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# DECAY OF STIMULUS SPATIAL CODE IN HORIZONTAL AND VERTICAL SIMON TASKS

Antonino Vallesi[#*$] and Carlo Arrigo Umiltà[*]

[#]International School for Advanced Studies, SISSA, Trieste, Italy; [*]Dipartimento di Psicologia Generale, Università degli Studi di Padova, Italy

[$]Corresponding author's contact information:

Antonino Vallesi

International School for Advanced Studies

Cognitive Neuroscience Sector

via Beirut 2-4; 34014 Trieste, Italy.

Telephone: +39-040-3787622

Fax: +39-040-3787615

E-mail: vallesi@sissa.it

Abstract

The evidence on the processes underlying the horizontal and vertical Simon effect is still controversial. The present study uses experimental manipulations to selectively delay the stages of response execution, response selection and stimulus identification in three experiments. A reduction is observed for both horizontal and vertical Simon effects when response execution is delayed by a go-signal presented 400-600 ms post-stimulus onset or when a spatial precue is presented 200-400 ms before the stimulus. When the overlap between stimulus spatial code formation and response selection is prevented by decreasing stimulus discriminability, the horizontal Simon effect decays, whereas the vertical Simon effect does not change. Activation theories, which propose a decay of the automatically activated response ipsilateral to the stimulus, mainly apply to the horizontal Simon effect. In contrast, translation theories, which propose that the effect occurs when stimulus features are translated into a response code, are more suitable to account for the vertical Simon effect.

Manual responses to stimuli appearing on the same side as the responding hand (corresponding condition) are faster and more accurate than those to stimuli appearing on the opposite side (non-corresponding condition), even when the stimulus spatial position is irrelevant for the task (Simon & Rudell, 1967). This phenomenon is known as the Simon effect (e.g., Simon, Hinrich, & Craft, 1970).

The Simon effect is a highly replicable phenomenon occurring under a variety of choice-RT tasks (see Lu & Proctor, 1995, for a review). It has been reported with auditory and visual stimuli (e.g., Roswarski & Proctor, 2003), with button-presses and wheel-rotation responses (Guiard, 1983), with crossed and uncrossed hand positions (Wallace, 1971; Wascher et al., 2001), with left and right stimuli presented in the same visual hemifield (Umiltà & Nicoletti, 1985; Umiltà & Liotti, 1987), with horizontal and vertical stimulus-responses (S-R) set (i.e., horizontal and vertical Simon effects; De Jong, Liang, & Lauber, 1994; Valle-Inclán & Redondo, 1998; Vallesi, Mapelli, Schiff, Amodio, & Umilta, 2005; Wiegand & Washer, 2005). The present study aims to investigate whether similar mechanisms underlie the horizontal and vertical Simon effects.

Two main types of accounts have been proposed to explain the standard (horizontal) Simon effect: (i) translation theories and (ii) activation theories. Translation theories (Hasbroucq & Guiard, 1991; Wallace, 1971) assume that both stimulus and response positions are cognitively represented through codes (e.g., left and right), that these codes are matched during response generation, and that when there is a mismatch between these codes, this should be resolved, giving rise to a cost in terms of RTs and accuracy. In contrast, activation theories (e.g., Kornblum, Hasbroucq, & Osman, 1990; Simon, 1969) assume that the irrelevant spatial code of a stimulus primes a congruent response code. This automatically generated code is thought to interfere with the activation of the relevant response code, which in turn derives from the task-relevant stimulus feature (e.g., colour or shape). With corresponding codes, the irrelevant code is assumed to facilitate response selection, whereas with non-corresponding codes a conflict has to be resolved, which delays responses (De Jong et al., 1994; Umiltà & Nicoletti, 1990; Zorzi & Umiltà, 1995).

