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A Simon effect for stimulus–response duration

Wilfried Kunde and Christian Stöcker

University of Würzburg, Würzburg, Germany

A non-spatial variant of the Simon effect for the stimulus–response (S–R) feature of duration is reported. In Experiment 1 subjects were required to press a single response key either briefly or longer in response to the colour of a visual stimulus that varied in its presentation duration. Short keypresses were initiated faster with short than with long stimulus duration whereas the inverse was observed with long keypresses. In Experiment 2 subjects were required to press a left or right key (according to stimulus form) either briefly or longer (according to stimulus colour). The stimuli concurrently varied in their location (left or right) and duration (short or long), which were both task irrelevant. Approximately additive correspondence effects for S–R location and S–R duration were observed. To summarize, the results suggest that the irrelevant stimulus features of location and duration are processed automatically and prime corresponding responses in an independent manner.

In choice reaction tasks (CRTs) responses are faster and more accurate when the irrelevant location of a stimulus corresponds with the location of the response rather than with non-corresponding stimulus and response locations. This influence of correspondence between the task-irrelevant location of a stimulus and the location of the required response is known as the Simon effect (Simon, 1969).

Explanations of the Simon effect can be roughly divided into two classes: those that focus specifically on the spatial Simon task itself, and those that treat the Simon effect as an instance of more general compatibility phenomena. Two examples of specific explanations are the initial suggestion by Simon (1969, 1990) that the influence of irrelevant stimulus location reflects a natural tendency of the observer to respond towards the location of a new stimulus and the recent "attentional" account, which assumes that the Simon effect emerges from the correspondence between shifts of spatial attention and the location of manual responses (Rubichi, Nicoletti, Iani, & Umiltà, 1997; Stoffer & Umiltà, 1997).

Examples of broader explanations are the dimensional overlap (DO) model by Kornblum (Kornblum, Hasbroucq, & Osman, 1990; Kornblum, Stevens, Whipple, & Requin, 1999) and

Requests for reprints should be sent to Wilfried Kunde, University of Würzburg, Psychological Institute III, Röntgenring 11, 97070 Würzburg, Germany. Email: kunde@psychologie.uni-wuerzburg.de

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the action concept model by Hommel (1997). A common assumption of these models is that stimuli prime responses automatically when both share a common feature. For instance, a left-sided stimulus automatically primes left-sided responses. This will pose no problem with a corresponding trial, but with a non-corresponding trial (e.g., a left-sided stimulus requires a right-sided response) an incorrect response will be primed, leading to a response conflict and to an observable increase of response times (RTs) and error rates. Most importantly, these models state that automatic response priming is not restricted to spatial features but should be observable whenever stimulus set and response set are "perceptually, conceptually or structurally similar" (Kornblum & Lee, 1995, p. 855).

The spatial Simon effect is a well-established phenomenon (e.g., Lu & Proctor, 1995; Proctor, Marble, & Vu, 2000; Proctor & Vu, 2002). However, given the claim that it is just one instance of influences of irrelevant stimulus features on response selection it is striking that little research has been conducted so far with features other than spatial stimulus–response (S–R) features (for recent exceptions, see De Houwer, 1998; Mattes, Ulrich, & Leuthold, 1999). As a result of the strong focus on the spatial domain, it is far from clear whether the Simon effect is also a robust phenomenon for non-spatial S–R features and, if it is, whether similar mechanisms may account for such non-spatial versions of the Simon task.

The purpose of the present study was to investigate whether the Simon effect transfers to the non-spatial S–R feature of duration, and furthermore to explore how this new effect is related to the well-known spatial Simon effect. We relied on the S–R feature of duration for two reasons. First, response duration has attracted considerable interest in research on motor control. It is a widely acknowledged finding that the time to programme a response is correlated with the duration of the to-be-performed response. This motivated the conclusion that response duration may be an obligatory component of motor programmes and that responses of longer duration require a more complex neuromuscular organization (Klapp & Erwin, 1976; Klapp, McRae, & Long, 1978). We assumed that if response duration really is an elementary feature of response programming, the chance that irrelevant stimulus duration affects response selection should be quite good, and the resulting influence of temporal S–R correspondence should be fairly robust. As the results show, this assumption seems to be justified. Second, the dimensions of duration and location appear to be entirely unrelated—that is, there is no reason that, say, the feature left should be more or less associated with the short duration than the feature right. This a priori assumption is supported by the observation that spatially varying movements to the left or right are performed equally quickly, independently of whether the requested movement duration is short or long (Klapp & Rodriguez, 1982). The independence of the two features allowed us to assess (for reasons discussed in more detail in Experiment 2), whether the S–R correspondence with respect to a certain S–R feature has the power to affect the compatibility effect of another, entirely unrelated S–R feature.

