Inhibitory influences on the Simon effect in a go/no-go task

Bachelor thesis
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Abstract

The Simon effect describes the phenomenon that subjects respond more quickly when stimulus and response side corresponded than when they did not, even when stimulus positions were irrelevant for the task. Current theories state the automatic production of spatial codes and explain the Simon effect with the conflict of noncorresponding stimulus and response codes. The two major explanations base the formation of spatial codes on stimulus selection and attentional shifting, respectively. A recent study examined which of the two basic cognitive principles could be held responsible for the Simon effect. Results indicated that spatial codes are formed exclusively by spatial attention shifting. It was predicted that the resolution of conflicting spatial codes could inhibit a quick resolution strategy in subsequent trials. The purpose of this paper is to examine whether these inhibitory effects can influence reaction times in a go/no-go Simon task.

Introduction

In 1967, Simon and Rudell discovered a phenomenon that caused different reaction times (RT) dependent on the layout of stimuli and response keys. In their experiment, subjects responded to stimuli on one side of the screen (left or right) with one of two buttons on either side. Trials in which both stimulus and response shared the same spatial side produced significantly quicker responses than trials where both items were present on different sides. Since then, the underlying mechanisms causing the so-called Simon effect have been investigated thoroughly. The first confirmation of this effect for visual stimuli was provided by Craft and Simon (1970), where a modified stereoscope divided the visual field into left and right halves, allowing for proper visual control. In their first experiment, participants were instructed to respond to red and green lights with their left or right hand. Colored lights were shown randomly in either side of the visual field, either for both eyes (in the binocular condition) or only in the corresponding eye (in the monocular condition). The results indicated that trials with stimulus-response (S-R) correspondence were up to 50 ms faster than noncorresponding trials, even if the stimulus location was irrelevant for the response decision. Not only confirming the Simon effect, the results also provided the first indication for the underlying cognitive processes. Because trials in the binocular condition averaged lower RT than trials in the monocular condition, the authors concluded that the effect was likely to be primarily based on interference from noncorresponding items rather than to facilitation from S-R correspondence. The term of interference is since then widely used in the context of differences between RT in trials with or without S-R correspondence (e.g. Hommel, 1993). Subsequent experiments investigated at which processing stage the Simon effect is most likely to occur. Guiard (1983) found a strong Simon effect when subjects responded to differently pitched tones with turning a wheel clockwise or counterclockwise. Clockwise rotations were initiated faster when tones were presented to the right ear, and vice versa, indicating that the Simon effect is based on response selection rather than on response execution. This interpretation was later confirmed by several experiments (e.g. Umiltà and Nicoletti, 1992). An early study by Hedge and Marsh (1975) suggested that S-R compatibility tasks lead to the automatic formation of a so called spatial code, even when spatial stimulus information was irrelevant to the task. In their second experiment, Craft and Simon (1970) projected the stimuli on each eye independently, but the exact same perceived location in the visual field. The experiment yielded no Simon effect, favoring the conflicts of spatial codes over “hard-wired” interference effects. In all example experiments, spatial codes were created even if stimulus location was irrelevant to the task, supporting the view of automated, unconscious creation.