Complementary to the activation theories is the temporal-overlap hypothesis (Hommel, 1993; see also Kornblum, Stevens, Whipple, & Requin, 1999), according to which the response activation by a task-irrelevant spatial code starts with the presentation of the stimulus, usually before the response activation associated with the task-relevant code, and then spontaneously decays over time. An implication of the temporal-overlap model is that any experimental manipulation that increases the temporal distance between formation of task-irrelevant and task-relevant codes reduces the Simon effect. A number of studies, indeed, demonstrate that the Simon effect is reduced when stimulus attributes (e.g., discriminability, eccentricity, intensity) are manipulated so that the overall processing time (and RT) increases (Hommel, 1993, 1994; Wascher, Verleger, & Wauschkuhn, 1996), or when response execution is experimentally delayed by instructions (e.g., Simon, Acosta, Mewaldt, & Speidel, 1976). This empirical evidence suggests that automatic response activation by the (irrelevant) spatial code decays as time elapses (e.g., Eimer, Hommel, & Prinz, 1995; Hommel, 1993, 1994).

Additional evidence for the decay hypothesis derives from examination of the RT cumulative distributions for corresponding and non-corresponding conditions (De Jong et al., 1994; Rubichi, Nicoletti, Iani, & Umiltà, 1997; Schiff et al., 2006; Vallesi et al., 2005). It has been found that the Simon effect disappears, or even reverses, at the longest ranges (so-called bins) of the two RT distributions. However, the decay hypothesis, as tested through RT distributional analysis, has encountered empirical exceptions. Although it has repeatedly been shown with regular horizontal S-R arrangements, the postulated decrease of the Simon effect with longer RTs has not been observed when participants performed a Simon task with crossed hands, with acoustical stimuli or with vertical S-R arrangements (e.g., Vallesi et al., 2005; Wascher et al., 2001; Wiegand & Wascher, 2005; but see De Jong et al., 1994). Moreover, the validity of the distributional analysis is an issue of debate (e.g., Roswarski & Proctor, 2003; Zhang & Kornblum, 1997). When the variances of the two underlying distributions are considerably different (which often happens), the assumptions of the bin analysis are violated and the results might consequently be invalid (see Zhang & Kornblum, 1997, for details).

Wascher and colleagues (2001; see also Wiegand & Wascher, 2005) proposed that different types of mechanisms of S-R transmission can be active during a Simon task, depending on the experimental settings. With the ergonomic hand position (i.e., horizontal, parallel posture), an activation account would apply, according to which stimulus spatial parameters are processed within privileged visuomotor pathways, resulting in a facilitation of the corresponding response for RTs in the shorter range. In contrast, with crossed hands or vertical positions, the translation account (e.g., Hasbroucq & Guiard, 1991) would apply, that is the Simon effect is held to originate from interference between spatial codes during translation of stimulus into response. This account would explain why the Simon effect can manifest itself even with relatively long RTs. However, De Jong et al. (1994) found that the vertical Simon effect can also decay. A possible reason for this discrepancy might be that, in De Jong et al.'s study (1994), also the response keys were coloured, which might have generated a task with different cognitive demands, similar to that in the Hedge & Marsh study (1975; type 5 ensemble in the taxonomy proposed by Kornblum, 1994).

Another source of evidence for different mechanisms underlying the horizontal and vertical Simon effects derives from studies using Lateralised Readiness Potentials (LRPs), an electrophysiological index of response selection (Vallesi et al., 2005; Wiegand & Wascher, 2005). With horizontal Simon tasks, early LRP shows a pre-activation of the response ipsilateral to the stimulus (suggesting automatic response activation). In the case of corresponding trials, the LRP continues to increase, as the direction of the pre-activation was correct. With non-corresponding trials, the LRP inverts its polarity at around 200-300 ms, as the pre-activated response is opposite to that required by the instructions. For the vertical Simon task, instead, no early deflection in the wrong direction is observed during non-corresponding trials. In this case, the LRP onset is only shifted in time with respect to corresponding trials.

This finding is at odds with previous studies in which the early LRP deflection in the wrong direction was observed even with vertical S-R arrangements (De Jong et al., 1994; Stuermer, Leuthold, Soetens, Schroeter, & Sommer, 2002), although, when the vertical task is directly compared to the horizontal one, this deflection is smaller in the former than in the latter case (Valle-Inclán, 1996). Moreover, it has been argued that the early LRP deflection might be due to volume conduction from posterior ERP lateralizations elicited by horizontal stimulus positions (Eimer, 1998; Valle-Inclán, 1996). However, using current source density analysis, Praamstra and Oostenveld (2003) showed that lateralizations measured over posterior and central electrodes may derive from different sources (but see Praamstra, 2007, for a more critical view on the use of LRP to compare vertical and horizontal Simon tasks).

