A Response-Discrimination Account of the Simon Effect

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Simon effects might partly reflect stimulus-triggered response activation. According to the response-discrimination hypothesis, however, stimulus-triggered response activation shows up in Simon effects only when stimulus locations match the top-down selected spatial codes used to discriminate between alternative responses. Five experiments support this hypothesis. In Experiment 1, spatial codes of each response differed by horizontal and vertical axis position, yet one axis discriminated between alternative responses, whereas the other did not. Simon effects resulted for targets on discriminating axes only. In Experiment 2, both spatial axes discriminated between responses, and targets on both axes produced Simon effects. In Experiment 3, Simon effects resulted for a spatial choice-reaction task but not for a go/no-go task. Even in the go/no-go task, a Simon effect was restored when a two-choice reaction task preceded the go/no-go task (Experiment 4) or when participants initiated trials with responses spatially discriminated from the go response (Experiment 5).

The combination of stimuli and responses is a major determinant of performance, a phenomenon called stimulus-response (S-R) compatibility (Fitts & Seeger, 1953). If, for example, participants’ task is to respond with a left or a right keypress to target stimuli (targets) presented to the left or right, performance is better in consistent conditions (left S–left R; right S–right R) than in inconsistent conditions (left S–right R; right S–left R).

Spatial compatibility effects also occur if target position is seemingly irrelevant for the task at hand, a phenomenon referred to as the Simon effect (for reviews, see Lu & Proctor, 1995; Simon, 1990). In a typical Simon task, participants respond with a left or a right keypress to target colors (e.g., red or green), and horizontal target position varies. In this situation, spatially corresponding conditions (left S–left R; right S–right R) still produce better performance than do noncorresponding conditions (left S–right R; right S–left R), although processing of target position is not explicitly instructed. The Simon effect also occurs when the positions of targets and responses vary on the vertical axis (e.g., Stürmer, Leuthold, Soetens, Schröter, & Sommer, 2002).

Many current explanations of the Simon effect assume that a spatial code is derived from the irrelevant target position and that this code either facilitates or interferes with response-related processing (cf. Hommel & Prinz, 1997; Lu & Proctor, 1995). Most of the accounts distinguish two parallel routes of response selection (Hommel, 1997; Kornblum, Hasbroucq, & Osman, 1990; Zhang, Zhang, & Kornblum, 1999). According to these dual-route models, a controlled (or indirect) pathway processes the task-relevant target dimension (e.g., color) to determine the correct response in accordance with the instructed S-R mapping. Simultaneously, in a stimulus-driven (or direct) route, target position activates a spatially corresponding response independently of the instructed S-R mapping. In corresponding conditions, the outputs of both routes converge, thereby facilitating response decision. In contrast, in noncorresponding conditions, a response conflict delays response decision.

As an example, consider the dominant account of the Simon effect, the dimensional overlap (DO) model (Kornblum et al., 1990; Zhang et al., 1999). According to the DO model, the Simon effect is produced whenever stimulus and response positions vary on the same (or associated but different) spatial dimension(s). Thus, the model describes processing along the direct route as stimulus-driven or strongly automatic. Confirmative evidence for the assumption of a stimulus-driven response activation comes from electrophysiological investigations: Target positions can activate corresponding hand areas in primary motor cortex (e.g., De Jong, Liang, & Lauber, 1994; see Valle-Inclán, Hackley, & de Labra, 2002).

As it stands, however, stimulus-driven response activation by stimulus position fails to account for several variations of the Simon effect. In the following, we summarize these variations or exceptions and outline a response-discrimination hypothesis to explain the Simon effect and its exceptions. Particularly, we assume that participants need to represent the to-be-discriminated alternative responses as part of their working-memory representation of the S-R mappings as these are instructed or afforded by the task. We consider the spatial codes of these top-down controlled response representations to be crucial for the bottom-up response activation to show up in the Simon effect (see also Hommel,
could have prevented Simon effects (e.g., by the participants result of no Simon effect in a case in which an S-R rule is specified 1998). Thus, S-R rule representations might well be necessary to the standard Simon effect. Simon effects are modified by attention being diverted from the targets). Simon effects are modified by their responses and that the Simon effect mainly arises with respect to the represented response features.

This objection cannot be made with respect to a second exception to the standard Simon effect. Simon effects are modified by the action goals of the participants (e.g., Hommel, 1993a; Riggio, Gawryszewski, & Umilta`, 1986). For instance, Hommel’s (1993a) participants responded with left or right keypresses to pitches of tones randomly presented to the left or right side. It is important to note that keypresses flashed lights opposite to the keys. One group had to press keys (i.e., press the left [right] key in response to the low [high] tone), whereas a second group had to flash lights (i.e., flash the left [right] light in response to the low [high] tone). The keypress group had a Simon effect of spatial tone–key relations (or an inverted Simon effect of spatial tone–light relations). In contrast, the light-flash group showed an opposite Simon-effect pattern. Hommel (1993a) explained his results by proposing that participants can select among different spatial features to represent their responses and that the Simon effect mainly arises with respect to the represented response features.

Thus, results of Hommel’s (1993a) study suggest that the (direction of the) Simon effect might depend crucially on how participants represent the required responses. Yet important questions remained: Does selectivity of spatial response representations show up in Simon effects of more conventional two-choice reaction tasks? And if so, what are the task requirements that determine which particular spatial code is selected to represent the responses? The response-discrimination hypothesis makes unique predictions for choice reaction tasks (CRTs): Spatial features that discriminate between alternative responses will be represented. They should give rise to a Simon effect. Spatial features that do not discriminate between alternative responses should not be part of a working-memory representation of the responses. The spatial features that are not represented should fail to produce a Simon effect. Alternatively, participants might use all available spatial codes to represent the responses in a CRT, or they might use all spatial codes needed to program and execute the responses (cf. Shiu & Kornblum, 1999). In the latter cases, the Simon effect should depend less on whether the underlying spatial response codes also discriminate between alternative responses. These predictions were tested in Experiments 1 and 2 of the present study.

A third exception to the standard finding of a Simon effect is observed in simple-response tasks (SRTs) or go/no-go tasks. In a typical SRT or in a go/no-go task, participants give one and the same response to all (possibly different) targets, except that in a go/no-go task, some alternative stimuli additionally require that the response be withheld. Early studies revealed a Simon effect in a go/no-go task that was significantly reduced as compared with that found in a CRT (Callan, Klisz, & Parsons, 1974). Callan et al. (1974) proposed that the diminished Simon effect could have been due to reduced response-selection requirements in the go/no-go task as compared with those in the CRT (see also Lu & Proctor, 1995). However, the response-discrimination hypothesis provides an alternative explanation. The go/no-go task does not require participants to discriminate between alternative responses by means of particular spatial codes. Hence, participants could have used individually varying spatial codes to represent the single response. In effect, no Simon effect of one particular spatial code would have resulted. Whether Simon effects in a go/no-go task can be abolished was tested in the present Experiment 3.

