Top-down control in the Simon task

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Abstract

The current study used precues in a Simon task to equip subjects with information about whether the upcoming trial would be of a corresponding or noncorresponding stimulus-response (S-R) location mapping. It was hypothesized that subjects could use the information to gradually alter their stimulus processing to be faster and more accurate if the cues were valid, but that these alterations would lead to more lags and errors when cues were invalid. The results supported the hypothesis. However, control over stimulus processing in this sense was highly limited when the preceding trial had been of a noncorresponding S-R mapping. Furthermore, the results were in line with proposals of a gating mechanism in which gradual adjustments in selection of stimulus features for processing is assumed to underlie control.

It has been known for more than four decades now, that human stimulus processing is not independent of stimulus location: people can respond faster and more accurate to stimuli when the side of stimulus presentation corresponds to the side on which a response has to be given, than when a response has to be given on the opposite side (e.g. Kornblum, Hasbroucq, & Osman, 1990). Surprisingly, such effects of stimulus-response compatibility (SRC) even occur when the location of the stimulus, according to the instructions, is completely irrelevant for response-selection - an effect that has become known as the Simon effect (for a comprehensive review, see Simon, 1990).

Ever since, research has tried to explain the mechanisms involved in the Simon effect. Although no generally accepted explanation is available yet (e.g. Stoffer & Umiltà, 1997), basically all current accounts of the phenomenon depend on the assumption that a spatial code of the stimulus is automatically formed and involved in response selection. Argumentations on this matter mostly concern the origin of this spatial code, or more precisely, whether it is formed in relation to an intentionally defined object, or the current focus of attention (i.e. the static vs. the attention-centered version of the referential-coding hypothesis), or whether it arises from the reallocation of attention in direction of the stimulus (attention-shift hypothesis). Although this discussion is out of the scope of this paper, we would like to attend the reader to a recent review of studies on the topic (Abrahamse & Van der Lubbe, 2008).

One of the most common explanations of the Simon effect builds on so called dual-route accounts of stimulus processing, which have proven useful in studies of SRC effects, in which information about stimulus location actually is of importance for response selection (e.g., Kornblum et al., 1990; Hommel, 1993; De Jong, Liang, & Lauber, 1994). Dual-route models of stimulus processing assume the existence of a conditional and an unconditional processing route that work in parallel, but independently from one another (Stürmer, Leuthold, Soetens, Schröter, & Sommer, 2002). The unconditional route is assumed to fast and automatically prime responses on the side

where the stimulus is presented. So, for example, when a stimulus is presented to the right, the unconditional route automatically primes, and thus facilitates, right-sided responses, irrespective of instructions or stimulus identity. This leads to faster reaction times (RTs) and less errors when the response has to be given on, in this case, the right side. Reactions are delayed and more error prone, however, if a response has to be given on the opposite side, because the response tendency that is pre-activated by the unconditional route has to be overcome in order to answer correctly. Moreover, influences from the unconditional route have been found to be completely suppressed on trials with noncorresponding stimulus-response (S-R) location mapping (a stimulus presented to the right, asking for a left response, for example), and on trials that are preceded by a noncorrespodning trial (Stürmer et al., 2002). Whether this is due to suppression of the unconditional route on noncorresponding trials, or whether suppression is the default mode of the unconditional route, and that its effects are temporarily released on corresponding trials, is to date still unknown (see Stoffels, 1996, for an argument for suppression as the standard mode of the unconditional route on non-Simon SRC studies). The conditional route is assumed to work in parallel with, but slower and less automatic than the unconditional route. In the conditional route responses can intentionally be selected and activated. It is further assumed, that a response verification mechanism detects response activation from the unconditional route that is not in agreement with task instructions and prevents direct execution. The conditional route is then activated to resolve the issue (Kornblum et al, 1990). Thus, reactions in accordance with task instructions have to be implemented via the conditional route, when they are not in line with the automatic tendency to react toward the locus of the stimulus.