As for today, there is still no consensus about the underlying mechanisms creating these spatial codes. Amongst all possible mechanisms, two major theories have been supported with most experimental evidence. First, the *attention-shift* hypothesis claims that spatial codes are formed by a shift of attention from the former to the actual target location, making stimulus codes independent from the physical task layout. Umiltà and Nicoletti (1989) conducted an experiment where a fixation point was present at one far side of the display, where participants were required to keep looking at. A row of six unfilled boxes was spread across the display, with a precue appearing between two of the boxes. After the subjects’ attention had shifted towards the precue, one of the two boxes showed a pattern which required an equivalent response. The results indicated that amount of the Simon effect could be influenced by the duration between precue and key stimulus, with longer preparation phases equaling a larger Simon effect. These results suggest that rather than absolute spatial information, the direction of the final attentional shift is producing the relevant stimulus codes. Second, the *referential coding* theory suggests that spatial codes are formed with respect to objects or frames of reference in the display. Hommel (1993) challenged the attentional shift hypothesis with an experiment that provided additional visual cues that were constant over time and strongly visible. The Simon effect was found in all conditions where the stimulus appeared in the context of a reference cue. A refined reference coding experiment by Rubichi et al. (1997) resulted in the suggestion that stimulus codes could be in fact be associated with the last relevant stimulus rather than with the element that initiates to the response decision. By introducing the suggestion that the relevant frame of reference could be identical with the locus of attention, the study connected the both theories with a common factor: attentional phenomena. Although it is widely suggested (e.g. Nicoletti & Umilta, 1989, 1994; Proctor and Lu, 1994; Treccani, Umiltà & Tagliabue, 2006; Abrahamse & Van der Lubbe, 2008) that attentional processes play an important role in creating the Simon effect, the different studies are far from expressing a univocal explanation. For example, neither attentional shift nor referential coding accounts provide a theoretical basis for the beneficial effect of precueing the likely response (e.g. Verfaellie, Bowers and Heilman, 1988). For an attempt of describing the underlying mechanism of the Simon effect, the dual-route model (De Jong, Liang and Lauber, 1994; Hommel, 1993) describes two separate cognitive routes that engage in processing stimulus and response codes. The conditional route is thought to be the slower, intentionally controlled path, and regulated by task instructions. In comparison, the unconditional route provides a fast bypass between perceptive and motor areas. If both spatial codes shared the same property, the unconditional route would be sufficient for a correct task resolution. Different stimulus and response codes are thought to produce a conflict that requires higher-level decisions (e.g. see Kornblum, Hasbroucq and Osman, 1990; Ridderinkhof, 2002). This conflict could, in turn, only be resolved by the conditional route, resulting in a slower reponse. Stürmer, Leuthold, Soetens, Schröter and Sommer (2002) predicted with data from functional imaging that the use of the conditional route would inhibit unconditional route activation in following trials. This inhibition has been found to spread over several seconds between trials, causing an interaction between correspondence and prior correspondence on RT (Van der Lubbe & Lauffs, in preparation). To examine these inhibitory effects, an experiment requiring the usage of conditional and unconditional routes would be necessary. A replication of the second experiment by Van der Lubbe and De Kleine (in preparation) was deemed adequate to assess this question with only minor modifications. The original experiment was conducted with the goal of determining whether attentional selection or the shifting of attention could be held responsible for the Simon effect. To be able to properly discriminate between these two hypotheses, the possibility of including unattended stimuli was rejected. The orienting response (see Posner, 1980 for a review) would be inevitable to interfere. For it being an attentional phenomenon, this effect would be difficult to measure even under constant EEG survey, let alone control. The adequate alternative was an attentional shift condition even in the absence of a stimulus. Therefore, both the original and the current experiment feature a condition in which a lateral attentional shift towards the opposite side of the display was required. This condition was implemented by showing a tiny grey dot in the peripheral visual field which had almost no salience value. Because the dot (and its unpredictive occurrence) was crucial to the response decision, the participants needed to shift their attention across the display in each trial. To prevent eye movements, instructions stated a fixation on the opposite (salient) stimulus, an unfilled circle. This circle, in combination with the grey dot, provided the necessary information to make a correct response. There were two color conditions: yellow and blue. If the circle had flashed yellow, the dot that appeared simultaneously on the opposite side had the role of a “go” cue. In this condition, an absent dot required no response. If the circle had flashed blue, the dot had the opposite role and only the absent dot required a response. The circle, appearing 2 s before the key stimulus, provided both fixation point and the role of a precue. The position of the circle was randomized, as well as the side of the required response. To prevent response side instructions to interfere with stimulus codes, the instruction on which side to respond was provided in the beginning of each trial. If the Simon effect relied on stimulus detection, the S-R interference would only have occurred in those cases in which the key stimulus (the small dot) was visible. However, results suggested that the interaction between color condition and Simon effect was neglectable, supporting the hypothesis of attentional shifts. This study is a follow-up of the second experiment by Van der Lubbe et al., reproducing the original task as well as possible. However, to include the analysis of serial effects, this study introduced a higher ratio of *go* versus *no-go* trials.