Moreover, according to the response-discrimination hypothesis, set effects might account for a residual Simon effect in Callan et al.’s (1974) go/no-go condition. In Callan et al.’s study, participants also performed in a CRT. In the CRT, participants had to represent alternative responses by discriminating spatial codes. Importantly, half of the participants performed in the CRT prior to the go/no-go task, and that might have produced a Simon effect in the latter task. To be precise, working-memory representations of the responses might have carried over from the CRT to the go/no-go task. In line with the assumption that spatial response codes to represent the responses can prevail in working memory to produce Simon effects in go/no-go tasks, changing response hands between alternative SRT blocks induces a (weak) Simon effect in SRTs (Hommel, 1996). Thus, the response-discrimination hypothesis makes a unique prediction: In a go/no-go task, Simon effects should be restored when a CRT precedes the go/no-go task so that set effects are possible. This prediction was tested in the present Experiment 4.

A final exception to the standard Simon effect is the fact that, in a go/no-go task, the Simon effect is stronger if participants place a passive finger on a response key in addition to the actively used finger (Hommel, 1996; Ivanoff & Klein, 2001). Again, this result suggests that the Simon effect might be a function of the spatial response-discrimination requirements. But it seems that the context of all afforded responses rather than the ensemble of the explicitly required target responses determines which and how responses are to be discriminated and, hence, how they are represented. This prediction was tested in Experiment 5 of the present study.

In summary, the response-discrimination hypothesis predicts under what conditions a Simon effect will arise for which spatial response features. The response-discrimination hypothesis makes four claims: First, the Simon effect arises if participants use spatial response features to represent their responses in working memory. Second, each response has a variety of spatial features, such as anatomical and relative effector positions, directions of joint and limb trajectories, and so forth. According to the response-discrimination hypothesis, the Simon effect does arise with respect to those spatial features that are used to discriminate among

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1 This is not to say that response-discrimination requirements are sufficient preconditions for the Simon effect. For instance, saliency of the spatial features (e.g., Vu & Proctor, 2001) or spatial attention shifts between visual elements (e.g., Rubichi, Nicoletti, Iani, & Umilta, 1997) might also be necessary preconditions for the Simon effect.
alternative responses by working-memory representations. Note that, according to the hypothesis, for a spatial response code to give rise to the Simon effect, it is not sufficient that this code be needed to correctly execute a response. Third, the decision of which (spatial) response code is used to discriminate between representations of alternative responses will depend on whether any functionally alternative responses are required or afforded in the current situation and on the spatial features of these responses. If, for example, the task requires participants to execute only one particular response (i.e., an SRT), and the situation does not afford any alternative response, then there is no need to represent the response by its relative spatial location. Fourth, because the response-discrimination hypothesis ascribes Simon effects to working-memory representations, it allows for set effects: Particular spatial codes that are selected to represent a response in Task A might carry over to a subsequent Task B. In other words, having represented a Response X by its relative position in Task A might bias participants to also represent Response X by its relative position in Task B, even if Task B does not require a (spatial) response discrimination.

Experiment 1

In Experiment 1, we investigated Simon effects in a situation in which each of two responses provided spatial codes on two spatial axes, but only one of these spatial axes discriminated between alternative responses. For this situation, the response-discrimination hypothesis predicts a Simon effect in the responses to the targets on the discriminating axis but no Simon effect in the responses to the targets on the nondiscriminating axis.

The task was the following: Two-alternative choice reactions to target colors (red and green) were required. In each trial, a single color target was presented unpredictably at one of four positions: above, below, left, or right of the center of a computer screen. All required responses started from the central home key (which was to be pressed to start a trial) and differed in their relative positions on both horizontal and vertical axes. For instance, for some participants, green targets required a press of the key above-left of the home key, and red targets required a press of the key below-left of the home key. Hence, programming and execution of correct responses required the use of spatial codes both on the horizontal and on the vertical axis.

It is important to note that only one spatial axis could be used to discriminate among the required alternative responses (discriminating axis). The second axis did not discriminate between responses because both responses had the same position on that axis (nondiscriminating axis). In vertical-mapping conditions, upward responses were required for one target color (say red), and downward responses were required for the other target color (say green). Therefore, vertical-axis positions discriminated between alternative responses. However, varying between participants, either both of the responses were upward (left-upward or right-upward), or both were downward (left-downward or right-downward). Hence, vertical-axis positions did not discriminate between the alternative responses.

In contrast, in horizontal-mapping conditions, each participant gave leftward responses to one color (say red) and rightward responses to the other color (say green). Therefore, horizontal-axis positions discriminated between alternative responses. However, varying between participants, either both of the responses were upward (left-upward or right-upward), or both were downward (left-downward or right-downward). Hence, vertical-axis positions did not discriminate between the alternative responses.

In principle, a Simon effect could occur with respect to vertical and horizontal codes in all conditions, regardless of whether the spatial code also discriminates between alternative responses (discriminating axis) or not (nondiscriminating axis). The reason for this is that vertical and horizontal codes are needed to program and to execute the required responses. As a result, spatial codes of target locations on both axes might activate responses at corresponding positions in a stimulus-driven manner, producing a Simon effect in all conditions. For instance, when green targets require up-leftward responses, and red targets require down-leftward responses, then green targets above screen center (response-discriminating—corresponding condition) might produce faster responses than green targets below screen center (response-discriminating—noncorresponding condition), and green targets left of the center (nondiscriminating—corresponding condition) might produce faster responses than green targets right of the center (nondiscriminating—noncorresponding condition).

In contrast, the response-discrimination hypothesis predicts Simon effects exclusively for responses to targets on the discriminating axis. In vertical-mapping conditions, we expected Simon effects for targets above and below screen center but not for targets left and right of screen center. Conversely, in horizontal-mapping conditions, we expected Simon effects for targets left and right of screen center but not for targets above and below the center.

Method

Participants. Seventeen students (9 female, 8 male), with a mean age of 27 years, took part in Experiment 1. One male participant was excluded. He gave consistently wrong responses in one of the response categories. Participants had normal or corrected-to-normal vision, were paid for their participation, and were mostly students at Bielefeld University, Bielefeld, Germany.