In the present study, Wiegand and Wascher's proposal (2005) of different mechanisms underlying horizontal and vertical Simon effects has been investigated. The criticisms against the distributional analysis and the electrophysiological data were circumvented using a more traditional approach. In particular, in experiment 1 a go-signal paradigm was employed. The aim of this manipulation was to explore the possible different outcome of selectively delaying the response execution stage on the horizontal and vertical Simon effects. In experiment 2, a spatial precue technique was adopted to delay the stage of identification of the relevant stimulus feature with respect to formation of the stimulus spatial code. Because, the abrupt onset of the stimulus in the same place of the spatial precue might have produced a new shift of attention, preventing the Simon effect to decay (Nicoletti & Umiltà, 1994; Rubichi et al., 1997; Stoffer & Umità, 1997), in experiment 3 the target stimulus was presented as a whole, but the stage of stimulus identification was delayed with respect to formation of its spatial code by making the discrimination of the task-relevant stimulus feature more difficult and time-consuming.

Stürmer and colleagues (Stürmer et al., 2002; Stürmer & Leuthold, 2003) reported findings supporting the existence of a process that actively controls the automatic response activation by the stimulus position in a Simon task. When a corresponding condition occurred on the preceding trial, a typical Simon effect is observed on the next trial. Critically, when a non-corresponding condition occurred on the preceding trial, the Simon effect was suppressed on the next trial. For this reason, we chose to analyse the current data by sorting the trials according to the correspondence condition of the previous trial.

## Experiment 1

The aim of experiment 1 was to investigate whether the locus of the vertical Simon effect extends after the response selection stage. To this purpose, a go-signal paradigm was introduced, in which the response had to be withheld until a go-signal appeared at stimulus location, even though the stimulus was available before the go-signal. The go-signal procedure had previously been adopted by Simon et al. (1976) to track the time-course of the interference effect by the irrelevant spatial stimulus code in the horizontal Simon task. As results of their experiment 1 showed, the Simon effect disappeared after a delay of 250 ms between the stimulus onset and the presentation of the go-signal. To our knowledge, no attempt has ever been made to study the same phenomenon in the vertical Simon task.

# Method

## *Participants*

All the participants were university students that voluntarily took part in the study and did not receive any remuneration. Twelve participants volunteered in experiment 1. They were 24 years old on average (range = 18-31; 4 females). All of them were right-handed (writing hand) and had normal or corrected-to-normal vision. All were naïve about the purposes of the experiment.

## *Apparatus and Materials*

Participants were tested individually in a silent and dimly illuminated room. A personal computer was used for stimulus presentation and response sampling. Visual stimuli were presented through a 17-inch VGA-display at a distance of about 60 cm. Responses were collected through the computer keyboard. All stimuli were presented on a black background. The fixation point, consisting of a white cross (0.3° x 0.3°), was presented in the center of the screen. The target stimuli were unfilled red or green squares (2° x 2°) presented along either the horizontal or the vertical meridian with an eccentricity of 6.5° visual angle from fixation (center to center). A go-signal replaced the stimulus for 200 ms after a delay that varied across four blocks (no-signal, 200, 400, 600 ms). The delay was varied across blocks rather than within blocks to avoid spurious preparatory effects observed when the foreperiod varies on a trial-by-trial basis (i.e., current and preceding foreperiod effects, see Vallesi, McIntosh, Shallice, & Stuss, 2009; Vallesi & Shallice, 2007). The go-signal consisted of a white square with the same dimension and eccentricity as the relevant stimulus.

