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# Unintentional and intentional learning of noncorresponding stimulus-response associations in the Simon task

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ABSTRACT

The Simon effect is a robust phenomenon that persists after extensive practice. However, several studies using a transfer paradigm have shown that the Simon effect is eliminated after practicing a location-relevant task with an incompatible spatial mapping. The present study examined whether this transfer effect is a result of implicit, procedural knowledge developed through repeated execution of noncorresponding responses in the practice session or a consequence of explicitly learning and reinstating a noncorresponding mapping rule. Results from two experiments show that, although a small part of the transfer effect may be due to residual activation of noncorresponding S-R associations from the prior task, the larger and more stable part is likely due to response-selection strategies performed intentionally in the practice task.


A question of interest to researchers in experimental psychology is whether a stimulus can automatically attract attention or elicit a response. Studies on associative learning with humans and non-human species have shown that when the association between a stimulus and response is strong, the onset of the stimulus can be sufficient to elicit a conditioned response automatically (e.g., classical conditioning, Pavlov, 1927; food aversion, Bernstein, 1978). However, several researchers have argued that most "automatic" response tendencies are, to some extent, under voluntary control because they occur under appropriate task sets and can vary as a function of task goals (e.g., Hommel, Müsseler, Aschersleben, & Prinz, 2001).

To evaluate the roles of automatic and controlled processes, researchers have used spatial stimulus-response compatibility (SRC) tasks because these tasks involve both automatic and controlled processes (see, e.g., Proctor & Vu, 2006). In an SRC proper task, stimulus location is relevant and participants are told to respond to a given stimulus with an assigned response. For example, if stimuli could occur in a left or right location and responses were presses of a left or right key, a compatible mapping of left stimulus to left response and right stimulus to right response would yield better performance than an incompatible mapping of left stimulus to right response and right stimulus to left response. Spatial correspondence effects also occur when stimulus location is an irrelevant stimulus dimension. Simon and Small (1969) had participants respond to high- and low-pitch tones, presented to the left or right ear, by pressing a left or right key. Responses were faster and more accurate when the tone pitch assigned to the right response was presented in the right ear and tone pitch assigned to the left response was presented in the left ear. The spatial correspondence effect when stimulus location is irrelevant is known as the Simon effect (Hedge & Marsh, 1975; see Simon, 1990).

Dual-route models of spatial compatibility effects attribute response selection to two processes (see, e.g., Kornblum, Hasbroucq, & Osman, 1990). The first process is a direct one in which a stimulus automatically activates its corresponding response. This direct activation is assumed to facilitate responding when the stimulus location corresponds to the response location and interfere with responding when it does not correspond. The second process is an indirect one in which differences in translation efficiency for the instructed S-R mappings influence performance. For example, when the location mapping is compatible, an identity rule can be applied that is more efficient than an opposite rule, which is appropriate for a mirrored, incompatible mapping (see Duncan, 1977; Proctor & Vu, 2006). Because the relevant S-R mapping for a spatial Simon task is usually arbitrary (e.g., a stimulus color or shape is assigned to a left or right response), there should be no inherent advantage for corresponding response locations based on translation efficiencies along the indirect route. The benefit for corresponding S-R

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locations, then, is attributed to the stimulus automatically activating its corresponding response via the direct route. For SRC proper, the compatible mapping not only benefits from the direct route, it also benefits from more efficient translation in the indirect route due to the fact that an identity transformation is typically more efficient than other types of transformations. Thus, both routes contribute to the mapping effects for SRC proper, but only the direct route contributes to the correspondence benefit obtained for the Simon task.

The contributions of direct activation and translation efficiency can be viewed as the influences of long-term and short-term associations, respectively, on performance (e.g., Barber & O'Leary, 1997; Stoffer & Umiltà, 1997; Zorzi & Umiltà, 1995). According to Zorzi and Umiltà's connectionist model for the Simon effect, there is a network of nodes representing stimulus positions, features, and responses. Each node has an activation level and is connected to other nodes by associative links. The stimulus position nodes are connected to their corresponding responses by long-term associative links. The feature nodes are connected to the response nodes by short-term links that are defined by the task instructions. In the Simon task, feature nodes are activated by the relevant stimulus dimension, and this activation should be similar for all trials because the relevant stimulus dimension is usually assigned arbitrarily to responses. In addition to this activation, at stimulus onset, the irrelevant position node is activated and propagates to the corresponding response node through the long-term associative links. The additional benefit from the long-term association for corresponding stimulus and response locations results in the Simon effect. Thus, similar to dual-route models, these association models attribute the Simon effect to the long-term associations alone.