Apparatus. The experiment was run on a computer that also collected the data. Stimuli were presented on a 15-in. (38.1-cm) color monitor. All responses were keypresses with the right index finger on the numeric keypad of a standard keyboard. To start a trial, participants pressed the central key (5). Then, depending on the mapping (see below) and on the target color, participants had to respond with one of two further target keypresses: 1 or 7, 7 or 9, 9 or 3, or 3 or 1 (balanced across participants). Response latencies of target keypresses were measured from target onset to the nearest millisecond. The participants were seated in a dimly lit room, 65 cm in front of the screen, with their line of gaze straight ahead and their heads supported by a headrest.

Stimuli and procedure. Targets were red or green disks of 1° diameter. They were presented for 120 ms on a dark background. In each trial, one target appeared either on the horizontal meridian, to the left or to the right of screen center, or on the vertical meridian, above or below screen center. Target eccentricity was 3.8°. Participants had to fixate the screen center. They were to respond as quickly and as accurately as possible to the target’s color. After an incorrect response, an error message was presented for 700 ms.

Two types of S-R mappings were used. In the horizontal-mapping condition, participants responded to green targets with a keypress to the left of the home key and to red targets with a keypress to the right of the home key, or vice versa (between participants). In contrast, in the vertical-mapping condition, participants responded to green targets with a keypress above the home key and to red targets with a keypress below the home key,
or vice versa (between participants). Different S-R mappings were balanced across participants.

In the horizontal-mapping condition, for half of the participants, both left and right response keys were above the central key (7 and 9), and for the other half of the participants, both response keys were below the central key (1 and 3). Similarly, in the vertical-mapping condition, for half of the participants, both upper and lower response keys were to the left of the central key (1 and 7), and for the other half of the participants, both response keys were to the right of the central key (3 and 9). As a result, in the horizontal-mapping condition, the horizontal axis was the discriminating axis (i.e., response positions varied on that axis), whereas the vertical axis was the nondiscriminating axis (i.e., response positions did not vary on that axis). In contrast, in the vertical-mapping condition, the vertical axis was the discriminating axis, whereas the horizontal axis was the nondiscriminating axis.

Spatial relations between targets and responses were either corresponding or noncorresponding. In corresponding conditions, relative positions of targets matched relative positions of responses on the horizontal axis or on the vertical axis (e.g., targets appeared left of fixation and required a left response). In noncorresponding conditions, relative positions of targets and responses did not match (e.g., targets appeared left of fixation and required a right response).

**Design.** The experiment had a 2 (mapping: vertical or horizontal) × 2 (target axis: horizontal or vertical) × 2 (S-R correspondence: corresponding or noncorresponding) mixed design. Mapping was a between-participants variable. Target axis and S-R correspondence were within-participant variables. The possible combinations of mappings, target colors, and response keys were balanced across participants. Each participant went through 24 practice trials and 160 experimental trials (2 target colors × 4 target positions × 20 repetitions, in a random order).

**Results**

Responses faster than 100 ms or slower than 1,000 ms were discarded (2.4%). The mean correct reaction times (RTs) and the error rates are depicted in Figure 1. In an analysis of variance (ANOVA) of the mean correct RTs, there was a significant main effect of S-R correspondence, *F*(1, 14) = 32.38, *p* < .01, and a significant Mapping × Target Axis × S-R Correspondence interaction, *F*(1, 14) = 27.72, *p* < .01. None of the other effects were significant (all *Fs* < 1). Responses were faster in corresponding (550 ms) than in noncorresponding (581 ms) conditions. Most important, the significant three-way interaction was due to the exclusive occurrence of significant net Simon effects (noncorresponding RT — corresponding RT) in the responses to targets that appeared on discriminating axes (vertical mapping—vertical axis: 67 ms, *t*(7) = 4.54, *p* < .01; horizontal mapping—horizontal axis: 70 ms, *t*(7) = 4.64, *p* < .01). In contrast, Simon effects were virtually absent for responses to targets that appeared on nondiscriminating axes (vertical mapping—horizontal axis: 4 ms, *t*(7) = 0.59; horizontal mapping—vertical axis: 4 ms, *t*(7) = 0.44). An ANOVA of the arcsine-transformed error rates yielded only a significant Mapping × Target Axis × S-R Correspondence interaction that paralleled the RT results, *F*(1, 14) = 5.75, *p* < .05 (all other *Fs* < 1).

**Discussion**

The results of Experiment 1 are in line with the response-discrimination hypothesis. We observed large Simon effects when targets were on a spatial axis that discriminated between alternative responses. In contrast, S-R correspondence had no significant effect when targets were on a spatial axis that did not discriminate between the responses. For example, in the horizontal-mapping condition, left-upward (or left-downward) responses were faster than right-upward (or right-downward) responses if targets appeared left of fixation. In contrast, in the same mapping condition, left-upward (or right-upward) responses had about the same speed as left-downward (or right-downward) responses if targets appeared above fixation. These results support the assumption that a Simon effect is due to those spatial response codes that are apt to discriminate between the alternative responses.

There are at least two alternative explanations for the absence of a Simon effect in the nondiscriminating conditions. First, there was one major difference between the spatial response codes of discriminating and nondiscriminating axes. Before the target ap-

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2 Here and later, post hoc *t* tests were Bonferroni adjusted (Hays, 1988).
peared, participants always knew the spatial response code of the nondiscriminating axis, but they never knew the spatial response code of the discriminating axis. Thus, participants could have prepared the nondiscriminating spatial response code prior to target onset, whereas they had to specify the discriminating spatial response code after target onset. However, evidence suggests that this difference does not account for our results. As Hommel (1996) has shown, the Simon effect does not depend on participants being uncertain about the to-be-executed response at the time of target presentation. Empirical support for this assumption also comes from Experiments 4 and 5 of the current study.

A second alternative explanation for the absent Simon effect in the nondiscriminating conditions is that, in our task, participants were not able or not willing to process spatial S-R relations on more than one axis or “dimension”: Participants might have linked only one pair of target and response positions, and they might have been biased toward linking positions on the discriminating axis. Again, evidence suggests that this explanation is unjustified: Simon effects have been obtained with respect to more than one spatial axis (e.g., Lamberts, Tavernier, & D’Ydewalle, 1992; Roswarski & Proctor, 1996); yet, in these studies, multiple axes’ Simon effects were averaged across participants and, hence, might have reflected individually different single-axis Simon effects. If the simultaneous use of spatial codes from two axes is impossible, each participant should have a Simon effect on only one of two spatial axes, even when both spatial axes discriminate between the alternative responses.