EXPERIMENT 1

The purpose of Experiment 1 was to establish a Simon effect for stimuli and responses of varying duration. Subjects were required to respond with a short vs. longer keypress to the colour of a visual stimulus. These responses have been termed "dit" and "dah" responses according to their labels in the standard Morse code. These labels will also be used in the following in order to avoid semantic confusions between response *duration* and response *latencies*. The critical feature of the present experiments is that not only responses but also the stimuli varied in their duration. The main question was whether the task-irrelevant stimulus duration would affect responses of varying duration in a similar way as the irrelevant location of stimuli affects responses of varying location in the original spatial Simon task.

Moreover, we assessed potential sequential dependencies of the proposed temporal Simon effect. It has recently been found that the S–R correspondence effect in a typical spatial Simon task is reduced (or even reversed) when the preceding trial was non-corresponding (Mordkoff, 1998; Stürmer, Leuthold, Soetens, Schröter, & Sommer, 2000). Some have taken this to suggest that the proposed automatic activation of stimulus-corresponding responses, which is assumed to cause the Simon effect, is not as "automatic" as it seems, but can be temporarily gated after subjects have experienced the negative influence of this "automatic" response tendency in a non-corresponding trial (the so called "gating account"; for an alternative view, see Hommel, 2000). There is no obvious reason why gating should be confined to the spatial Simon effect itself, and thus observing sequential dependencies for the proposed temporal Simon effect could broaden the validity of the gating account. This is certainly desirable as the gating account provides a challenge to traditional concepts of automatic S–R translation in general that, by definition, consider automatic processes to be relatively immune to strategical influences. The absence of sequential effects for the temporal Simon effect would, on the other hand, put tight constraints on the gating account (and any other account) of sequential dependencies of the Simon effect.

Method

Participants

A total of 10 students and staff members from the University of Würzburg (4 men, 6 women) aged between 22 and 33 years participated.

Apparatus and stimuli

An IBM-compatible computer with a 17-inch VGA-Display was used for stimulus presentation and response sampling. Responses were recorded by a single microswitch connected to the parallel port of the computer. The key was pressed with the index finger of the right hand The key had a size of 12 × 12 mm and was positioned centrally in front of the subjects. The imperative stimulus was a red or green (from the standard VGA-Palette) colour dot (45 mm in diameter) presented in the middle of the screen on black background. The colour stimulus was presented either briefly (for 3 refresh cycles of the display, i.e., 42 ms) or long (14 refresh cycles, 200 ms). The required response was either a brief keypress ("dit" response: release of the response key in less than 120 ms after pressing the key) or a longer keypress ("dah" response: release of the response between 121 ms and 300 ms after pressing the key).

Procedure

Following an intertrial interval of 1500 ms an auditory warning click (1000 Hz, 20 ms) was emitted by the speaker of the computer. After an interval of 800 ms following the tone onset the stimulus was presented for either 42 ms or 200 ms. Then response onset (starting from stimulus onset) and response duration were measured. When response duration did not match the required duration or exceeded the upper limit of 300 ms a visual error feedback (the messages "Key pressed too long" vs. "Key pressed too short" in German) was displayed for 1500 ms.

The participants were instructed to execute the required response as fast as possible according to the stimulus colour. Half of the participants responded to the red stimulus with a "dit" response and to the green stimulus with "dah" response. For the other participants this mapping was reversed. They were explicitly instructed to ignore the stimulus duration as far as possible. The participants performed 40 practice trials followed by 200 experimental trials. These trials were composed of 50 replications of the possible combinations of the two stimulus colours and two stimulus durations. Each participant received a different random order of trials.