A recent functional magnetic resonance imaging (fMRI) study by Kerns (2006) found involvement of the dorsal anterior cingulate cortex and the prefrontal cortex in the Simon task. It was found that the anterior cingulate cortex responded to response conflicts on noncorresponding trials, in consequence to which the prefrontal cortex was activated. The prefrontal cortex also stayed more active on the next trial if the previous trial had been noncorresponding. Kerns' results can well

be seen as a neurobiological reflection of dual-route processing: once automatic processing is disrupted by the noncorrespondence of a trial, the less automatic and hence slower, but more flexible processing of the conditional route resolves the conflict employing prefrontal regions. The activity in the anterior cingulate cortex that seems to trigger prefrontal activity likely reflects the working of a control mechanism, like the response verification mechanism suggested by Kornblum and colleagues (1990). Even more recent studies have confirmed the involvement of the prefrontal cortex in response-conflict resolution using transcranial magnetic stimulation (Stürmer, Redlich, Irlbacher, & Brandt, 2007; Rounis, Yarrow, & Rothwell, 2007).

Few research has, however, tackled the question to which extent processing of both routes can be controlled voluntarily. Logan and Zbrodoff (1982) precued the correspondence level of upcoming trials in a Stroop task and found RT decreases on informatively cued trials, relative to uninformatively cued trials. They inferred from their results that participants had switched their attention to irrelevant stimulus features (i.e. the location of the stimulus) and away from the relevant stimulus features (in their case word meaning: “above”, “below”) when informatively cued. Cognitive interference on noncorresponding trials would then have been reduced, because identity information would not have been processed to a sufficient degree as to activate a different response than the spatial information. With respect to the dual-route model, one could imagine the conditional and unconditional routes as having connections to response selection stages. By focusing or not focusing on relevant input for the mechanisms of one of these routes (i.e. spatial information for the unconditional route and identity information for the conditional route) one could control which route will gain access to response stages. In the face that it seems not possible to neglect the spatial information of a stimulus entirely (Simon effect), focusing solely on the location of the stimulus seems a way to prevent the conditional route from activating a response and thus to prevent response conflict. An alternative explanation of the findings by Logan and Zbrodoff (1982) was offered by Wühr and Kunde (2008). They suggested that participants might not have switched their attention in an all-or-nothing fashion from relevant to irrelevant stimulus dimensions, but

pointed to the fact that gradual increases or decreases in attention for either stimulus feature can also explain the findings. In terms of the dual-route model, they thus argued against a total exclusion of information relevant for e.g. the conditional route, and for the possibility of gradual adjustments in the amount of activation conveyed by either route to response stages. This would be accomplished by gradually increasing or decreasing the amount of relevant information for processing in either route that is selected. In the context of an Eriksen task a similar mechanism was suggested by Gratton, Coles and Donchin (1992), who had found pronounced flanker interference following cues that predicted a corresponding trial, while flanker interference following noncorresponding cues was the same as following neutral cues. They suggested that in response to compatible cues participants had extended their focused processing of the visual scene to also include the stimuli presented to the left and the right of the target, while their attention was focused exclusively on the target when the cue had been neutral or noncorresponding.

In a recent study Wühr and Kunde (2008) investigated the possibility of this, as they called it, gating (also see Mordkoff, 1998) in a two- and three-choice Simon paradigm. Using 100% reliable cues about the correspondence level of the upcoming trial, as well as neutral cues, they found that their participants could switch their attention from stimulus identity to stimulus location in a two-choice task. In a three-choice task, however, a 'noncorresponding' cue does not reduce response alternatives to one per stimulus location (e.g. the middle and right response button are both noncorresponding for a stimulus on the left). Thus, in order to answer reliably correct and still experience RT profit from the information conveyed by the cue, a spread of attention across both stimulus features would be required (gating). Pure reliance on spatial information would result in errors on half of all trials cued as noncorresponding. Such RT benefits were not found in a three-choice task when the noncorrespondence of a trial was known in advance, indicating that participants had not been able to use the spatial information given by the cue.

The current study builds on the studies by Stürmer et al. (2002) and Wühr and Kunde (2008) in gathering more evidence on the possibility and extent of top-down control in the Simon task, while

examining possible influences from the correspondence level of the previous trial (sequence effects). Inclusion of the correspondence level of the previous trial seems to be crucial in studies on voluntary control in the Simon task, because cue-induced control seems to differ from the processes involved in sequential modulations (Alpay, Goerke, & Stürmer, 2008). Averaging across these levels could thus well lead to different conclusions than when looked at apart.