**Experiment 2**

In Experiment 2, we tested whether each participant had Simon effects for responses to targets on both the horizontal axis and the vertical axis when both axes discriminated between the alternative responses. As in Experiment 1, participants responded to the colors of targets that were shown on the horizontal or on the vertical axis. Unlike in Experiment 1, the two alternative response positions covaried on two spatial axes. One group of participants responded to one color (say green) with an up-leftward keypress and to the other color (say red) with a down-rightward keypress. Another group of participants responded to one color with an up-rightward keypress and to the other color with a down-leftward keypress. Hence, both horizontal and vertical codes discriminated between the alternative responses.

If participants are either unwilling or unable to use spatial response codes from two axes simultaneously, then most participants should show Simon effects on one axis but not on the other. In contrast, the response-discrimination hypothesis allows for the simultaneous use of spatial response codes from both axes. In fact, representing responses by spatial codes from two axes might allow for an even better discrimination between the responses (a “redundancy gain,” so to speak). As a result, most participants should show Simon effects on both spatial dimensions.

**Method**

**Participants.** Sixteen students (10 female, 6 male), with a mean age of 30 years, took part in Experiment 2. Participants had normal or corrected-to-normal vision, were paid for their participation, and were mostly students at Bielefeld University.

**Apparatus, stimuli, and procedure.** These were the same as those in Experiment 1, with the exception of the response set. Half of the participants responded to green targets with a keypress below-left of the home key (1) and to red targets with a keypress above-right of the home key (9), or vice versa (between participants). The other half of the participants responded to green targets with a keypress above-left of the home key (7) and to red targets with a keypress below-right of the home key (3), or vice versa (between participants).

**Design.** Experiment 2 was based on a 2 (mapping: down-left or up-right [DL-UR], down-right or up-left [DR-UL]) × 2 (target axis: horizontal or vertical) × 2 (S-R correspondence: corresponding or noncorresponding) mixed design. To determine whether a majority of the participants had Simon effects on both horizontal and vertical axes, additional sign tests of the Simon effects on the horizontal axis and on the vertical axis were conducted. Participants went through 24 practice trials and 160 experimental trials.

**Results**

Responses faster than 100 ms or slower than 1,000 ms were discarded (2.5%). The mean correct RTs and the error rates are depicted in Figure 2. In an RT ANOVA, there was a significant main effect of S-R correspondence, $F(1,14) = 80.75, p < .01$, and a marginally significant Mapping × S-R Correspondence interaction, $F(1,14) = 3.90, p = .07$. Responses were faster in corresponding (540 ms) than in noncorresponding (589 ms) conditions. Also, the Simon effect tended to be stronger with the DL-UR mapping (59 ms) than with the DR-UL mapping (38 ms). Most important, however, reliable net Simon effects (noncorresponding RT — corresponding RT) occurred with each combination of mapping and target axis (DL-UR—horizontal: 50 ms, $t(7) = 5.93, p < .01$; DL-UR—vertical: 69 ms, $t(7) = 4.60, p < .01$; DR-UL—horizontal: 42 ms, $t(7) = 6.20, p < .01$; DR-UL—vertical: 33 ms, $t(7) = 4.41, p < .05$). None of the other main effects or interactions were significant (all $p_s > .14$). Separate sign tests revealed that all but 1 participant showed Simon effects for both the vertical- and the horizontal-axis condition (both $p_s < .01$). The ANOVA of arcsine-transformed error rates yielded only a significant main effect of S-R correspondence, $F(1,14) = 7.97, p < .05$. Error rates were lower in corresponding (0.3%) than in noncorresponding (1.8%) conditions (all other $p_s > .18$).

**Discussion**

In Experiment 2, participants either chose between up-left and down-right responses, or they chose between up-right and down-left responses. Thus, in contrast to Experiment 1, spatial response codes of horizontal-axis and vertical-axis positions discriminated between the alternative responses. Also, as before, target location varied on horizontal and vertical dimensions. In this situation, almost all participants had Simon effects for responses to targets on both spatial axes, irrespective of the S-R mapping. Thus, consistent with the response-discrimination hypothesis, participants can use redundant information to efficiently discriminate between alternative responses. It is also in line with previous observations that Simon effects can reflect redundant and yet different response-discriminating spatial codes (e.g., of hand location in crossed-hand experiments, anatomical hand location, and action goal) in different amounts (e.g., Hommel, 1993a). At the same time, results of Experiment 2 make it clear that an inability to simultaneously process S-R relations on two spatial dimensions
(cf. Logan, 1994) does not explain the absence of a Simon effect in the nondiscriminating conditions of Experiment 1. Rather, the absence of a Simon effect in the nondiscriminating conditions presumably resulted from the uselessness of the nondiscriminating codes for the purpose of response discrimination. In summary, the results of Experiments 1 and 2 support the response-discrimination hypothesis. Experiments 3–5 tested predictions of the hypothesis in go/no-go tasks.

Experiment 3

In Experiment 3, we tested whether Simon effects were observed in a go/no-go task. According to the response-discrimination hypothesis, this should not be the case in many instances. Of course, in a typical two-alternative CRT (see Experiments 1 and 2), participants have to decide which of two possible responses has to be given when a target appears. In contrast, in the typical go/no-go task, when a stimulus appears, participants have to decide whether to respond or not with the only possible reaction. This difference in task demand should affect the participants’ representations of alternative modes of behavior and, hence, the Simon effect in two-alternative CRTs as compared with go/no-go tasks. In particular, in a typical go/no-go task, the participant can discriminate between alternative modes of behavior without reference to one particular spatial code, although spatial codes are certainly needed in order to program and to execute the go response, a Simon effect of spatial target–response relations might result. For example, go responses with the right hand might be faster to right targets (corresponding condition) than to left targets (noncorresponding condition). Alternatively, because in a go/no-go task participants can discriminate between alternative modes of behavior (i.e., to respond or to withhold response) without reference to one specific spatial code, the response-discrimination hypothesis predicts that no Simon effect will result here (cf. Hommel, 1996; Ivanoff & Klein, 2001). To rule out sample errors, each participant first performed in a go/no-go task and then in a two-alternative CRT.