Results

Keypresses with a duration of more than 300 ms (0.2% of "dit" responses and 6.2% of "dah" responses) or response latencies below 150 ms or above 1500 ms (0.5% of all trials) were discarded. RTs were entered into a two-way repeated measures analysis of variance (ANOVA) with the following variables: temporal S–R correspondence, corresponding (short stimulus–short response, long stimulus–long response) vs. non-corresponding (short stimulus–long response, long stimulus–short response); and temporal S–R correspondence in the preceding trial. RTs were significantly lower with temporal S–R correspondence: correspondence, 371 ms; non-correspondence, 396 ms, $F(1, 9) = 29.21$, $p < .01$. No other effect approached significance. In particular the temporal S–R correspondence in the preceding trial had no influence on the correspondence effect in the present trial ($F < 1$). The duration correspondence effect amounted to 24 ms with a corresponding trial preceding, and it amounted to 26 ms with a non-corresponding trial preceding. No effects were present in the error data. The mean error rates for corresponding/non-corresponding trials were 5.2%/8.2% with a corresponding trial preceding, and 5.8%/5.3% with a non-corresponding trial preceding.

An additional separation of the data into response type (short, "dit" vs. long, "dah") and stimulus duration (short vs. long) showed that "dah" responses had longer response latencies than "dit" responses, $F(1, 9) = 17.34$, $p < .01$, replicating the standard result of a higher programming effort for "dah" responses (see Klapp et al., 1978). The mean RTs (error rates in parenthesis) for short vs. long stimuli were 355 ms (5.0%) vs. 379 ms (4.0%) for "dit" responses and 416 ms (9.6%) vs. 388 ms (5.9%) for "dah" responses.

Duration of responses

The only significant and rather trivial effect in the analysis of response duration was that of response type ("dit" vs. "dah"), indicating that, as instructed, "dah" responses had longer response duration than "dit" response, $F(1, 8) = 358.90$, $p < 01$. No other effect reached significance. For "dit" responses the mean response duration was 77 ms with a short stimulus and 75 ms with a long stimulus, and for "dah" responses it was 225 ms with a short stimulus and 224 ms with a long stimulus.

Discussion

The task-irrelevant duration of a response signal affected the latencies to initiate responses of varying duration. When a short keypress was required, RTs were lower with a short than with a long stimulus, whereas the opposite was true when a long keypress was required. This influence was observed although subjects were extensively instructed to ignore stimulus duration. Thus, the results of Experiment 1 represent a Simon effect for the S–R feature of duration.

Although this influence was pronounced in response latencies it was virtually absent in the executed duration of the keypresses. This suggests that the temporal correspondence of stimuli and responses affected response selection rather than response execution, which is also a widely accepted assumption for the spatial Simon effect (Lu & Proctor, 1995).

One reviewer suggested that the observed temporal Simon effect might be due to a rather different mechanism from that of the automatic priming of stimulus-corresponding responses. One may assume that the offset of the stimuli, for whatever reason, puts some time pressure on the participants to initiate the requested responses. This could pose a problem for short stimulus duration and a required "dah" response, because long responses require more time to be programmed and can thus not be performed as readily as "dit" responses. Although this conjecture may account for the lower RTs of "dit" responses and short-lasting stimuli, it faces serious problems when trying to explain why "dit" responses were initiated more *slowly* with stimuli of long than with stimuli of short duration, even though with long stimulus duration there is even more time to programme the response in advance of the stimulus offset. Given this problem, we favour the view that stimuli of certain duration tend to prime responses of corresponding duration, much like stimuli in a certain location prime responses of corresponding location.

There was, however, an interesting deviation of the new temporal Simon effect from the spatial Simon effect. The temporal Simon effect, unlike the spatial Simon effect, was not affected by the S–R correspondence in the preceding trial. Before discussing plausible reasons for this deviation from the spatial Simon effect we intended to replicate and extend the duration Simon effect in a second experiment.