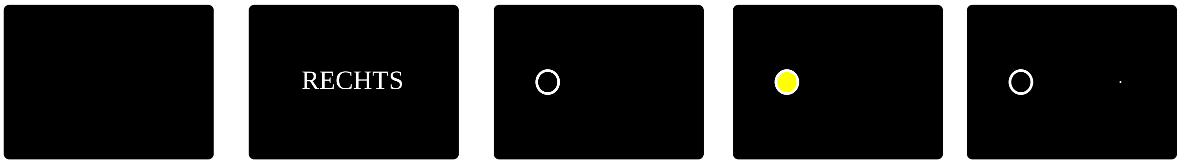
On the basis of the specified findings about the Simon effect, two hypotheses are postulated in this paper. First, this study aims to replicate the findings from the second experiment by Van der Lubbe et al.; especially the presence of a Simon effect and the absence of interaction between color condition and S-R correspondence. Second, inhibitory effects from the usage of the conditional route are expected to increase RT in following trials with corresponding stimuli and response codes.

Methods

Participants. Seventeen students from the University of Twente participated in the experiment in exchange for course credits. Their history was reported to be free of neurological diseases. All participants had normal or corrected to normal vision. The study was approved by the ethics committee of the local faculty, and all participants signed a written informed consent. The 17 subjects (1 male and 16 females, 3 left-handed and 14 right-handed) had a mean age of 22.4 years (range: 17-26).

Stimuli and Procedure. Stimuli were presented on a 17 inch monitor at a distance of 70 cm in front of the participant in a darkened room. The software "Presentation" (version 11.0) was used for stimulus presentation. The default screen (for a complete trial illustration, see Fig. 1) consisted of a black background. A trial started with the default screen shown for 2500 ms. Next, the centered word “links” (i.e. left, Arial 15 white) or “rechts” (i.e. right) could be read for the duration of 1000 ms. Then, an unfilled white circle (r = 6 mm) was positioned on either the left or right side of the screen, resulting in a deviation of 12.7° from the middle. After 2000 ms, the circle was briefly filled with the color yellow or blue for 25 ms (a process further referred as color presentation). Afterwards, in a tiny (r = 0.04°) grey colored pixel appeared on the other side of the screen, providing the key stimulus. In approximately 50% of the cases, no such dot was presented. This key stimulus remained in place for 1000 ms. 1000 ms after initiation of the dot, or if a response was given within this timeframe, the next trial started by showing the default screen again. 80 trials of the experimental design *color* (2) x *correspondence* (2) x *go/no-go* (2) were combined to an experimental block of about 10 minutes. 6 succeeding blocks resulted in 480 trials. After each block, a short break was conducted. Duration of the break was according to the participants' will, as they could continue their trials by a key press.

Task. There were three independent conditions which decided the correct outcome for each trial. First, the shown word ("links" or "rechts") indicated if the left or the right Ctrl key had to be pressed at the end of the trial. Participants were instructed to remember the correct response location. Second, the color of the filled circle determined the role of the tiny dot. Participants were instructed to look at the circle and to hold their eyes steady until responding. Third, the tiny dot in combination with the color presentation determined the correct response. In case of a yellow circle, the presence of a tiny dot meant that a key press was required. In case of a blue circle, only the absence of a tiny dot meant that a key press was required. Both cases are defined as "go" condition. For the opposite cases, no response had to be given. Accordingly, these cases are defined as "no-go" condition. The ratio of go vs. no-go trials was defined as 4:1 (80% go trials). Instructions included responding as quickly and as accurately as possible. An incorrect response, either given with the wrong hand or given when no response was expected, resulted in an error warning after a delay of 500 ms. This warning consisted of a centered circle filled red, presented for 1000 ms, and the simultaneous Windows XP "Error" sound. Eye movements were constantly monitored for movements in the critical period of time (especially movements towards the grey dot) using the EOG measurements and subjects were reminded of this particular instruction if necessary.