It is important to note that the sequence of the tasks prevents set effects—that is, carryover of spatial response representations from the CRT to the go/no-go task. In a previous study, small but significant Simon effects were observed in a go/no-go task (Callan et al., 1974). Yet, in that study, half of the participants performed in a CRT before performing in the go/no-go task. The Simon effect in Callan et al.’s go/no-go task might therefore have reflected a set effect. If our interpretation is correct, no Simon effect should occur in the go/no-go task of the present experiment, whereas a Simon effect should occur in a go/no-go task if the sequence of tasks is reversed (as in Experiment 4 below).

Method

Participants. Eight students (4 female, 4 male), with a mean age of 26 years, took part in Experiment 3. Participants had normal or corrected-to-normal vision, were paid for their participation, and were mostly students at Bielefeld University.

Apparatus, stimuli, and procedure. Participants responded either with left keypresses with their left index fingers on a computer mouse or with right keypresses with their right index fingers. The mouse was on a table, located between participant and monitor, with the left and right mouse buttons directed to the monitor. Stimuli were red and green disks, presented for 120 ms either left or right of the screen center. Each participant performed in two tasks. In the go/no-go task, participants had to respond with a keypress when a target of one color appeared (go condition), but they had to withhold the response when a stimulus of the alternative color...
went through 12 practice trials and 100 experimental trials (2 colors was always administered before the CRT. Within each task, participants in the go/no-go task were balanced across participants. The go/no-go task design. Mappings of colors to responses and the use of left and right keys (S-R correspondence: corresponding or noncorresponding) full-factorial procedure were identical to those of the previous experiments.

In all other respects, apparatus, stimuli, and the alternative index finger to the other color stimulus (i.e., the no-go task). Additionally, they had to respond with the alternative keypress to the same target color as in the go condition of the go/no-go task. In all other respects, apparatus, stimuli, and procedure were identical to those of the previous experiments.

Results

Design. Experiment 3 was based on a 2 (task: go/no-go or CRT) × 2 (S-R correspondence: corresponding or noncorresponding) full-factorial design. Mappings of colors to responses and the use of left and right keys in the go/no-go task were balanced across participants. The go/no-go task was always administered before the CRT. Within each task, participants went through 12 practice trials and 100 experimental trials (2 colors × 2 positions × 25 repetitions).

Results

Responses faster than 100 ms or slower than 1,000 ms were discarded (0.2%). See Figure 3 for the mean correct RTs and the error rates. An RT ANOVA revealed significant main effects of both S-R correspondence, \( F(1, 7) = 12.9, p < .01 \), and task, \( F(1, 7) = 23.22, p < .01 \), and a significant S-R Correspondence × Task interaction, \( F(1, 7) = 8.65, p < .05 \). RT was shorter in corresponding (389 ms) than in noncorresponding (407 ms) conditions. Moreover, RTs were shorter in the go/no-go task (368 ms) than in the CRT (428 ms). Most important, the significant two-way interaction was due to a selectively significant net Simon effect (noncorresponding RT — corresponding RT) in the CRT: 33 ms, \( t(7) = 4.02, p < .05 \). No significant Simon effect was observed in the go/no-go task: 3 ms, \( t(7) = 0.46 \). A corresponding ANOVA of the arcsine-transformed error rates of the CRT and the false-alarm rates (go responses to no-go stimuli) of the go/no-go task yielded neither significant main effects (both \( Fs < 1 \)) nor a significant interaction, \( F(1, 7) = 2.84, p = .14 \). In the go/no-go task, misses (no responses to go targets) were absent.

Discussion

The results of Experiment 3 confirm the predictions of the response-discrimination hypothesis. Participants did not produce Simon effects in the go/no-go task, but the same participants produced Simon effects in a subsequently performed CRT (cf. Hommel, 1996). In particular, latencies of specific responses in the go/no-go task, such as right-index-finger responses, did not exhibit a Simon effect as long as there was no second response providing an alternative spatial code. However, in the latencies of the same responses, a Simon effect showed up as soon as a second response provided an alternative spatial code in the CRT.3

These results suggest that the same response is represented differently in the CRT and in the go/no-go task and that the occurrence of the Simon effect depends on how responses are represented. Participants certainly used spatial codes to program and to execute go responses in the CRT and in the go/no-go task. Yet different participants either used individually variable spatial codes to represent the go responses in the go/no-go task, or they made a go/no-go decision without reference to spatial codes. In any instance, our interpretation implies that the top-down selection of particular spatial codes to represent the responses is responsible for whether bottom-up response activation shows up in the Simon effect (in the CRT) or not (in the go/no-go task).

Again, our results and interpretation can be questioned. First, in contrast with the present experiment, Callan et al. (1974) observed Simon effects in a go/no-go task. Second, one might object that preprogramming of go responses in the go/no-go task prevented a spatial response decision proper and, therefore, a Simon effect. Fortunately, the response-discrimination account makes a unique prediction as compared with a preprogramming account: It allows

3 In the CRT of Experiment 3, the Simon effect of right-hand responses was 25 ms for participants with a right-hand go response in the go/no-go task, and the Simon effect of left-hand responses was 40 ms for participants with a left-hand go response in the go/no-go task (both \( ps < .05 \)).
for set effects. If working-memory representations of to-be-discriminated responses carry over from a CRT to a go/no-go task, Simon effects should be restored when the CRT precedes the go/no-go task. This sequence of tasks might have also been responsible for the residual Simon effects of Callan et al.’s go/no-go task, because half of their participants went through a CRT prior to the go/no-go task. In contrast to the response-discrimination hypothesis, changing the task sequence does not alter the predictions of a response-programming account. Response-programming requirements of the go/no-go task are the same, irrespective of task sequence. Therefore, we tested whether, in a go/no-go task, participants can be biased to represent a single response by its spatial code when a preceding CRT requires a discrimination of spatial response codes (Experiment 4) or when the context otherwise affords such a spatial discrimination (Experiment 5).

Experiment 4

In Experiment 4, we tested whether performing a CRT before a go/no-go task might give rise to the Simon effect in the go/no-go task. Previous work showed that the temporal relationship between the encoding of target position and the selection of a response code is crucial for the Simon effect. Simon effects are abolished, for instance, if target position is encoded well before the response position can be selected (Umiltà & Liotti, 1987). The question is whether coding of response position in advance of target position prevents Simon effects in a similar way. True, precuing of responses tends to increase, and not to decrease, Simon effects (Verfaellie, Bowers, & Heilman, 1988, 1990). But response precuing operates on a far smaller time scale than does the preprogramming of response parameters for an extended period of time. Thus, the latter influence should be controlled for.