EXPERIMENT 2

The purpose of Experiment 2 was to study how the new version of the Simon effect for stimulus and response duration is related to the standard spatial Simon effect. For this purpose, subjects were required to execute responses that varied on the dimensions of location and duration concurrently. The task was to respond to the form of a stimulus (X vs. O) with a left or right keypress, which should either be short or long according to the stimulus colour. The stimuli additionally varied with respect to their location and duration, which were both task irrelevant. Hence, stimuli varied in their spatial correspondence as well as in their duration correspondence to the required responses. The question of interest was whether the two types of correspondence would affect response latencies in an independent or interactive manner.

One can come up with two plausible predictions for the interaction of these two correspondence effects. On the one hand the S–R attributes of location and duration are unrelated—that is, they show no dimensional overlap (cf., Klapp & Rodriguez, 1982; Kornblum et al., 1990). Consequently, each of the two irrelevant stimulus attributes should automatically prime only the particular aspect of the response with which it overlaps. As a consequence the correspondence effects of the two S–R features should combine in an additive manner. This may be termed the "independent priming" hypothesis. This logic should also apply to potential sequential dependencies. Given that a certain stimulus feature primes its corresponding response feature independently from other features, it is conceivable that correspondence effects vary strictly according to the S–R correspondence of this particular feature in a preceding trial. In other words, the spatial correspondence in trial n–1 should exclusively affect the effect of spatial correspondence in trial *n*, but leave the effect of duration correspondence relatively untouched. Likewise, the duration correspondence in the preceding trial should exclusively affect the effect of duration correspondence (if it has an influence at all, see Experiment 1) but leave the effect of spatial correspondence relatively untouched.

Viewed from traditional stage theory one may, on the other hand, argue that both correspondence manipulations affect the same processing stage (i.e., response selection), which would allow the two correspondence effects to interact. It is, for example, conceivable that the automatic priming from a certain stimulus feature may be blocked after having registered non-correspondence to the respective other S–R feature. This may be called the "cross-dimensional blocking" hypothesis (cf., Kingstone, 1992, for within-trial crosstalk between S–R features). Such cross-dimensional blocking would result in a reduction of the correspondence effect for a given S–R feature when the trial is non-corresponding with respect to the other S–R feature. Hence, the cross-dimensional blocking hypothesis predicts an *underadditive* interaction of the S–R correspondence effects of location and duration. As in the case of the independent priming hypothesis this logic may also apply to sequential influences—that is, the experience of non-correspondence for a certain S–R feature in the preceding trial may have the power to block the automatic processing of the other S–R feature in the following trial. This would result in influences of the correspondence of one S–R feature in trial *n*–1 on the effect of correspondence of the other S–R feature in trial *n*.

Method

Participants

A total of 24 students from the University of Würzburg (2 men, 22 women) aged 19 to 34 years participated. None of them had participated in Experiment 1.

Apparatus, stimuli, and procedure

The same apparatus as that in Experiment 1 was used. The stimuli were the uppercase letters O or X, presented in either red or green on a black background. The letters were 15 mm high and 10 mm wide and were presented so that their midpoints were located 30 mm to the left or right of a permanently displayed central fixation cross. The two response keys were separated by approximately 15 cm to the left or right of the body midline of the participants and were pressed with the index fingers. After an intertrial interval of 1500 ms an auditory warning click (1000 Hz, 20 ms) was emitted by the speaker of the computer. After an interval of 800 ms following the tone onset the letter X or O was presented in red or green to the left or right of the fixation cross either briefly or slightly longer. In order to ensure that stimulus form was clearly discriminable, the short presentation duration was increased to 56 ms whereas the long duration remained at 200 ms as in Experiment 1.

The participants were required to respond to the form of the stimulus (O vs. X) with a left vs. right keypress, which was either brief ("dit") or long ("dah") contingent on the stimulus colour (red vs. green). The mapping of stimulus form to response location and of stimulus colour to response duration was counterbalanced over subjects. As the task was considerably more demanding than that in Experiment 1, the criteria for accepting responses as "dit" and "dah" responses were slightly relaxed. Responses with a duration of less than 151 ms were counted as "dit" responses, and responses with a duration above 150 ms and below 400 ms were counted as "dah" responses. Separate error feedback concerning the adequacy of the location and the duration of the response was provided. After 40 trials of practice, the participants worked through 256 trials that resulted from the factorial combination of 2 (stimulus forms) × 2 (stimulus colours) × 2 (stimulus positions) × 2 (stimulus durations) × 16 (repetitions). Each participant received a fresh random order of trials.