## *Procedure and Tasks*

Participants had to make fast and accurate choice responses as a function of stimulus colour in two consecutive tasks. In the horizontal task, stimuli could appear to either the left or the right of the central fixation cross (50% each) and responses had to be given based on colour. Half of the participants were required to press the left key of the computer keyboard (‘C’) for the red square (left index finger) and the right key (‘M’) for the green one (right index finger), independently of stimulus side. The opposite colour-key mapping was assigned to the other half of the participants. In the vertical task, stimuli could appear either above or below the fixation cross (50% each) and responses were executed by half of the participants with the upper key (‘7’) to the red square and the lower key (‘N’) to the green one. The opposite colour-key mapping was assigned to the other half of the participants. Half of the participants pressed the upper key with their right index finger and the lower key with their left index finger. The position of the hands was counterbalanced for the other half of the participants.

The order of presentation of the horizontal and vertical tasks was also counterbalanced across participants. In each task, 4 blocks of 80 trials were presented (20 per each stimulus colour-position combination). The delay between target stimulus and go-signal was manipulated across blocks (no signal, 200, 400 and 600 ms post-stimulus onset), with the order of block presentation randomized (a different sequence for each participant). The total trial duration was kept constant by shortening the fixation duration according to the lengthening of the delay between target and go-signal (duration of fixation: 1100, 900, 700 or 500 ms for no signal, 200, 400 and 600 ms, respectively).

After this period, the target stimulus (coloured square) appeared to either the right or left of fixation (50% each; horizontal task), or either above or below fixation (50% each; vertical task). Participants had to refrain from responding until the go-signal (a white square) replaced the coloured square in all the blocks apart from the no-signal block. In the latter, participants did not wait for a go-signal to respond to the coloured square, but had to execute the response in the moment they saw the target stimulus (i.e., the colored square itself). This block provided a control condition for estimating the size of the Simon effect without a go-signal delay. The time-limit for the response was 2000 ms (200 ms go-signal duration plus 1800 ms blank). When a response was detected, an extra blank of 200 ms was provided. Then the program jumped to the next trial.

*Data Analysis*

An overall 2x4x2 ANOVA was initially carried out including task (horizontal vs. vertical), go-signal delay (no signal, 200, 400 or 600 ms) and preceding correspondence (corresponding vs. non corresponding: $C_{n-1}$ vs. $NC_{n-1}$), as the within-subject factors, and the Simon effect (RT difference in the non-corresponding vs. corresponding trials, that is $NC_n$ - $C_n$) as the dependent variable. The data from the two tasks (horizontal vs. vertical) were then analysed separately. For each task, mean RTs were analysed through 4x2x2 repeated measures ANOVAs, with go-signal delay (no signal, 200, 400 or 600 ms), current correspondence ($C_n$ vs. $NC_n$) and preceding correspondence ($C_{n-1}$ vs. $NC_{n-1}$), as within-subject factors. The same analysis was performed for accuracy. Responses faster than 100 ms or slower than 1500 ms (i.e., typical cut-off values in the literature on the Simon effect) and anticipations given before the go-signal led to the exclusion of the current trial. The latter were analysed separately to ascertain whether participants followed the instruction to wait until the go-signal before responding. The Greenhouse-Geisser ε correction was performed when appropriate. All the significant effects were further analysed by means of post-hoc Newman-Keuls tests.

## Results

*Simon effect for Horizontal and Vertical tasks.* The ANOVA comparing the two tasks yielded several significant effects (i.e., go-signal duration: $F(3, 33) = 19.6$, partial $\eta^2 = .64$, $p < .001$; preceding correspondence: $F(1, 11) = 27.2$, partial $\eta^2 = .71$, $p < .001$; and their interaction: $F(3, 33) = 6.9$, partial $\eta^2 = .39$, $p < .001$), which will be presented in the subsequent separate analyses, but the 3-way interaction was far from significance ($p > .99$), demonstrating that effects found with the two tasks were basically comparable.