blank screen (2500) response cue (1000) fixation point color presentation (25) key stimulus (1000)

Figure 1. Illustration of one trial sequence (from left to right).
Exemplary screen items are not to scale. Slide durations are given in ms.

Data Acquisition. EEG data were recorded using 64 Ag/AgCl ring electrodes placed on a standard 10/10 cap. Electrode impedance was held below 5 kΩ. Button triggers, EEG and electrooculographic (EOG) data were amplified by a Quick-Amp (BrainProducts GmbH) and recorded at a sample rate of 1000 Hz with BrainVisionRecorder (Version 1.4). EEG data were digitally filtered (TC = 0 s, high-cutoff filter of 200 Hz, notch filter of 50 Hz) by Brainvision Recorder. Vertical EOG electrodes were positioned above and below the left eye, whereas horizontal EOG electrodes were placed on the outer canthi of both eyes. Every second break, the lights were turned on to measure electrode conductivity, and to reestablish proper electrode contact if necessary.

Data Analysis. Due to a software error, one participant finished the experiment prematurely. The equivalent experimental trials were removed from the data set, leaving 16 subjects for the analysis. Trials including behavioral errors or EOG activity exceeding 60µV until 400ms after color presentation were counted individually and then removed from the final data set. No EEG data was taken into consideration for this analysis. Only if the expected response was given (i.e. suppressed, for no-go trials) between 100 and 1500ms after the color presentation, the trial was considered correct and the according response time (RT) was selected for further analysis. “Corresponding” trials were indicated by color presentation and response on different spatial sides (because the area where the dot could appear then corresponds with the response side). Similarly, “Noncorresponding” trials included color presentation and response on the same spatial side. To analyze the effect of S-R correspondence during the previous trial, the variable *prior correspondence* was introduced supplementary. Mean RT were computed per participant by repeated measures ANOVA with five experimental factors (*color*, *stimulus side*, *response side*, *correspondence* and *prior correspondence*). The proportion of correct responses (PC) was evaluated separately for “go” and “no-go” trials.

Results

Responses were faster for yellow circles than for blue circles F(1,15) = 17, p < .001. There was a very weak interaction between *stimulus side* and *color*, F(1,15) = 2.5, p < .14. The interactions *color* x *response side* and *color* x *prior correspondence* did not reach significance, F(1,15) < 2.3, p > .20. A main effect of *response side* was found, with trials given with the left hand being 16 (6.1) ms faster than those given with the right hand, F(1,15) = 7.2, p < .017. A main effect of *stimulus side*, with 14 (2.9) ms slower responses for circles on the left side against circles on the right side, F(1,15) = 23, p < .001, could be found. The interaction *response side* x *stimulus side*, which describes the variable *correspondence*, indicated that corresponding trials produced 8.9 (3.7) ms faster responses than noncorresponding trials, F(1,15) = 5.8, p < .030. Neither the interaction *stimulus side* x *prior correspondence* nor the interaction between *color* and *correspondence* reached significance F(1,15) < 2.3, p > .20. More important, there was also neither a main effect of *prior correspondence*, F(1,15) = 0.03, p = .87, nor an interaction *prior correspondence* x *correspondence*, F(1,15) = 0.16, p = .70.

