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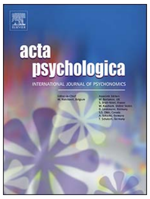

Transfer of learned category-response associations is modulated by instruction

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ABSTRACT

Although instructions often emphasize categories (e.g., odd number → left hand response) rather than specific stimuli (e.g., 3 → left hand response), learning is often interpreted in terms of stimulus-response (S-R) bindings or, less frequently, stimulus-classification (S-C) bindings with little attention being paid to the importance of category-response (C-R) bindings. In a training-transfer paradigm designed to investigate the early stages of category learning, participants were required to classify stimuli according to the category templates presented prior to each block (Experiments 1–4). In some transfer blocks the stimuli, categories and/or responses could be novel or repeated from the preceding training phase. Learning was assessed by comparing the transfer-training performance difference across conditions. Participants were able to rapidly transfer C-R associations to novel stimuli but evidence of S-C transfer was much weaker and S-R transfer was largely limited to conditions where the stimulus was classified under the same category. Thus, even though there was some evidence that learned S-R and S-C associations contributed to performance, learned C-R associations seemed to play a much more important role. In a final experiment (Experiment 5) the stimuli themselves were presented prior to each block, and the instructions did not mention the category structure. In this experiment, the evidence for S-R learning outweighed the evidence for C-R learning, indicating the importance of instructions in learning. The implications for these findings to the learning, cognitive control, and automaticity literatures are discussed.

1. Introduction

A remarkable feature of human performance is the ability to rapidly learn and perform novel tasks from simple instructions. Instructions usually specify particular stimulus-response (S-R) mappings (e.g., X → left index finger, O → right index finger in a simple two-choice task) or slightly more complex/abstract category-response (C-R) mappings (e.g., odd → left hand, even → right hand in a digit classification task; living → index finger, non-living → middle finger in an object classification task). According to Chein and Schneider's (2012) triarchic theory of learning, a *metacognitive* system allows the rapid acquisition of such mappings by orchestrating (and then monitoring) the activity of a *cognitive control* system during the very early stages of learning. This is achieved by initiating (and terminating) the control routines that make successful initial performance possible and then monitoring their progress in order to enhance performance/learning by modifying any unsuccessful routines. The cognitive control system remains active throughout learning (under the guidance of the metacognitive system) and monitors, organizes, and alters the activity of a lower-level *representation* (associative learning) system to maximize efficient performance. More specifically, during the early stages of learning the cognitive control system is responsible for directing attention toward task-relevant information and away from distractions according to the current task goals. It is also responsible for selecting, updating and sequencing task-relevant actions and, as learning progresses, adjusting task parameters following suboptimal outcomes (under the direction of the metacognitive system). Thus, the early stages of learning can be characterized as the orchestration and monitoring of information processing toward the current goal and is largely under the guidance of the metacognitive and cognitive control systems.

After sufficient practice, performance is mostly supported by the representation system (Chein & Schneider, 2012). Theories of automaticity assume that performance has become automatized when exposure to a stimulus directly elicits an associated response. Schneider and Shiffrin (1977) distinguished between consistent and varied mappings of stimuli onto responses. In *consistent mapping*, the stimulus is

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consistently mapped onto the same response throughout practice, whereas in *varied mapping*, the stimulus is inconsistently mapped onto different responses throughout practice. In consistent mapping, associations between the stimulus and response are formed and automatic processing develops across practice. In varied mapping, inconsistent stimulus-response associations are formed, thereby preventing automatic processing (Schneider & Shiffrin, 1977). In a similar vein, Instance Theory (Logan, 1988, 1990) construed automaticity as a memory phenomenon. Initially, people would perform a task based on task rules (algorithmic processing). But after every stimulus encounter, they would store a new processing episode, which consists of a specific combination of the stimulus, the interpretation given to the stimulus, the response, and the task goal. When the stimulus is repeated, previous processing episodes are retrieved, facilitating performance when the mapping is consistent, but impairing performance when the mapping is inconsistent. Eventually, in consistent-mapping conditions, performance can rely entirely on memory retrieval (bypassing the cognitive control system) and is said to be 'automatic'.