In our endeavor we relied on the use of cues, that were presented to the participants before each trial in a visual two-choice Simon task. The cues, consisting of the letters c and i, indicated whether the upcoming trial would have a corresponding or noncorresponding S-R location mapping. Predictions made by both of these cues were valid only 80% of the time, the rationale behind this being that when the correspondence of the upcoming trial is known in advance with certainty, it is possible to solely rely on stimulus location for response selection (attention switching, see Wühr & Kunde, 2008). To prevent subjects from adopting such strategies, 20% of all trials were preceded by invalid cues (c cue while the upcoming trial is in fact noncorresponding, i cue while the upcoming trial is in fact corresponding). Neglecting stimulus color and relying solely on the combined information from cue and stimulus location would thus show in exceptionally high error rates on these invalidly cued trials. Also, a non-informative cue ("--") was introduced to establish a basis for comparison with informatively cued trials and earlier studies. Subjects were instructed to prepare themselves for the upcoming stimulus by visually imagining the scenario predicted by the cue. They then had to respond to the color of a filled circle by pressing one of two buttons with either their left or right index finger as fast and accurate as possible.

It was expected that deliberate, top-down control over stimulus processing, in a sense of gradual adjustments in the amount of involvement of the conditional and unconditional route (gating), would show in Simon effects on trials cued as corresponding or non-informative, while error rates stay within reasonable boundaries even on invalidly cued trials. Meanwhile, on trials cued as noncorresponding, one would expect the absence or a reversal of a Simon effect because subjects anticipate the negative influence of the automatic tendency to respond on the same side of stimulus

presentation on performance and choose to rely more on elaborate conditional route processing. Of particular concern in this matter was the question of whether these expectations would come out when the preceding trial had been of a noncorresponding S-R location mapping, because unconditional route processing would then have to be expected to be suppressed on the current trial. In this case it would need deliberate unblocking of the unconditional route by our subjects to arrive at a Simon effect on validly cued corresponding trials.

Methods

Participants. Eighteen undergraduate students (three male, 15 female, mean age 20.5 years) from the Faculty of Behavioral Sciences of the University of Twente participated in the study for course credits. All participants had normal or corrected to normal vision and were not colorblind, as checked for with the Ishihara test for colorblindness (Ishihara, 1976). Sixteen participants were right handed and two left handed as indexed by the Annett Handedness Inventory (Annett, 1970). All participants gave written informed consent prior to the study. The study was approved by an ethics committee of the University of Twente.

Apparatus. Participants were seated in a darkened room behind a desk with a generic QWERTY keyboard and about 60cm away from a 17" CRT monitor running at a resolution of 1024x768 pixels and a 70Hz refresh rate. Stimuli were presented using Neurobehavioral Systems Presentation (v 11.0) on a X-68 based home PC with single core 3GHz processor, 1GB of RAM and onboard video card. Auditory feedback was presented from standard computer speakers. Event markers containing information on the sort of stimulus, reaction and feedback were sent to a Brain-Amp amplifier (Brainproducts GmbH) connected to a second PC, where they were recorded alongside the electro-oculogram (EOG), using Brainvision Recorder (v 1.03). Vertical and horizontal electro-oculograms (vEOG, hEOG) were recorded from AgCl electrodes below and above the left eye and on the outer canti at a sampling rate of 1000Hz and a resolution of 0.0715µV per electrode. A high cutoff filter was implemented by the hardware at 280Hz. A Notch filter at 50Hz was applied using software. Trials with eye artifacts of more than 60µV horizontally and/or 120µV vertically during the first 200ms after stimulus onset were identified, counted and removed prior to further data analysis.

Task and procedure. Each participant completed 840 experimental trials which were subdivided in 7 blocks with an approximate duration of 10 to 11 minutes each (total runtime of the experiment including EOG setup and pauses was about 90min). Before the recording was started participants completed a practice block of another 80 trials. Between every two blocks short pauses were held with the lights on. Also the response-to-cue interval contained a resting period of 1000ms to give participants the opportunity to blink and relax the eyes. Each trial had an approximate duration of at max 5.8s, and was ended upon any response given by the subject after stimulus offset. If this response was false or no response was given within 1500ms after stimulus presentation auditory feedback was presented and the response was registered as a mistake/miss, respectively. Responses within the first 100ms after stimulus onset were classified as premature.