If preprogramming of a single response well in advance of the targets prevents a Simon effect, no Simon effect should occur in a go/no-go block. In contrast, the possible carryover of response representations with left–right spatial codes from a preceding CRT block to a subsequent go/no-go block should give rise to a Simon effect in the go/no-go task. Thus, under these conditions, a Simon effect would occur in a go/no-go task despite the fact that (a) the go response does not have to be discriminated from responses at alternative locations, and (b) preprogramming of go responses is possible.

Previous research by Hommel (1996) indicated that changing response hands between SRT blocks induces a small Simon effect. However, it is doubtful whether prevailing response representations from the previous blocks produced the Simon effects in Hommel’s SRT task. Hommel found a numerically larger Simon effect in the second of two successive SRT blocks, as would have been expected. Yet an interaction of blocks and S-R correspondence was far from significant (p > .60; Hommel, 1996, p. 566). It is likely that the relatively rare response discriminations between blocks curtailed both the Simon effect and the power of the analysis. If so, the frequent response discriminations in the CRT blocks of the current experiment should provide sufficient power to test the response-discrimination hypothesis.

Method

Participants. Eight students (5 female, 3 male), with a mean age of 24 years, took part in Experiment 4. Participants had normal or corrected-to-normal vision, were paid for their participation, and were mostly students at Bielefeld University.

Apparatus, stimuli, and procedure. These were the same as those in Experiment 3, with the exception that the CRT was always administered before the go/no-go task. Experiment 4 was based on a 2 (task: go/no-go or CRT) × 2 (S-R correspondence: corresponding or noncorresponding) full-factorial design.

Results

Go responses faster than 100 ms or slower than 1,000 ms were discarded (0.4%). See Figure 4 for the mean correct RTs and the error rates. In an RT ANOVA, task had no significant effect, $F(1, 7) = 2.79, p = .14$. However, the main effect of S-R correspondence, $F(1, 7) = 9.76, p < .05$, was significant. RTs were shorter
in corresponding (401 ms) than in noncorresponding (428 ms) conditions. Most important, and in contrast to the results of Experiment 3, is the fact that the S-R Correspondence × Task interaction was far from significant (F < 1). Net Simon effects (noncorresponding RT — corresponding RT) were 25 ms in the CRT and 29 ms in the go/no-go task.

A corresponding ANOVA of the arcsine-transformed error rates of the CRT block and the false-alarm rates (go responses to no-go stimuli) of the go/no-go block yielded only a tendency toward a significant main effect of task, \( F(1, 7) = 4.66, p = .07 \), but neither a significant main effect of S-R correspondence \( (F < 1) \) nor a significant S-R Correspondence × Task interaction, \( F(1, 7) = 1.34, p = .29 \). False-alarm rates in the go/no-go task (3.5%) were somewhat higher than the error rates in the CRT (2%).

Discussion

The results confirm the prediction of the response-discrimination hypothesis. Simon effects were observed in a go/no-go task that did not require left–right response decisions when the go/no-go task followed a CRT that required left–right response decisions. Thus, the possibility of programming responses in advance of the targets does not prevent a Simon effect: A Simon effect in the go/no-go task resulted, although participants knew that a single response was required for the final 100 trials of the experiment. Given that there was no need to discriminate responses at alternative locations in the go/no-go task, the currently observed Simon effect confirms the hypothesis of a carryover of response representations from the CRT to the go/no-go task. These results are in line with a wealth of data suggesting that Simon effects are affected by relatively enduring yet selective representations of spatial codes in working memory (for related results, see Hommel, 1996; Marble & Proctor, 2000; Tagliaebue, Zorzi, Umiltà, & Bassignani, 2000). Likewise, carryover of spatial response representations likely accounts for residual Simon effects in the go/no-go task of Callan et al. (1974) because half of their participants performed in a CRT prior to the go/no-go task.

Notably, Simon effects were of about the same size in the CRT and in the go/no-go task of Experiment 4. Therefore, Simon effects obviously did not decrease much in the course of the go/no-go block; otherwise, the average Simon effect of the go/no-go task would have been smaller than that of the CRT. This nondiminished Simon effect in the go/no-go task contrasts with some results of Hommel’s (1996) study. Hommel found a relatively weak Simon effect that further decreased within 80 trials in the SRT of his Experiment 3. A likely reason for the divergent results is that, in the present Experiment 4, the frequent left–right discriminations in the 100 trials of the CRT induced a stronger bias to represent responses by their spatial codes or caused a higher activation of the spatial codes in our experiment than in Hommel’s Experiment 3. In the latter study, a single change from the left to the right hand (or vice versa) between the long SRT blocks necessitated only one discrimination of left–right response codes.

Experiment 5

In Experiment 3, the Simon effect was absent in a go/no-go task when participants had to decide whether a single key had to be pressed or not. The response-discrimination hypothesis ascribes this result to the fact that, in this task, the single response can be represented without reference to one particular spatial position. This does not imply, however, that a Simon effect will never arise if there is only one valid go response to the targets in a task. Rather, a Simon effect should result as soon as the participant is either urged or inclined to use spatial codes in his working-memory representation of even a single response. This should also happen when the alternative response is not one of the instructed target responses. It should be sufficient that the broadly defined task context affords or requires a spatial response discrimination (cf. Hommel, 1996; Ivanoff & Klein, 2001). In Experiment 5, we tested this prediction.

The participants’ task in Experiment 5 was to initiate each trial with a particular start keypress, and then, when the target occurred, to decide whether to give a second response or not. Thus, decisional demands of the task, at least with respect to target processing, were the same as in Experiment 3. But Experiment 5 manipulated the spatial relation between an obligatory trial-start response and the go response. One group of participants started trials with the same response that was used as a go response to the target (same-side start response condition). In contrast, another group of participants started a trial with a response on the opposite side to the target-go response (opposite-side start response condition).

According to the response-discrimination hypothesis, participants in the opposite-side start response condition should be inclined to represent go responses by means of horizontal spatial codes, whereas horizontal codes should not be useful at all for response discrimination in the same-side start response condition. In the opposite-side start response condition, the context of functionally alternative responses affords a representation of the go response in terms of left–right spatial codes. In contrast, in the same-side start response condition, the start responses and the go responses cannot be discriminated by their horizontal spatial codes: Participants have to use other response features (e.g., sequential position) to discriminate between the responses. Therefore, a Simon effect was expected in the opposite-side start response condition but not in the same-side start response condition.