Most work on learning and automatization has focused on the formation of specific associations between stimuli and responses (Hazeltine & Schumacher, 2016). However, some research has questioned the way a 'stimulus' and 'response' should be conceptualized (e.g., Henson, Eckstein, Waszak, Frings, & Horner, 2014) and the relative importance of S-R associations (e.g., Hazeltine & Schumacher, 2016; Logan, 1990). For example, Horner and Henson (2009, 2011) asked participants to classify pictures of everyday items in a study-test design in which the stimulus (picture vs. word), the action (left vs. right button press), the decision (yes vs. no) or the classification (e.g., larger than a shoe box vs. larger than a wheelie bin) could change between the study and test phases. They found that at least two levels of stimulus representation (specific stimulus vs. abstract/semantic representation) could independently become associated with at least three levels of response representation (action, decision, classification). In a similar vein, Moutsopoulou, Yang, Desantis, and Waszak (2015) (see also Moutsopoulou & Waszak, 2012, 2013; Waszak, Hommel, & Allport, 2004) have compared the formation and durability of stimulus-action and stimulus-category (S-C) associations. They also asked participants to classify pictures of everyday items and manipulated whether the classification and/or response (action) switched or repeated between prime and probe phases. Like Horner and Henson, Moutsopoulou and colleagues confirmed that S-R and S-C associations are relatively independent (see also Dreisbach, 2012, for a review of recent research investigating the importance of task rules in modulating performance). Finally, Allenmark, Moutsopoulou, and Waszak (2015) have demonstrated that stimulus-action and stimulus-category associations do not depend on very low-level perceptual features (e.g., color), which led them to conclude that higher level representations (e.g., objects or semantic classifications) become associated with categories or actions (see also Frings, Moeller, & Rothermund, 2013, and Denkinger & Koutstaal, 2009; but for an example of evidence to the contrary, see Schnyer et al., 2007). Combined, these studies indicate that people can learn different types of associations when they perform a task. Learning different types of associations might even be the norm (e.g., Dreisbach, 2012; Hall, 2002; Verbruggen, Best, Bowditch, Stevens, & McLaren, 2014). The research summarized above has investigated several such associations, but none has offered a direct comparison between C-R associations (independent of the stimulus), S-R associations (independent of the classification), and S-C associations (independent of the response). The aim of the present study was to compare the relative contribution of these types of associations to learning by assessing the extent to which they transferred to novel stimuli, classifications and responses (respectively). Of particular interest was the relative contribution of C-R associations to learning which has thus far been the subject of few experimental reports.

1.1. C-R associations in the control and learning literature

C-R associations (e.g., odd → left hand response) are presumably an important part of rule-based performance. But despite being regularly utilized when instructing people how to perform a task, C-R associations have received little attention in the automaticity and control literature. Where it has been investigated experimentally, research has largely been dominated by visual-search paradigms (e.g., Kramer, Strayer, & Buckley, 1991; Neisser & Beller, 1965; Schneider & Fisk, 1984) and/or the use of well-learned taxonomic categories such as letters, numbers, animals, colors, etc. (e.g., Neisser & Beller, 1965; Pashler & Baylis, 1991; Schneider & Fisk, 1984). Although these reports have been informative and largely indicate that learned C-R associations transfer to novel stimuli from the practiced categories, it is not possible to generalize their findings to more abstract category structures. Kramer, Strayer, and Buckley (1990) note two particularly relevant reasons why the use of well-learned taxonomic categories is not ideal in this regard: (1) it is possible that a portion of the observed transfer effect could be due to extra-category associations (e.g., 'cat' and 'dog' might be associated by the phrase 'raining cats and dogs') rather than the experimenter-defined category structure (e.g., 'animals'); (2) it is possible that the observed transfer effect is limited to those members of the category that have been learned prior to the experimental session and does not generalize to novel exemplars that adhere to the category rules but were not known prior to testing (e.g., 'cat' and 'dog' are well-known animals that are likely to benefit from transfer, but 'caracal'[2] is less well-known and is therefore less likely to benefit from transfer in experiments that use word stimuli despite also being a member of the category 'animals'). Thus, a critical part of (instructed) learning is the ability to rapidly apply novel rules, but the use of well-learned taxonomic categories in research investigating C-R associations necessarily limits the extent to which the results can be generalized.

In an attempt to address the above criticisms, Kramer et al. (1990) used 'artificial' rule-based categories in two experiments investigating the development and transfer of automatic processes. The target stimuli were four concentric circles with two digits presented at random locations within their boundaries and the task was to determine whether the digit values and locations were consistent with rule-defined categories such as "1 ring apart, outer = inner" (i.e., are the digits presented one ring apart and are their values equal?). Kramer and colleagues observed effective transfer of learned C-R associations to novel exemplar stimuli, which is consistent with the notion that C-R associations make an important contribution to learning. However, their design does not allow for a clean measure of S-R learning independent of the classification because each stimulus could only be consistent with a single category (rule). Thus, a change of S-R mapping was necessarily confounded by a change of classification, making a direct comparison between S-R and C-R associations impossible.

More recently, Cohen-Kdoshay and Meiran (2007, 2009) have demonstrated that the flanker congruency effect (i.e., better performance on trials in which irrelevant stimuli presented alongside the target stimulus afford the same response as the target relative to trials on which the irrelevant stimuli afford a different response to the target) can be observed on the first trial following some simple C-R instructions (e.g., letter from the first half of the alphabet → left hand response, letter from the last half of the alphabet → right hand response). Cohen-Kdoshay and Meiran framed their discussion in terms of S-R bindings, but their results suggest that all members of the instructed categories automatically activate the relevant responses, even when they should be ignored. However, because all of the relevant exemplar stimuli used in the subsequent block were presented during the instructions phase, it is not possible to make any strong claims regarding the extent to which participants activated C-R bindings independent of the specific stimuli they were presented with.

Cohen-Kdoshay and Meiran's experiments have also initiated a recent interest in another relevant line of research investigating

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[2] A caracal is a rare wild cat that lives in Africa.