In each trial either a blue or a yellow filled circle (r = 0.5°) was presented against black background for 100ms within 4-5° to the left or the right of fixation (a chinrest was not used in the study, so head distance to the screen could vary slightly). The task was to use the left index finger to push the left ctrl key or the right index finger to push the enter key of the numpad as quickly and accurate as possible in response to the color of the circle (instructions concerning color-to-finger mapping were counterbalanced across participants). Prior to presentation of the stimulus a light-grey cue (0.9° x 0.9°) comprising one of the letters c, i, or -- was presented at fixation for 800ms and followed by an interval of 2500ms in which only the centrally located fixation cross was shown, so a total of about 3300ms was available for preparation before the target stimulus occurred. Participants were instructed to use this time to internally visualize the supposedly upcoming screen that was predicted by the cue. It was explained to the participants that the cue c stood for “corresponding” which denoted that in the upcoming trial the response would most probably have to be given at the same side as the stimulus appears and that the cue i stood for “noncorresponding” and meant that in

the upcoming trial the response would most probably have to be given at the opposite side[1]. The cue "--" contained no information concerning the correspondence of the stimulus-response location of the upcoming trial. Participants were also informed that the predictions of the c and i cues were sometimes inaccurate to prevent them from basing their responses solely on the location of the stimulus. It was repeatedly emphasized that it was crucial for the experiment to succeed that subjects would actually make an effort to use the information provided by cues.

Fifty percent of all trials presented were of a corresponding, the other 50 percent of a noncorresponding stimulus-response location mapping. On 83 percent of the trials the cue was informative (c or i cues) and 17 percent were preceded by the non-informative cue (-- cue). Occurrence of a c or a i cue was equiprobable. The predictions concerning the stimulus-response location correspondence of the upcoming trial made by c or i cues were accurate 80 percent of the times (about 67 percent of the total number of trials) and 20 percent of the times inaccurate (about 17 percent of the total number of trials)[2]. Cue and stimulus to be presented were selected randomly by the computer with respect to the above restrictions.

[1] The letters c and i were actually chosen because of their relation to the terms compatible and incompatible. For better comprehensiveness and consistency, in this paper we chose to use the equivalent words corresponding and noncorresponding instead.

[2] During practice trials accurate predictions were actually more frequent (89%) to enforce use of the cues in the subsequent experimental blocks.

Results

On average less than five percent of the trials were occluded from analysis due to eye artifacts (sd = 3.6%, max = 14%). Previously, the data of one participant had been excluded from the study because of an excessive loss of trials due to eye movements (> 57%). Reaction time data from the remaining trials were analyzed using repeated measures analyses of variance (RM ANOVAs) with prediction of the cue (corresponding vs. non-informative vs. noncorresponding), correspondence of the current trial N (corresponding vs. noncorresponding) and correspondence of the previous trial N-1 (corresponding vs. noncorresponding) as within-subject factors. Greenhouse-Geisser corrections were used where appropriate. Corresponding and noncorresponding trials were compared using two-sided paired-sample t-tests. Error rates were analyzed in a separate RM ANOVA using the same factors as for RTs. None of the participants responded prematurely throughout the experiment. Analysis of error percentages confirmed good adherence to task instructions, for error terms did not exceed 26% for all cells and subjects and were generally low. An overview of mean RTs and error rates is depicted in Table 1 and Table 2, respectively. A graphic presentation of the found Simon effects per level of cue and N-1 can be found in Figure 1.

RT. Analysis of RT data indicated a highly significant overall Simon effect (14ms), $F(1, 16) = 24.89$, $p < .000$. The correspondence of the previous trial (N-1) had a highly significant effect on RTs, $F(1, 16) = 15.76$, $p = .001$, and interacted highly significant with the correspondence of the current trial (N), $F(1, 16) = 21.13$, $p < .001$, which confirms findings from earlier research on the effect of noncorresponding trials on unconditional route processing and RTs. An overall effect of the cue was insignificant, $F(1.30, 20.79) = 1.12$, $p = .32$. The effect of the cue interacted, however, significantly with the compatibility of the current trial (N), $F(1.06, 16.95) = 4.42$, $p = .049$, and highly significantly with the correspondence of the previous trial (N-1), $F(2, 32) = 18.79$, $p < .000$. Also, a highly significant second order interaction between all three factors was found, $F(2, 32) = 13.97$, $p < .001$.

Further analysis was therefore performed separately for trials with corresponding and noncorresponding predecessor.

