it was possible to assess whether the sequence learning effects would be expressed as a function of the reinstatement of training context in the transfer blocks.

In Experiment 1, there were two distinct goals. First, we aimed to identify a procedure that could be used to measure learning of two complementary sequences as a function of context, by using target shape and response hand as contextual features. Second, we examined whether sequence knowledge was expressed when the two contexts were randomly intermixed. The results of Experiment 1 revealed significant context-specific sequence learning in the training blocks, but this learning effect was not evident in the transfer blocks in which the two contexts were randomly intermixed. In Experiment 2, we increased the distinctiveness of the two contexts by adding vertical location as an additional contextual feature. Here we replicated the context-specific implicit sequence learning effect reported in Experiment 1, and found a marginal learning effect in the transfer blocks. In Experiment 3, we increased the distinctiveness of the two contexts once again, by using target