Results

Keypresses with a duration of more than 400 ms (0.1% of "dit" responses and 3.8% of "dah" responses) and responses below 150 ms or above 1500 ms (1.8% of all trials) were discarded. RTs and error rates were analysed as a function of four variables: spatial S–R correspondence, correspondence (left stimulus–left response, right stimulus–right response) vs. non-correspondence (left stimulus–right response, right stimulus–left response); temporal S–R correspondence, correspondence (short stimulus–dit response, long stimulus–dah response) vs. non-correspondence (short stimulus–dah response, long stimulus–dit response); and spatial S–R correspondence and temporal S–R correspondence in the preceding trial. The mean RTs and error rates of the factorial combination of these variables are listed in Table 1.

The analysis of RTs revealed significant influences of temporal S–R correspondence, $F(1, 23) = 22.84$, $p < .01$, as well as of spatial S–R correspondence, $F(1, 23) = 4.57$, $p < .05$. These effects were additive, $F(1, 23) = 2.71$, $p > .11$, for the interaction of spatial and temporal correspondence. The temporal Simon effect was 24 ms with spatial S–R correspondence, and 38 ms with spatial non-correspondence. The spatial Simon effect was 6 ms with duration S–R correspondence, and 21 ms with duration non-correspondence. Hence, if anything, the correspondence effect for one S–R feature was *larger* with non-correspondence in the other S–R feature, which is the opposite of the prediction of the "cross-dimensional gating" hypothesis.

There were also influences of S–R correspondence in the preceding trial. In keeping with previous findings (Hommel, 2000; Mordkoff, 1998; Stürmer et al., 2000) the spatial Simon effect was affected by the spatial S-R correspondence in the previous trial, $F(1, 23) = 4.67$, $p < .05$, for the interaction of spatial S–R correspondence in preceding and current trial. With a spatially corresponding trial preceding, the spatial Simon effect amounted to 25 ms, whereas with a spatially non-corresponding trial preceding, it was only 3 ms. In contrast, the temporal

TABLE 1
Response times and error rates as a function of spatial S–R correspondence, temporal S–R correspondence, spatial S–R correspondence in the preceding trial, and temporal S–R correspondence in the preceding trial in Experiment 2

		S–R correspondence							
		L+				*L–*			
S–R correspondence in preceding trial		*D+*		*D–*		*D+*		*D–*	
		RT	*PE*	*RT*	*PE*	*RT*	*PE*	*RT*	*PE*
L+	D+	706	8.6	715	12.1	695	9.9	768	13.0
	D–	683	5.0	725	10.6	731	11.7	734	13.3
L–	D+	713	9.4	735	10.7	726	7.7	718	10.7
	D–	716	6.6	739	10.1	693	6.8	779	12.8

Note: RT = response times in milliseconds; PE = percentage of errors. L+ = location corresponding; L– = location noncorresponding. D+ = location corresponding; D– = duration noncorresponding.

Simon effect was unaffected by the temporal S–R correspondence in the preceding trial, $F(1, 23) = 1.37$, $p > .25$, for the interaction of temporal S–R correspondence in current and preceding trial. If anything the temporal Simon effect was smaller when the preceding trial was duration corresponding (24 ms) than when it was duration non-corresponding (38 ms). The fact that the spatial correspondence in the preceding trial affected the spatial Simon effect, whereas the temporal correspondence in the preceding did not affect the temporal Simon effect, led to a four-way interaction, $F(1, 23) = 18.65$, $p < .01$. Additionally, there was a triple interaction between the variables of temporal correspondence, the temporal correspondence in the preceding trial, and spatial correspondence in the preceding trial, $F(1, 23) = 11.81$, $p < .01$. Whereas the temporal Simon effect increased slightly when the preceding trial was duration corresponding as well as spatially corresponding, it decreased when the previous trial was temporally corresponding but spatially non-corresponding. There appears no obvious explanation for this data pattern.

The analysis of error rates replicated the effects of temporal correspondence, $F(1, 23) = 8.18$, $p < 0.1$, as well as spatial correspondence, $F(1, 23) = 5.90$, $p < .05$. These effects were additive also in error rates ($F < 1$). No other effect reached significance (all *ps* > .10).