In Experiment 5, we used two different tasks, a color-discrimination task and an orientation-discrimination task, because previous research indicated that Simon effects can be affected by target processing (cf. Hommel, 1993b; Stoffler & Yakin, 1994). For instance, Hommel (1993b) observed weaker Simon effects in conditions in which targets were presented with high eccentricity, low signal quality, or low contrast than in conditions in which targets were presented with low eccentricity, high signal quality, or high contrast. Likewise, Simon effects are sometimes absent if participants are forced to focus attention narrowly on the targets.

From a comparison of Figures 3 and 4, it might appear that a Simon effect in the false-alarm rates of the go/no-go conditions occurred in Experiment 3 but not in Experiment 4. This was not the case. In an ANOVA of the false-alarm rates of the go/no-go conditions with experiment (3 or 4) as a between-participants variable and S-R correspondence (corresponding or noncorresponding) as a within-participant variable, an Experiment × S-R Correspondence interaction was far from significant \( (F < 1) \). Only the main effect of experiment, \( F(1, 14) = 7.83, p < .05 \), was significant.
prior to a decision about the accurate response (cf. Stoffer & Yakin, 1994). In the preceding experiments, we might have inadvertently studied Simon effects under unfavorable conditions. The orientation task was used to test whether the pattern of results (i.e., Simon effects for discriminating but not for nondiscriminating spatial codes) generalizes to tasks other than color discrimination.

Method

Participants. Thirty-two students (17 female, 15 male), with a mean age of 26 years, took part in Experiment 5. Participants had normal or corrected-to-normal vision, were paid for their participation, and were mostly students at Bielefeld University.

Apparatus, stimuli, and procedure. Stimuli were red or green disks with a missing segment either at the top or at the bottom. Two tasks were used. Half of the participants performed in the color task, and the other half of the participants performed in the orientation task. The color task was almost identical to the go/no-go task of Experiments 3 and 4. In the orientation task, half of the participants responded to targets with a top segment missing with a left keypress on a mouse and withheld the responses to no-go stimuli with a bottom segment missing, or vice versa. The other half of the participants received similar instructions but responded to the go targets with a right keypress on a mouse.

In all conditions, the sentence Start! was presented at screen center at the beginning of each trial until the participants pressed a particular, predefined start key. Two start-response conditions were used. In the same-side condition, participants pressed the same key to start a trial and to respond to go signals. In the opposite-side condition, participants pressed one key (e.g., the left one) to start a trial and pressed another key on the opposite side (e.g., the right one) to respond to go signals. The imperative stimulus appeared 800 ms after the start keypress.

Design. The experiment was based on a 2 (task: color discrimination or orientation discrimination) × 2 (start response: same side or opposite side) × 2 (S-R correspondence: corresponding or noncorresponding) mixed design. Task and start response were between-participants variables, with 8 participants in each group. S-R correspondence was a within-participant variable. Each participant went through 24 practice trials and 160 (2 colors × 2 shapes × 2 positions × 20 repetitions) experimental trials. Mappings of different possible color and orientation targets to go responses were balanced across participants.

Results

Go responses faster than 100 ms or slower than 1,000 ms were discarded (0.2% in the orientation task and 0.4% in the color task). The mean correct RTs and error rates are depicted in Figure 5. In an RT ANOVA, there was a significant main effect of S-R correspondence, \( F(1, 28) = 9.37, p < .01 \). RTs were shorter in corresponding (410 ms) than in noncorresponding (424 ms) conditions. Also, there was a marginally significant S-R Correspondence × Task interaction, \( F(1, 28) = 3.63, p = .07 \), suggesting a larger average Simon effect (noncorresponding RT — corresponding RT) in the color task (23 ms), \( t(15) = 3.47, p < .01 \), than in the orientation task (5 ms), \( t(15) = 0.67 \). The most important result was the significant S-R Correspondence × Start Response interaction, \( F(1, 28) = 8.97, p < .01 \). A significant net Simon effect was present in opposite-side conditions (28 ms), \( t(15) = 4.58, p < .01 \), but absent in same-side conditions (0 ms), \( t(15) = 0.04 \). None of the remaining main effects or interactions were significant (all \( F_s < 1 \)).

An ANOVA of the arcsine-transformed false-alarm rates (go responses to no-go stimuli) revealed a significant main effect for S-R correspondence, \( F(1, 28) = 14.4, p < .01 \). No-go stimuli in corresponding conditions triggered more responses (6.3%) than no-go stimuli in noncorresponding conditions (3.3%). Also, the Start Response × Task interaction tended toward significance, \( F(1, 28) = 2.88, p = .10 \). In the shape-discrimination task, false-alarm rates were numerically higher in same-side (5.2%) than in opposite-side (3.4%) conditions. This pattern was numerically reversed in the color-discrimination task (same side: 3.6%; opposite side: 6.9%). The remaining main effects (both \( F_s < 1 \)), the remaining two-way interactions (both \( F_s < 1 \)), and the three-way interaction, \( F(1, 28) = 1.97, p = .18 \), were not significant. Misses (no responses to go targets) were too rare to be analyzed (0.2%).

Discussion

Again, the results are in line with the response-discrimination hypothesis. In the go/no-go task of Experiment 5, a Simon effect
was observed in the latencies of the go responses if the participant initiated each trial with a response spatially opposite to the go response. In contrast, this Simon effect was absent if the participant used the same key to initiate a trial and to make a go response. Thus, the need to press two keys in succession fails to produce a Simon effect if left–right codes do not discriminate between start responses and go responses. In contrast, the need to successively press two keys produces a Simon effect if left–right codes discriminate between the alternative responses. These results were observed in two different discrimination tasks. Therefore, in the color-discrimination task, Simon effects were not studied under particularly unfavorable conditions. In fact, Simon effects were stronger in the color-discrimination task than in the orientation-discrimination task. The orientation discrimination might have required more focusing of attention prior to the response decision, with the effect of curtailing the Simon effect (cf. Stoffler & Yakin, 1994).

In Experiment 5, we demonstrated a Simon effect, although spatial parameters of the required go responses were constant(s) (cf. Hommel, 1996; Ivanoff & Klein, 2001). Thus, a spatially discriminated response to the targets is not a necessary precondition for the Simon effect. Once again, the results suggest that Simon effects depend less on the response-programming demands and more on the response-discrimination demands. It might be objected that what seems to be a Simon effect in the RTs of Experiment 5 could have reflected a speed–accuracy trade-off. False-alarm rates were higher in corresponding than in noncorresponding conditions. Yet this argument is weak for theoretical reasons. In a go/no-go task, a higher false-alarm rate in spatially corresponding conditions might reflect the same tendency to respond to the side of stimulation that is evident in the latencies. In go/no-go tasks, increased false-alarm rates in corresponding conditions are more the rule (cf. Hommel, 1996; Stürmer, et al., 2002) than the exception (Ivanoff & Klein, 2001).