RT	SLeft	SRight	RLeft	RRight	Corr	NonC
Yellow	542 (26)	531 (26)	527 (27)	546 (26)	533 (27)	540 (27)
Blue	600 (31)	583 (31)	585 (29)	599 (34)	586 (30)	597 (33)

Table 1. Mean RT (in ms) and their standard errors (in brackets) as a function of color (yellow/blue) for the variables stimulus side (SLeft/SRight), response side (Rleft/Rright) and correspondence (Corr/NonC)

Analysis of “go”-PC revealed that responses for blue circles were less accurate than yellow circles (97.2 (0.3) % vs. 98.0 (0.3) %, F(1,15) = 4.46, p < .035). This difference could also be found in “no-go”-PCs (74.2 (1.4) % vs. 85.2 (1.4) %, F(1,15) = 29.8, p < .001). No other effects were found (F < 2.3).

PC	Go	No-Go
Yellow	98.0 (0.3)	85.2 (1.4)
Blue	97.2(0.3)	74.2 (1.4)

Table 2. Proportion of correct responses (in %) and their standard errors (in brackets) as a function of the variable color (yellow/blue) for the go/no-go condition

Discussion

The results concerning response times and accuracy clearly demonstrate the influence of the Simon effect during trials. Successfully replicating the findings from the second experiment by Van der Lubbe et al., responses were faster and more accurate when the direction of the attentional shift corresponded with the response location. As the Simon effect was of equal size for both color conditions, this effect did not at all depend on the presence of a visual stimulus. These findings, altogether, confirm the first hypothesis. More importantly, no interference from previous noncorresponding trials was found. By supporting the null hypothesis, this result provides evidence against the second hypothesis. As inhibition processes usually take place in the magnitude of one second (Stürmer et al., 2002), a possible explanation includes that the duration of one trial cycle (still approximately 7.5 seconds) was too long for this effect type to interfere with RT. However, a current study (Van der Lubbe and Lauffs, in preparation) shows in a similar experiment. Assuming that the dual-route model fully applies to this particular task environment, it is safe to conclude that reaction speed was not influenced by the inhibition of the unconditioned route. However, there is some reasonable doubt that the dual-route model can describe the mechanism that caused the Simon effect to take place during the experiment. In contrast with the majority of other studies covering this topic, the response cue was given at the beginning of each trial cycle. While this procedure reduced the effective decision workload for the subject, it is also possible that the conflict between spatial codes was reduced or eliminated by introducing a long response preparation time (of approximately 5 seconds). By resolving spatial conflicts during this preparative period, the dual-route-model would have been reduced to the constant application of the unconditional pathway during the response section. Because only very few findings confirm the formation of Simon effects during decision preparation (e.g. see Vallé-Inclan, 1996), is is difficult to conclude whether the observed interference can be explained by this interpretation.

A final notation includes the comparison of this analysis to the replicated original. The findings from the second experiment by Van der Lubbe et al. indicate a Simon effect of twice the size, compared to our results. Our data analysis revealed the strong main effect of stimulus side, which, together with the unexpected RT advantage of the left hand, indicates a different size of Simon effects for either responding hand. This artifact could be explained when the seating position of the research assistant is taken under consideration. During this experimental task, the assistant and the control station was constantly positioned on the left side of the participant. We expected a slight interference beforehand and reduced the salience of the control station (by turning the dimmed monitor out of sight and by sitting in the far peripheral visual field). However, the results suggest that the mere presence of the assistant on one side provided enough attentional interference to collapse Simon effects on the opposite response site completely. Therefore, we suggest posing adequate attention towards potential social, or at least spatial, asymmetries in the environment layout.

In conclusion, the current experiment provided additional support for the attentional shift hypothesis, a possible explanation for the mechanism producing stimulus codes. No response interference appeared across different correspondence conditions. Considering the dual-route model as a description of the cause for Simon effects, there was no inhibition effect from the conditional route on unconditional decisions. Whether this phenomenon relies on decision preparation effects or provides the basis for an alternative explanation model for the Simon effect is subject for future research.

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