Discussion

Experiment 2 replicated the influence of irrelevant stimulus duration on duration-varying responses found in Experiment 1. Additionally, a significant influence of spatial S–R correspondence was observed. The spatial correspondence effect was relatively small. This is not too surprising given the fact that the RT level in Experiment 2 was relatively high, and irrelevant spatial stimulus codes have been shown to decay rapidly after stimulus onset—that is, they are less likely to affect responses the later the responses are emitted (De Jong, Liang, & Lauber, 1994; Hommel, 1994). More importantly, the spatial correspondence effect and the temporal correspondence effect affected RTs and error rates in an approximately additive manner, suggesting that the duration and location attributes of the stimuli primed the corresponding duration and location aspects of the responses independently of each other.

The sequential analysis replicated previous findings that the spatial Simon effect is reduced (in fact virtually absent) when the preceding trial was spatially non-corresponding. In contrast, and replicating Experiment 1, the temporal Simon effect was unaffected by the temporal correspondence in the preceding trial. This suggests that the gating of an automatic response route, which may account for the absence of the spatial Simon effect following spatially non-corresponding trials, does not apply to the temporal domain. Additionally, there were few hints for cross-feature sequential modulations of correspondence effects. In particular it was not the case that spatial non-correspondence in the preceding trial systematically reduced the overall duration correspondence effect, nor did duration non-correspondence in the preceding trial systematically reduce the overall spatial correspondence effect which one would expect if non-correspondence in a given feature would block the automatic response priming from another stimulus feature. Nevertheless, there was one (rather complex) significant cross-feature interaction in the sequential analysis of RTs: The duration correspondence effect was reduced when the preceding trial was spatially non-corresponding and duration corresponding. This leaves open the possibility that non-correspondence in a given feature may, under certain circumstances, have the power to block the automatic priming from another S–R feature at least in the subsequent trial. Future research is certainly warranted to clarify the detailed preconditions for such cross-feature sequential modulation.

GENERAL DISCUSSION

The present study investigated whether the irrelevant duration of a stimulus affects responses of varying duration in a similar way as the irrelevant stimulus location affects responses of varying location in the classical Simon task. The answer is clear cut: It does. Moreover, temporal S–R correspondence and spatial S–R correspondence affected performance simultaneously,[1] with the effects of spatial correspondence and of duration correspondence on RTs being additive. Thus, the location of the stimulus appears to prime the corresponding location attribute of responses independently of the response duration attribute and vice versa. This conclusion is reinforced by the observation that the spatial correspondence effect was relatively unaffected by the preceding temporal correspondence and vice versa. To summarize, the correspondence of one feature did not systematically affect the correspondence effects of the other feature, neither within nor between trials. Taken together this pattern of results suggests an architecture with several feature-specific "automatic" S–R routes, some of which (e.g., the one processing location) can, and some of which (e.g., the one processing duration) cannot, or not that easily, be blocked voluntarily.

It should, however, be noted that in Experiment 2 there was a non-significant but numerically substantial interaction between the two correspondence effects opposite to the prediction of the cross-dimensional suppression hypothesis—that is, a relatively *larger* spatial correspondence effect when duration was non-corresponding and vice versa. What are the reasons for this data pattern? A plausible speculation is that, although the stimulus-driven priming of location and duration response features may proceed independently of each other, the processes that prevent the execution of primed responses in the case of non-correspondence (e.g., the "abort" process in the DO model by Kornblum et al., 1990) may at least partly rely on some common resource. For example, when a given trial is spatially non-corresponding, the control mechanism to prevent the erroneous execution of the primed response(s) is required and is less available for the concurrent inhibition of a duration-corresponding response. Thus, the proposed abort mechanism may be overloaded by simultaneous non-correspondence in two features. Indeed, Simon (1982, p. 70) made a similar suggestion to account for increases of spatial correspondence effects under dual-task workload. A way to test the "overload" hypothesis in the future would be to include appropriate neutral conditions for features of both location and duration. The prediction is that, although the benefits for two S–R features may be additive (due to independent priming), the costs may be overadditive (due to reliance on a common abort process).