Corresponding N-1

On trials with corresponding predecessor an overall Simon effect was found, 26ms, $F(1, 16) = 90.02$, $p < .001$. The cue also had an overall effect on RTs, $F(2, 32) = 8.02$, $p = .002$. Both effects interacted with each other, $F(1.11, 17.83) = 5.79$, $p = .024$. Separate analyses per level of N revealed that noncorresponding trials did not differ significantly across cue conditions, $F(1.25, 19.97) = .60$, $p = .483$, but corresponding trials did, $F(1.12, 17.9) = 16.16$, $p = .001$. In line with earlier research that did not use cues, a Simon effect emerged for non-informatively cued trials, 54ms, $t(16) = 8.43$, $p < .001$. On trials cued as corresponding a same sized Simon effect was found, 53ms, $t(16) = 2.64$, $p = .018$. Although both effects were of the same size (54 vs. 53ms), RTs on corresponding trials were generally faster when preceded by a corresponding cue than when preceded by a non-informative cue (22ms), $t(16) = 3.56$, $p = .003$. This suggests that processing in the unconditional route is not fully exploited under uncued conditions as used in most earlier Simon research and can actively be enhanced. A Simon effect was absent and even insignificantly reversed on trials preceded by a noncorresponding cue, -29ms, $t(16) = 1.54$, $p = .14$. Moreover, responses on corresponding trials were on average 69ms slower when preceded by a noncorresponding cue than when preceded by an non-informative cue, $t(16) = 3.25$, $p = .005$. This finding points to the fact that processing of the unconditional route was mostly disabled following a noncorresponding cue, even on corresponding trials.

Noncorresponding N-1

On trials with noncorresponding predecessor an overall Simon effect was absent, $F(1, 16) = .18$, $p = .678$. So was an overall effect of the cue, $F(2, 32) = 2.21$, $p = .127$. However, both factors interacted significantly, $F(1.12, 17.93) = 4.58$, $p = .043$. Separate analysis per level of N indicated differences

between RTs for noncorresponding trials as a function of the cue, $F(1.05, 16.77) = 5.78$, $p = .027$, but not for corresponding trials, $F(1.26, 20.11) = 1.08$, $p = .329$. Further analysis using two-sided paired sample t-tests revealed a significant reversal of the Simon effect after non-informative cues (-19ms), $t(16) = 2.22$, $p = .041$. Although bigger in size than on non-informatively cued trials, a reversal of the Simon effect was insignificant following non-corresponding cues (-31ms), $t(16) = 1.54$, $p = .142$. In the face of a blocking of the unconditional route from a preceding noncorresponding trial, we would have expected this effect to be significant, if people could place more emphasis on stimulus identity processing. Another t-test showed that RTs for noncorresponding trials were indeed shorter following a noncorresponding cue, than following a non-informative one (10ms), $t(16) = 2.31$, $p = .034$, but obviously this difference was insufficiently big for a Simon effect to reach significance. A significant Simon effect was found for trials cued as corresponding (56ms), $t(16) = 2.36$, $p = .031$. This effect was mainly due to higher RTs on noncorresponding trials that were cued as corresponding as compared to RTs on noncorresponding trials that were non-informatively cued (54ms), $t(16) = 2.21$, $p = .042$. Also, corresponding trials tended to be faster following a corresponding cue than following a non-informative cue (21ms), $t(16) = 2.57$, $p = .021$, suggesting that our subjects have tried to unblock unconditional route processing in response to corresponding cues, possibly by increasing attention for the spatial information of the stimulus. This might have lead to greater difficulties in overcoming location-based responding when a trial cued as corresponding was in fact noncorresponding, thereby explaining aforementioned higher RTs.

Error rates. Overall main effects of the cue and the correspondence of the current trial (N) failed to reach significance, $F(2, 32) = 2.17$, $p = .131$, and $F(1, 16) = .30$, $p = .591$, respectively. Effect of the cue, however, depended again on the correspondence level of N and N-1, $F(2, 32) = 4.54$, $p = .018$, and $F(2, 32) = 12.35$, $p < .000$, respectively. Due to a second order interaction effect on the initial RM ANOVA, $F(2, 32) = 8.99$, $p = .001$, separate analyses were performed for each level of N-1.