**General Discussion**

Several previous studies revealed exceptions to the standard Simon effect that are not in line with an explanation of the Simon effect by purely bottom-up, stimulus-triggered response activation within the direct route (Callan et al., 1974; Hommel, 1993a, 1996; Ivanoff & Klein, 2001; Riggio et al., 1986; for a review, see Hommel, 2000). These exceptions to the Simon effect can be explained by assuming that a top-down set of response representations is decisive for whether bottom-up response activation is reflected in the Simon effect or not (cf. Hommel, 1993a). In particular, we tested a response-discrimination hypothesis that explains both the standard finding of a Simon effect and its exceptions (cf. Hommel, 2000). The hypothesis explains under what conditions a Simon effect will arise for which spatial response features. It claims, first, that the Simon effect arises if a spatial response feature is used to represent one or more responses in working memory. Second, the particular spatial codes that are selected to represent the responses must be useful to discriminate between functionally alternative responses. In effect, the hypothesis predicts that the Simon effect arises with respect to responses discriminating spatial codes. Third, the hypothesis entails, therefore, that (a) task instructions, (b) contexts of afforded responses, and (c) previous representations of currently used responses (set effects) will have systematic effects on the Simon effect.

Five experiments confirmed the predictions of the response-discrimination hypothesis. In Experiment 1, horizontal and vertical spatial codes were needed to program and to execute the responses, but only the horizontal or the vertical axis discriminated between the responses. In line with the response-discrimination hypothesis, Simon effects were restricted to the responses to targets that were presented on the response-discriminating axis. In Experiment 2, responses were discriminated by horizontal and vertical codes, and for almost all participants, responses to targets on both axes (vertical and horizontal) yielded Simon effects. Therefore, an inability or an unwillingness of the participants to simultaneously relate spatial codes of two axes was not responsible for the lack of a Simon effect in the nondiscriminating conditions of Experiment 1.

In Experiment 3, in line with the response-discrimination hypothesis, Simon effects were present in the CRT, in which spatial codes discriminated between the alternative responses. But in a go/no-go task, in which a variety of different spatial codes could have been used to represent the required response (e.g., relative position of response finger to adjacent finger, of response finger to the response device, of responding hand, etc.), the same spatial target–response relations did not lead to a Simon effect. However, an important precondition to prevent Simon effects in go/no-go tasks has been to administer go/no-go tasks prior to CRTs: This measure prevented a set effect—that is, a carryover of spatial response representations from the CRT to the go/no-go task. This is clear from Experiment 4, in which Simon effects were observed in a go/no-go task that was administered after a CRT. Likewise, in the go/no-go task of Experiment 5, a Simon effect was restored when spatially discriminated responses were required to initiate each trial and to respond to the go targets. In contrast, in the control condition of Experiment 5, no Simon effect resulted when each trial was initiated with the response that was also used as a go response. Taken together, results of Experiments 4 and 5 also rule out the possibility that a programming of spatial response parameters prior to target onsets prevented the Simon effect in the nondiscriminating conditions. If this explanation had been correct, no Simon effect should have occurred in the go/no-go tasks of Experiment 5, and even more so in Experiment 4, because participants knew in advance of all go targets which spatial response was to be given. The Simon effect nevertheless occurred.

In summary, results of the present study suggest that a Simon effect of stimulus-driven response activation by target locations is contingent on a match of the target location codes to the spatial codes of the participants’ top-down set of response representations. What is more, the necessity to discriminate between functionally alternative responses appears to be a major determinant for the selection of spatial codes used for the response representations and, hence, for the Simon effect. In contrast, uncertainty about the required responses or the spatial response-programming demands of the task appear to be insufficient factors to account solely for the occurrence and the direction of the Simon effect. Thus, the present results are at variance with models that disregard the effects of variable, top-down controlled response representations on the direct-route contributions to the Simon effect. The direct route does not unconditionally relay stimulus-position-triggered response activation, as has been claimed by several authors (e.g., Kornblum et al., 1990; Zhang et al., 1999; Zorzi & Umiltà, 1995).
To be clear, we do not deny that these models, for instance the DO model, could be adjusted (e.g., by assuming surplus top-down influences on stimulus-location-driven response activation) to account for modifications of the Simon effect as they were presently observed. But the results of the present study challenge these models at a more fundamental level: It is the distinction between bottom-up and top-down influences that becomes blurred altogether when it comes to accounting for the Simon effect.

To conclude, for a variety of reasons, a response-discrimination hypothesis explains the Simon effect most adequately. First, a response-discrimination account allows for variability of the spatial codes that are used for response discrimination. Thus, it allows for exceptions to the standard Simon effect (Callan et al., 1974; Hommel, 1993a; Ivanoff & Klein, 2001; Riggio et al., 1986). Second, the response-discrimination hypothesis ascribes the Simon effect to operations at working-memory level. Therefore, it is in line with recently observed effects of second-task S-R mappings on the Simon effect. The Simon effect is absent, for example, if participants perform an inconsistent spatial-compatibility task prior to the Simon task (Tagliaube et al., 2000). Increasing the temporal interval between the two tasks to 7 days even reverses the Simon effect (Tagliaube et al., 2000, Experiment 5). Likewise, intermixing of Simon-task trials and inconsistent (but not consistent) spatial-compatibility-task trials can invert the Simon effect, even if the upcoming task is precued (Marble & Proctor, 2000; Proctor, Marble, & Vu, 2000; see Proctor & Vu, 2002, for a review).

Finally, top-down control of response representations must be assumed to account for the evident ability to arbitrarily discriminate among otherwise reconcilable movements in the first place. In many instances, there is no peripheral constraint which prevents simultaneous execution of instructed alternative responses. This is the case, for instance, if alternative responses are given with the left and right fingers or hands (for examples, see Experiments 3–5). Yet, if the relative positions of hands or fingers discriminate among alternative responses, the use of these discriminating spatial features turns reconcilable movements into mutually exclusive responses. If, under CRT conditions, both of the alternative responses are concurrently activated, significant costs in terms of increased RTs result (e.g., Leuthold & Kopp, 1998). Therefore, a response-discrimination account is also in accord with a realistic description of human motor performance.

References


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