One question concerning SRC effects in general and the Simon effect in particular, is whether the effects are transitory or relatively permanent. If the disadvantage for the noncorresponding mapping can be overcome by practice or training on the task, then the detrimental effects may no longer be a factor for experienced performance. Welford (1976) indicated that the efficiency of S-R translation can be changed by practice because the stimuli and their assigned responses will be more strongly associated after practicing the task. However, both SRC effects (e.g., Dutta & Proctor, 1992; Vu, Rabas, & Roberson, 2009) and Simon effects (e.g., Prinz, Aschersleben, Hommel, & Vogt, 1995; Proctor & Lu, 1999) are reduced but not eliminated by practice. These findings suggest that the short-term, task-defined associations do not override the long-term associations (e.g., Prinz et al., 1995; Proctor & Dutta, 1995). Although the Simon effect is not eliminated after extensive practice, it can be eliminated or even reversed after participants perform a task in which they respond to the stimulus location with an incompatible mapping (e.g., Proctor & Lu, 1999; Tagliabue, Zorzi, Umiltà, & Bassignani, 2000; Vu, 2007; Vu, Proctor, & Urcuioli, 2003).

Proctor and Lu (1999) provided the initial demonstration that the Simon effect can be influenced by prior practice responding with an incompatible spatial mapping. In their Experiment 2, participants were presented with letter stimuli, H and S, in left or right locations and were asked to respond to the stimuli by pressing a key located in a left or right position. In the practice session, the location of the letter stimulus was relevant and its identity was irrelevant to the task. Participants performed 930 trials with a spatially incompatible mapping of left stimulus to right response and right stimulus to left response over 3 days. On the fourth day, participants were transferred to a Simon task in which they were to respond to letter identity (S or H) with one or the other keypress and ignore the letter's location. In this transfer session, the Simon effect reversed, yielding better performance on noncorresponding trials than on corresponding trials. This finding shows that the incompatible spatial mapping from the previous task continued to influence response selection for the current Simon task. Although the short-term associations between noncorresponding locations defined for the location-relevant task were no longer applicable to the Simon task, they, and not the long-term associations between corresponding locations, determined the direction of the Simon effect.

Tagliabue et al. (2000) showed that considerably less practice is needed for the incompatible mapping to influence the Simon effect in the transfer session. Their participants performed 72 practice trials with an incompatible mapping in a single session prior to performing the Simon task after a five-minute delay. The Simon effect was eliminated but not reversed, as in Proctor and Lu (1999) study, most likely because of the lesser practice received. Consistent with this practice hypothesis, Vu (2007) showed that the transfer effect was larger for horizontal stimulus and response sets when the number of incompatible practice trials was 600 than when it was 72. Other studies showed that the nature of the S-R associations also determines whether transfer occurs (e.g., Tagliabue, Zorzi, & Umiltà, 2002; Proctor, Yamaguchi, & Vu, 2007; Proctor, Yamaguchi, Zhang, & Vu, 2009).

Vu (2007) provided evidence that participants can develop response-selection strategies during the practice session that transfer to the subsequent Simon task. In that study, participants performed 72 trials with a spatially incompatible mapping of horizontally or vertically arrayed stimuli and responses. They then were transferred to a Simon task in which the relevant dimension was stimulus color, but the stimuli and responses were arrayed along either the same dimension as in practice or the alternative dimension. Prior practice with the incompatible spatial mapping eliminated the Simon effect in the transfer session only when the stimuli and responses in the practice and transfer session were both arrayed along the horizontal dimension. However, when the number of incompatible practice trials was increased to 600, the Simon effect was eliminated or reversed for both the horizontal and vertical dimensions, regardless of whether the stimuli in the practice session were arrayed horizontally or vertically. This cross-dimension transfer effect suggests that participants acquired a "respond opposite" strategy that could be applied to stimuli along a different dimension than that used in practice.

The fact that response-selection strategies influence performance is consistent with the notion that SRC and Simon effects are not just based on correspondence between the stimulus location and the location of the effectors executing the response, but vary as a function of the response goal (Guiard, 1983; Hommel, 1993; Proctor & Vu, 2006). Hommel presented participants with high- and low-pitch tones delivered to the left or right ear, and had them respond by pressing a key that turned on a light located in a left or right position. When the mapping of light to key was incompatible in that the left key operated the right light and right key operated the left light, the Simon effect varied as a function of whether the action was to result in a keypress or a goal of turning on the light. In one condition, subjects were instructed to press one key for the high pitch tone and the alternative key for low pitch tone, whereas in another condition, subjects were instructed to turn on one light for the low pitch tone and the other light for the high pitch tone. When the instructions were in terms of the keys, the Simon effect was 52 ms, but when the instructions were in terms of turning on the lights, the Simon effect reversed to a −30 ms. These finding indicates that the direction of the Simon effect was dependent on the task goal.

Given that strategies and task goals can alter the size and direction of the Simon effect, one question that arises for the practice-transfer paradigm is whether the intention to respond with a noncorresponding keypress in the practice task is necessary for the prior incompatible spatial mapping to transfer to the Simon task. Hommel (1994) examined response selection strategies in the Simon task by manipulating the relative frequencies of noncorresponding and corresponding trials, showing that this variable altered the magnitude of the Simon effect. In Hommel's Experiment 1, the proportion of corresponding to noncorresponding trials was .50–.50 or .25–.75. The Simon effect was 14-ms larger when the proportion of noncorresponding trials was .50 than when it was .75. Hommel attributed the benefit for the noncorresponding trials to participants using the frequency information to prepare for making the noncorresponding response rather than to