For trials with corresponding predecessor the tests indicated a highly significant main effect of the cue, $F(2, 32) = 8.57$, $p = .001$, and an interaction of the cue with the correspondence of the current trial, $F(2, 32) = 7.87$, $p = .002$. A Simon effect was again absent when averaged across cue levels, $F(1, 16) = .23$, $p = .638$. Also, like for RTs, error rates on noncorresponding trials did not vary as a function of the cue, $F(1.39, 22.18) = .36$, $p = .624$, while error rates on corresponding trials did, $F(2, 32) = 10.25$, $p < .000$. Paired sample t-tests indicated Simon effects following corresponding (2.8%) and non-informative (2.8%) cues, $t(16) = 1.76$, $p = .098$, and $t(16) = 3.12$, $p = .007$, respectively. Following noncorresponding cues the effect was significantly reversed (4.9%), $t(16) = 3.21$, $p = .005$. Note that these findings are generally in line with our expectations and the results from RT analysis. Especially the latter finding confirmed the tendency towards a reversed Simon effect following trials cued as noncorresponding. For trials with noncorresponding N-1 there were neither a significant interaction of cue with N, $F(2, 32) = 1.94$, $p = .161$, nor a main effect of the cue, $F(2, 32) = .67$, $p = .518$ or overall Simon effect, $F(2, 32) = .81$, $p = .381$.

Although effects were often insignificant, the general pattern of errors was the same as for RTs (compare Table 1 and 2). Also, error rates were highest under the same conditions under which highest RTs were recorded, thereby indicating that a speed-accuracy tradeoff has not to be expected.

Discussion

In the current study we presented cues containing information on the likely correspondence of the upcoming trial prior to presentation of target stimuli. It was hypothesized that subjects could use this information to exhibit control over stimulus processing, which would ultimately alter RTs. Suggestions were made that these adjustments were accomplished by intentionally shifting the focus of attention gradually from identity to spatial features of the cue, or vice versa, in response to the cues. Thereby the amount of relevant input for processing mechanisms in the assumed conditional and unconditional route, and thereby the power of their response activation, could be increased or decreased, respectively. The current study provides evidence that control in this sense can be exhibited. Also, it confirms that the degree of control depends highly on the correspondence level of the previous trial. In case of a corresponding previous trial the results of the current study indicate that subjects could exhibit control upon the degree of involvement of the unconditional route. In this fashion, RTs were faster for corresponding trials when a cue had previously predicted its correspondence, than when a neutral cue was shown. Also, RTs on corresponding trials were seriously lagged when a cue had previously indicated that the upcoming trial would be noncorresponding. Under conditions that mainly require involvement of the conditional route (i.e. noncorresponding trials) no modulations as a function of the cue were found when the previous trial had been corresponding. However, in case the current trial was preceded by a noncorresponding trial, control over stimulus processing seemed limited, but still not completely absent. For trials with noncorresponding predecessor RTs on noncorresponding trials differed in the expected way as a function of the cue, being significantly higher on trials invalidly cued to be corresponding. This lead to a significant Simon effect, that according to earlier studies should be absent when unconditional route processing is blocked from the noncorrespondence of the previous trial. Under the same conditions there also was an insignificant trend for corresponding trials to be faster than when neutrally cued. It can thus be assumed that a gradual unblocking of the unconditional route caused higher response conflict on noncorresponding trials, the resolution of which was time consuming and

lagged RTs. There also was a trend towards a reversal of the Simon effect on trials cued as noncorresponding. Although insignificant, this trend is in line with the assumption that more emphasis can be placed on the processing of relevant information when the cue indicates which information is relevant in the current setting. In the present study a noncorresponding cue indicated the relevance of identity information, resulting in a trend towards faster responses for noncorresponding as compared to corresponding trials. On trials for which no predictions concerning their correspondence were made (non-informative cue), a reversed Simon effect was found when the previous trial had been noncorresponding. This effect was absent in earlier studies on sequence effects that did not use any form of cueing. We therefore suggested that the use of informative cues in the present study increased the awareness of uncertainty concerning correspondence of the upcoming trial on neutrally cued trials on which this information was not given. This might have triggered strategic adjustments towards less automatic processing to 'play it safe' and not risk faulty responses triggered by automatic processing of spatial features. A different hypothesis was put forward by Wühr and Kunde (2008). They suggested that the correspondence level of the previous trial possibly induces biases to respond either in line or opposite to stimulus location, depending on whether the preceding trial was corresponding or noncorresponding. Although both hypotheses imply some sort of control on stimulus processing, further evidence will be needed to decide between the two.