*Horizontal Task*

*RTs.* Mean RTs are shown in figure 1. A go-signal delay main effect [$F(3, 33) = 18.4$, partial $\eta^2 = .63$, $p < .001$] suggested that the RT decreased as a function of delay duration (397, 301, 266 and 258 ms). Polynomial contrasts showed a significant linear trend for this factor [$F(1, 11) = 28.2$, $p < .001$]. The preceding x current correspondence interaction [$F(1, 11) = 11.1$, partial $\eta^2 = .5$, $p < .01$] indicated that the Simon effect was present only after a $C_{n-1}$ trial (23 ms), whereas it disappeared after a $NC_{n-1}$ trial (-5 ms). No significant post-hoc comparison was present for this interaction. The go-signal delay x current correspondence interaction [$F(3, 33) = 10.5$, partial $\eta^2 = .48$, $p < .001$] was due to the Simon effect being present in the no go-signal block (35 ms, $p < .001$) and disappearing after a go-signal delay equal or longer than 200 ms (7, -8, 1 ms, for the 200, 400 and 600 ms go-signal delay, respectively; n.s.).

The go-signal delay x preceding correspondence x current correspondence 3-way interaction [$F(3, 33) = 6.4$, partial $\eta^2 = .37$, $p < .01$] indicated that the Simon effect decreased as a function of the go-signal delay after a $C_{n-1}$ trial, from 64 ms for the no go-signal block ($p < .001$) to 31 ms for the 200 ms go-signal delay block ($p < .01$), to a non significant Simon effect for the 400 and 600 ms delay conditions (-3 and 1 ms, respectively; n.s.). In contrast, no Simon effect was found after a $NC_{n-1}$ trial for any go-signal delay, apart from a reverse Simon effect for the 200 ms delay (-17 ms, post hoc, $p < .05$; for all the other delays, n.s.).

--- *Insert figure 1 about here* ----

*Accuracy*. Responses faster than 100 ms were 3%, responses slower than 1500 ms were 0.03%, anticipations given before the go-signal were less than 1% overall (but see analysis below). Percentage of correct responses for all the 3 experiments is reported in Table 1. In the ANOVA concerning accuracy, the preceding x current correspondence interaction [$F(1, 11) = 24$, partial $\eta^2 = .69$, $p < .001$] replicated the results obtained with RTs: accuracy was higher for $C_n$ trials (97.1%) than for $NC_n$ trials (93.4%) after a $C_{n-1}$ trial, while the contrary was true after a $NC_{n-1}$ trial (93.9 vs. 95.9%). No post-hoc effect reached significance. The go-signal delay x preceding correspondence x current correspondence interaction [$F(3, 33) = 4$, partial $\eta^2 = .27$, $p < .05$] indicated that a significant Simon effect for accuracy was obtained after a $C_{n-1}$, for the no go-signal block only (8.3%; $p < .01$), whereas no Simon effect was obtained for all the other blocks (all $p > .08$).

A further non-parametric Friedman ANOVA was conducted on the percentage of anticipations (i.e., responses given before the go-signal). The within-subject factor was go-signal delay (200, 400, and 600 ms delays). This analysis was significant [Chi Sqr. (N: 12, df: 2) = 14.6, $p < .001$], indicating that percentage of anticipations increased as a function of go-signal delay (0, 2 and 3%).

--- *Insert Table 1 about here* ----

*Vertical Task*

*RTs.* Also for the vertical task, the go-signal delay effect [$F(3, 33) = 16.3$, partial $\eta^2 = .6$, $p < .001$] was due to RT decreasing as a function of delay duration (418, 315, 273 and 250 ms). Polynomial contrasts showed a significant linear trend for this factor [$F(1, 11) = 28.8$, $p < .001$]. The current correspondence main effect [$F(1, 11) = 29.5$, partial $\eta^2 = .72$, $p < .001$] denoted the presence of a significant Simon effect of 16 ms. The preceding correspondence effect [$F(1, 11) = 5.2$, partial $\eta^2 = .32$, $p < .05$] was due to RTs being slightly but significantly shorter after a $C_{n-1}$ trial (317) than after an $NC_{n-1}$ one (311).

