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Transfer of an implied incompatible spatial mapping to a Simon task

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ABSTRACT

When location words *left* and *right* are presented in left and right locations and mapped to left and right keypress responses in the Hedge and Marsh (1975) task (Arend & Wandmacher, 1987), a compatible mapping of words to responses yields a benefit for stimulus–response location correspondence (sometimes called the Simon effect), whereas an incompatible mapping yields a benefit for noncorrespondence (called the Hedge and Marsh reversal). Experiment 1 replicated the correspondence benefit and its reversal by using Chinese location words 左 (left) and 右 (right) in the Hedge and Marsh task. Experiments 2 and 3 examined whether the tendency to respond with the noncorresponding response when the mapping is incompatible transfers to the task version in which the mapping is compatible, and Experiment 4 examined whether transfer similarly occurs from the compatible mapping to the task version with incompatible mapping. Transfer of the incompatible relation was apparent in a lack of correspondence benefit when the mapping was changed to compatible, but transfer of the compatible relation to the incompatible mapping did not occur. The results suggest that an association between noncorresponding stimulus–response locations is acquired when the word–response mapping is incompatible, even though this relation is only implicit, regardless of whether through misapplication of a logical recoding rule or spatial representations shared by the locations and words. These associations then continue to affect processing of location when the mapping is compatible.

1. Introduction

In a typical two-choice spatial reaction task, left and right keypresses are assigned to left and right stimulus locations. Responses are faster and more accurate with a compatible mapping of right stimulus to right response and left stimulus to left response than with an incompatible mapping of right stimulus to left response and left stimulus to right response, which is called the stimulus–response (S–R) compatibility effect (see review by Proctor & Vu, 2006). Moreover, when stimulus location is task-irrelevant and a non-spatial attribute (e.g., color or shape) conveys the task-relevant information, responses are faster and more accurate if the stimulus location and response position correspond than if they do not, a phenomenon called the Simon effect (see reviews of Lu & Proctor, 1995; Simon, 1990; Umiltà & Nicoletti, 1990).

Terminology is less consistent for tasks in which the task-relevant dimension also has spatial meaning (e.g., the task is to respond to the location word *left* or *right*, presented in a task-irrelevant left or right location). Correspondence benefits in such tasks are sometimes called Simon effects (e.g., Georgiou-Karistianis et al., 2012; Toth et al., 1995), based on stimulus location being irrelevant and the responses being keypresses, and sometimes spatial Stroop effects (e.g., Lu & Proctor, 1995), based on the extra overlap of the relevant stimulus dimension with the irrelevant dimension and the responses (Kornblum, Hasbroucq, & Osman, 1990). In the present study, we refer to the location correspondence effect obtained with the words *left* and *right* as the task-relevant stimulus dimension as a Simon effect, consistent with Arend and Wandmacher's (1987) study on which our method is based, but acknowledging that the additional sources of dimensional overlap may play a role.

The Simon effect and its variants have typically been attributed to automatic processing of task-irrelevant spatial information. According to dual-route models (De Jong, Liang, & Lauber, 1994; Kornblum et al., 1990), the task-relevant dimension is processed via a controlled, or conditional, route, by which a response is activated based on instructions. In contrast, the task-irrelevant stimulus location is processed via an automatic, or unconditional, route, by which the response corresponding to the stimulus location is activated. The Simon effect size is a function of the strength of the activation created by the unconditional route relative to that created by the conditional route. Similarly, Zorzi and Umiltà (1995) proposed that the Simon effect arises from two types of S–R links, called short-term memory (STM) and long-term memory (LTM) links. STM links associate stimuli with responses via task instructions, and LTM links connect spatially corresponding stimuli and responses. On incompatible trials the two link types activate different responses, whereas on compatible trials both links activate the same (correct) response, which together create the Simon effect.

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Simon effects are also evident when the irrelevant location information is conveyed by a centrally presented word (*left* or *right*) or arrow (pointing left or right) and stimulus color is task-relevant (Proctor & Vu, 2002). A question of interest is whether words and symbols activate the same shared, mode-independent spatial representations activated by location stimuli or distinct conceptual representations (e.g., verbospatial vs. visuospatial; Miles & Proctor, 2012).

Moreover, although the Simon effect for physical locations is robust, it can be eliminated or even reversed in certain contexts. In the present study, we used two such contexts to examine the relation between processing of location words (Chinese symbols for left and right) and of stimulus locations (left and right): (a) Simon tasks for which the relevant S–R mapping is incompatible, and (b) Simon tasks performed after practice with an incompatible S–R mapping.

1.1. Reversal of the Simon effect with an incompatible relevant S–R mapping

Hedge and Marsh (1975) provided evidence that the task-defined mapping can generalize across different features within the same task. They presented red or green stimuli on the left or right of a display panel and had participants respond by moving an index finger from a start button to one of two response buttons, located to the left or right but also colored red or green. In a compatible-mapping condition the instructions were to respond with the same color (i.e., press the green button for green stimuli and red button for red stimuli), whereas in an incompatible mapping condition the instructions were to respond with the opposite color (i.e., press the green button for red stimuli and the red button for green stimuli). The compatible color mapping showed a typical Simon effect, faster responses when stimulus and response positions corresponded than when they did not, but the incompatible mapping showed a reversed effect, faster responses when stimulus and response positions did not correspond than when they did. This *Hedge and Marsh reversal* with an incompatible color mapping has been replicated in many studies, including ones with keypresses made with left and right index fingers (e.g., De Jong et al., 1994; Hasbroucq & Guiard, 1991; Lu & Proctor, 1994; Wühr & Biebl, 2009), although the color labels for the keys may need to be visible (Proctor & Pick, 2003).