Concluding, the current study thus provides evidence for the possibility of top-down controlled, strategic manipulations of stimulus processing in the Simon task. Wühr and Kunde (2008) have put forward a powerful account for how this control is implemented and their assumptions find general agreement in the present results. The results of the current study disagree, however, with those of Wühr and Kunde concerning the possibility of gradual adjustments in processing (gating). Gating proved to generally be possible in the present study, although to a very limited degree when the previous trial had been noncorresponding. Wühr and Kunde had not found RT benefits on three-

choice Simon trials whose noncorrespondence was known in advance, i.e. when a gradual involvement of location information would be needed in addition to the more relevant information on stimulus identity to experience those benefits. They therefore concluded that gating cannot voluntarily be adopted for the regulation of response conflict on noncorresponding Simon trials and that attentional switching to irrelevant stimulus dimensions is what causes RT benefits from reliable cues. However, Wühr and Kunde addressed the problem that when using reliable cues the combined information of cue and stimulus location becomes sufficient for response selection, thereby rendering processing of stimulus identity unnecessary, quite differently than we did. By introducing a third response alternative to the task, on noncorresponding trials information from cue and stimulus location would no longer suffice to select an adequate response. The possibility of using unreliable cues had been dismissed because of worries about contamination of the RT data by RT differences caused by the mere surprise of seeing another display than was predicted by the cue and training effects on the much more frequent correctly cued trials. While these worries are theoretically justified, spatial cuing experiments have produced considerable results in spite of the ubiquitous presence of sort alike problems in this field. More importantly, however, the question should be whether better alternatives are available. For example, in order to have three horizontally aligned response alternatives, Wühr and Kunde (2008) had their participants respond by button presses with either the index, middle or ring finger of the same hand. Although Simon effects were found with this setup under certain conditions, it might not be optimal with regard to the comparability with other Simon studies, because other processes are thought to cause these effects in unimanual tasks (Wiegand & Wascher, 2007). Therefore, while we applaud the ingenuity of the solution presented by Wühr and Kunde (2008), we feel that the use of unreliable cues is the better alternative under the given circumstances. In our opinion, the avoidance of the possibility of influences from training and frequency effects on RT data simply do not weigh up against running the risk of studying a quite different mechanism than originally intended.

Of particular interest for future studies should be the control processes involved in the blocking of the unconditional route in response to noncorresponding trials. The results of the current study suggest that this blocking is somewhat flexible, in that RT trends existed that should be expected when one tried to lift the restrictions on the unconditional route when a cue indicates its usefulness. A study by Alpay et al. (2008) showed that different control processes are involved in the initiative blocking of automatic processing in response to noncorrespondence of a trial and the adjustments that were made in response to cues. At this point it seems as if voluntary control processes lose the race against an automatic process, with both competing for processing resources. Future studies should invest the relationship of the two and whether their relative power can be altered.

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Table 1. Mean RTs and standard errors (between parentheses) in milliseconds (ms). Columns indicate the prediction of the cue, rows the correspondence of the current trial N.

RTs and standard errors between parentheses in milliseconds (ms)

N-1 = corresponding				N-1 = noncorresponding			
	cue				cue		
N	corr	non-inf	noncorr	N	corr	non-inf	noncorr
Corr	474 (20)	496 (20)	565 (28)	corr	521 (23)	542 (26)	543 (26)
Noncorr	527 (31)	550 (21)	535 (23)	noncorr	577 (31)	523 (21)	512 (22)

Table 2. Mean error rates and standard errors between parentheses in percent (%).

Error percentages and standard errors between parenthesis (%)

N-1 = corresponding				N-1 = noncorresponding			
	cue				cue		
N	corr	non-inf	noncorr	N	corr	non-inf	noncorr
corr	.55 (.16)	1.78 (.65)	8.35 (1.63)	corr	2.91 (.55)	4.33 (1.11)	3.63 (1.10)
noncorr	3.30 (1.57)	4.53 (1.09)	3.50 (.60)	noncorr	4.36 (1.44)	2.60 (.96)	1.84 (.36)

Figure 1. Graphic depiction of the found Simon effects as a function of the correspondence level of the previous trial N-1 and the prediction made by the cue. An asterisk indicates significance of the effect at .05 level.