The main conclusion from the present study that the automatic priming of responses that share a task-irrelevant feature with the stimulus is not restricted to spatial features accords well

[1]In principle, it is also conceivable that the two compatibility effects did not affect responses in parallel but that spatial correspondence affected responses in a certain proportion of trials, whereas duration correspondence affected responses in another proportion of trials. However, if this were the case the duration correspondence effect in Experiment 2 should be considerably lower than that in Experiment 1 because a lower proportion of trials would have affected responses in Experiment 2. Obviously, this is not the case.

with two other recent reports of non-spatial Simon effects. De Houwer (1998) showed that the semantic category of a word affected the latency of a verbal response to this word even when word meaning was task irrelevant. Similarly, Mattes, Ulrich, and Leuthold (1999) reported that responses of varying force are initiated faster when the task-irrelevant stimulus intensity and the required response force match than when they do not match. Although these findings support broader models that treat the spatial Simon effect as just one instance of influences of irrelevant stimulus features, they are not evidence against the specific accounts of the spatial Simon effect outlined in the Introduction. However, the present results make clear that a similar effort as undertaken in determining the relevant factors in the spatial version of the Simon task can be undertaken (and in our opinion should be undertaken) to determine the relevant factors for other versions of the Simon effect. For example, in the spatial version of the Simon task, a given stimulus location may be considered as either left or right, depending on the spatial frame of reference that is adopted to code the stimulus location. A number of studies have tried to determine which frames of reference are of particular relevance (Lamberts, Tavernier, & d'Ydewalle, 1992; Roswarski & Proctor, 1996; Umiltà & Liotti, 1987). In the same way a given stimulus duration may be considered as either short or long according to which duration is taken as a reference. This raises the question of the "temporal frames of reference" relative to which a given stimulus duration is coded.

The present study also makes it clear that the detailed mechanisms of the spatial and duration Simon effect may differ. By and large it appears that the duration Simon effect is much less subject to strategic influences than is the spatial Simon effect. This is suggested by informal reports of our participants as well as by some aspects of the data. Most participants reported that they had tried, but failed, to overcome the spontaneous tendency to respond with a stimulus-corresponding response duration, whereas they reported few problems in overcoming the tendency to react towards the location of the stimulus. Indeed, whereas 21 of the 24 subjects in Experiment 2 showed a temporal Simon effect, only 15 showed a spatial effect. The introspective reports are corroborated by the fact that the spatial Simon effect but not the duration Simon effect was modulated by the S–R correspondence in the previous trial.

It should also be noted that the temporal Simon effect in Experiment 2 was slightly larger than that in Experiment 1, although the absolute RT level was about 300 ms higher, which is also a discrepancy from the spatial Simon effect that typically declines with increasing RT level due to the decay of the stimulus' irrelevant location code (De Jong et al., 1994; Hommel, 1994). The independence of the temporal Simon effect from RT level suggests that the duration code of the stimulus does not decay or decays considerably more slowly than the spatial code. This conclusion is also supported by explorative distribution analyses that we conducted, which also revealed no reduction of the duration Simon effect with increasing RT. We do not, however, want to make a strong point of this outcome because unlike the spatial stimulus code, the time at which the duration code of the stimulus is available is not that sharply defined, and it is thus difficult to determine when the stimulus duration is really coded to a degree that would allow decay. Yet these observations point to the possibility that the stimulus duration in the present experiments was less likely to be ignored (and thus to passively decay) than was the spatial stimulus code. A reason for this may be that the duration of short and long stimuli in the present experiments exactly matched the duration of the required short and long responses. Hence, participants may occasionally have attended to stimulus duration because it served as a useful response model that occasionally reminded them of the required response durations. A way to test if this was the reason for the observed independence of the temporal Simon effect from RT level would be to use stimulus durations that resemble the response durations less closely.

Whatever the reasons are for these discrepancies between the temporal Simon effect and the spatial Simon effect, they suggest that, although the basic Simon effect appears to be the same, the precise mechanisms that underlie this effect may vary considerably according to the particular feature in which stimuli and responses overlap. In our opinion it is a worthwhile future project to determine the causes of these differences in more detail.

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