Hedge and Marsh (1975) offered a logical recoding account of the reversed Simon effect. They proposed that participants apply a logical recoding rule of "respond opposite" to select the response to the relevant color dimension, and this logical recoding rule is misapplied within the task to the irrelevant location dimension as well. De Jong et al. (1994) elaborated this account to incorporate a finding that, whereas the Simon effect decreases across the RT distribution, the Hedge and Marsh reversal increases. They suggested that activation of the spatially corresponding response occurs at stimulus onset via an unconditional route, regardless of whether the color mapping is compatible or incompatible, but diminishes rapidly. The relevant transformation rule is implemented in a conditional route through which "automatic generalization and application of the task-defined transformation of the relevant stimulus attribute to the spatial stimulus code" (p. 737) occurs. The "respond opposite" transformation rule, appropriate when the color mapping is incompatible, is applied at the time of response selection and produces the Hedge and Marsh reversal.

Treccani, Milanese, and Umiltà (2010) showed that logical recoding can generalize across different tasks that share partial similarity. In their study, trials of a Simon task with the task-relevant dimension of stimulus shape were intermixed with those of a color-mapping Simon task similar to that used by Hedge and Marsh (1975). The Simon effect for the shape stimuli showed a nonsignificant reversal when the color mapping was incompatible (e.g., press red key to green stimuli; Experiment 1), indicating that the "respond opposite" rule applicable to the color trials generalized to stimulus location in the shape Simon task. Treccani et al. also reported that the Simon effect was eliminated or reversed for the shape Simon task when the intermixed color stimuli were presented at the center of screen and did not vary in location. This outcome suggested that the logical recoding rule relevant to the color task was misapplied to the irrelevant stimulus-location dimension of the shape-judgment task. However, Baroni, Yamaguchi, Chen, and Proctor (2013) provided evidence that the elimination in the latter case was due to a general slowing of responses and not between-task logical recoding. In contrast, when the color stimuli also varied in location, "respond opposite" recoding for an incompatible color mapping did seem to be the source of the tendency for the shape Simon task to reverse.

The Hedge and Marsh reversal has also been obtained for incompatible mappings in tasks for which the task-relevant stimulus dimension overlaps with the response and task-irrelevant stimulus dimensions. These tasks include ones in which the task-relevant dimension is left or right arrow direction (Arend & Wandmacher, 1987), the German word *links* (left) or *recht* (right; Arend & Wandmacher, 1987), the French word *gauche* (left) or *droite* (right; Hasbroucq & Guiard, 1991, footnote 9) and the English word *left* or *right* (Lu & Proctor, 1994). A benefit of such tasks is that the response keys do not have to be labeled, and the S–R compatibility manipulation is more straightforward because the responses are left and right keypresses. The results obtained when the task-relevant dimension has spatial meaning have also been attributed to logical recoding (e.g., Arend & Wandmacher, 1987; Lu & Proctor, 1994), but an alternative explanation is possible because both the relevant and irrelevant stimulus dimensions involve location. If response activation is mediated at least partially by shared, mode-independent spatial representations that are activated by location words and stimulus locations, then short-term S–R links established for the relevant location-word dimension (e.g., location word *left* to right response) may also be activated by the location in which the stimulus occurs (e.g., left).

Evidence consistent with this latter possibility can be found in studies for which location-relevant trials are intermixed with location-irrelevant Simon-task trials. When the location dimension for both trial types is spatial location, the Simon effect in the location-irrelevant trials is positive if the location-relevant mapping is compatible (i.e., right stimulus–right key, left stimulus–left key) but reverses to favor noncorresponding responses if the mapping is incompatible (i.e., right stimulus–left key, left stimulus–right key; Marble & Proctor, 2000). Of importance, the spatial Simon effect is eliminated when the Simon-task trials are intermixed with trials on which participants respond to the centered words *left* and *right* with incompatibly mapped keypresses (e.g., left/right keypress to word *right*/*left*, respectively; Notebaert, De Moor, Gevers, & Hartsuiker, 2007; Proctor, Marble, & Vu, 2000; Vu, Ngo, Minakata, & Proctor, 2010). This elimination has been interpreted as implying that the location words and spatial locations may activate shared, mode-independent codes. It could also be a consequence of misapplication of a "respond opposite" rule, but the previously cited evidence against misapplication of logical recoding across tasks when the stimuli in the incompatible trials do not vary in location (Baroni et al., 2013) implies that this interpretation is less likely.

1.2. Reversal of the Simon effect in the transfer paradigm

The Simon effect is also eliminated or reversed when a task with incompatible spatial mapping is practiced prior to the Simon task. Proctor and Lu (1999) had participants practice 900 trials responding to the positions of the letters *S* and *H* with incompatible keypresses (i.e., right stimuli–left key, left stimuli–right key). When letter identity was made relevant and stimulus position irrelevant, responses were still faster when stimulus and response positions did not correspond than when they did (a reverse Simon effect). Likewise, Tagliabue, Zorzi, Umiltà, and Bassignani (2000) found that the normal Simon effect was absent following 72 practice trials with an incompatible mapping of left/right positions to left/right keypresses.

Tagliabue et al. (2000) proposed an STM-link account for the transfer paradigm, according to which the transfer is due to acquisition of