These effects were qualified by the preceding x current correspondence interaction [$F(1, 11) = 25.7$, partial $\eta^2 = .7$, $p < .001$], which indicated the presence of a significant Simon effect (37 ms) only after a $C_{n-1}$ trial (Newman-Keuls, $p < .05$), with no Simon effect after an $NC_{n-1}$ trial (-3 ms; n.s.). The go-signal delay x current correspondence interaction [$F(1.78, 19.61) =10.4$, partial $\eta^2 = .49$, *Adjusted* $p < .001$] was due to the Simon effect being present in the no go-signal block (42 ms; $p < .001$), reduced after a 200 ms delay (18 ms; $p < .05$) and absent after a longer delay (1 and 5 ms, for the 400 and 600 ms delay, respectively; n.s.).

Similarly to the horizontal task, the go-signal delay x preceding correspondence x current correspondence 3-way interaction [$F(3, 33) = 3.9$, partial $\eta^2 = .26$, $p = .05$] indicated that the vertical Simon effect decreased as a function of go-signal delay after a $C_{n-1}$ trial, from 79 ms in the no go-signal block ($p < .001$) to 47 ms for the 200 ms go-signal delay condition ($p < .01$), to a non-significant Simon effect in the 400 and 600 ms delay conditions (for both, 10 ms; n.s.). In contrast, no Simon effect was found after an $NC_{n-1}$ trial for any go-signal delay (5, -10, -8, 0 ms, respectively; n.s.).

*Accuracy.* Percentage of accurate responses is reported in Table 1. Responses faster than 100 ms were 5%, responses slower than 1500 ms were 0.03%, anticipations were 1.6% (see analysis below). Accuracy data are reported in Table 1. The go-signal delay main effect [$F$(3,

33) = 10, partial $\eta^2$ = .48, $p$ < .001] indicated that accuracy increased as a function of go-signal delay (92.8, 95.5, 97.4, and 98.4%, for the “no go-signal”, 200-, 400- and 600 ms go-signal delays, respectively), with the polynomial contrasts for the linear trend being significant [$F$(1, 11) = 21.8, $p$ < .001]. The current correspondence effect [$F$(1, 11) = 21.1, partial $\eta^2$ = .65, $p$ < .001] indicated a significant Simon effect, as accuracy was higher after a $C_n$ trial (97.4%) than after an $NC_n$ trial (94.6%). The preceding x current correspondence interaction [$F$(1, 11) = 23.6, partial $\eta^2$ = .68, $p$ < .001] indicated that a significant Simon effect was present after a $C_{n-1}$ trial (7.2%) while no Simon effect was present after an $NC_{n-1}$ trial (- 1.5%). However, no post-hoc comparison was significant.

Similarly to the horizontal task, a further non-parametric Friedman ANOVA was conducted on percentage of anticipations. This analysis was significant [Chi Sqr. (N: 12, df: 2) = 17.2, $p$ < .001], indicating that anticipations increased as a function of the go-signal delay (0, 1 and 6%).

## Discussion

Experiment 1 basically confirmed previous findings concerning the Simon effect and the sequential effects. The decrease of RTs at long go-signal delays can be interpreted as a result of inadequate response preparation for shorter delays (e.g., Gottsdanker, 1992). More critically, experiment 1 demonstrated that the Simon effect decays as the go-signal delay increases, disappearing with a 400 to 600 ms delay, which presumably is after response selection and before response execution. This was true for both the horizontal and the vertical Simon tasks. This result suggests that also for the vertical Simon task, the Simon effect decays when a long enough delay elapses before response execution.

## Experiment 2

With the procedure adopted in experiment 1, the response execution stage might have begun before the onset of the go-signal. This possibility is suggested by the analysis of anticipations, which showed that anticipations increased significantly as a function of the go-signal delay in both tasks, and more so from 200 to 400 ms delay, namely when the Simon effect disappears. In experiment 2, the procedure prevented participants from starting the response selection/execution stages before the moment specified by the experimenter.

## Method

### *Participants*

Eighteen volunteers, all different from those performing experiment 1, took part in experiment 2. They were 24 years old on average (range = 20-42; 12 females, all right-handed, with handedness defined by writing hand). All had normal or corrected-to-normal vision and were naïve about the purposes of the experiment.

### *Apparatus and Materials*

The apparatus was the same as that used in experiment 1. The same stimuli used in experiment 1 were used also in experiment 2 but in a different order. The go-signal of experiment 1 (unfilled white square) was used as a spatial precue in experiment 2 and was presented for 0, 200, 400 or 600 ms before stimulus onset. The coloured stimuli were the same as in experiment 1 but were presented after the precue for 200 ms on the horizontal or vertical meridian, with the same eccentricity and size as the precue.

### *Procedure and Task*

The procedure of experiment 2 was similar to that of experiment 1. However, a white spatial precue was presented before the target stimulus and no go-signal was required to give a response to this target stimulus. The duration of the precue was manipulated across blocks (0, 200, 400 and 600 ms pre-stimulus onset), with order of block presentation counterbalanced across participants. Like in experiment 1, the total trial duration was kept constant by shortening the fixation duration as the precue duration became longer (1100, 900, 700, 500 ms, for a precue of 0, 200, 400 and 600 ms, respectively). Participants had to give a fast and accurate response when the target stimulus (coloured square) replaced the spatial precue. A 200 ms blank subsequent to the response separated one trial from another.

*Data Analysis*

An overall 2 tasks (horizontal vs. vertical) x 4 spatial cue durations (no precue, 200, 400 or 600 ms) x 2 preceding correspondence ($C_{n-1}$ vs. $NC_{n-1}$) ANOVA was performed first, with the Simon effect as dependent variable. Then, as for experiment 1, mean RTs as well as percentage of correct responses were analysed through two subsequent 4x2x2 ANOVAs, separately for each Simon task (horizontal vs. vertical). The latter analyses employed spatial cue duration, correspondence on the current trial ($C_n$ vs. $NC_n$), and correspondence on the preceding trial ($C_{n-1}$ vs. $NC_{n-1}$) as the within-subjects factors. Incorrect responses, RTs outside the 100-1500 ms range, and anticipations given during the precue led to the exclusion of the current trial from the RT analysis.

## Results

*Simon effect for Horizontal and Vertical Tasks.* The overall analysis yielded the following significant effects, that will be explained in the separate ANOVAs: spatial precue [$F(3, 51) = 2.93$, partial $\eta^2 = .15$, $p < .05$], preceding correspondence [$F(1, 17) = 59.18$, partial $\eta^2 = .78$, $p < .001$], spatial precue x preceding correspondence [$F(3, 51) = 7.5$, partial $\eta^2 = .31$, $p < .001$], and task x precue x preceding correspondence [$F(3, 51) = 2.81$, partial $\eta^2 = .14$, $p <$

.05]. The 3-way interaction is the key result of this analysis. Newman-Keuls post-hoc test showed a significant reduction of the Simon effect from the no precue condition to the 200 ms precue condition after a $C_{n-1}$ trial in the horizontal task ($p < .05$). In the vertical task, the Simon effect was reduced in the 400 ms precue condition with respect to the no precue condition after a $C_{n-1}$ trial ($p < .05$), whereas Simon effect after a $C_{n-1}$ trial in the 200 ms and in the 400 ms precue conditions did not differ significantly ($p = .09$).

*Horizontal Task*

*RTs.* The spatial precue effect [$F(2.03, 34.66) = 7.01$, partial $\eta^2 = .29$, $p < .01$] indicated that RT decreases as a function of precue duration (465, 436, 416 and 402 ms). Polynomial contrasts showed a significant linear trend for this factor [$F(1, 17) = 34.94$, $p < .001$], presumably because of an increasing advantage yielded by advance spatial precuing. The processing time of the forthcoming stimulus conceivably benefited from the lengthening of the spatial precue duration. The correspondence effect (i.e., the Simon effect, $F(1, 17) = 10.29$, partial $\eta^2 = .38$, $p < .01$) was due to RTs being shorter on a $C_n$ trial than on an $NC_n$ one (422 vs. 437 ms). The preceding correspondence effect [$F(1, 17) = 8.33$, partial $\eta^2 = .33$, $p < .01$] was due to RTs being shorter after a $C_{n-1}$ trial than after an $NC_{n-1}$ one (425 vs. 435 ms). The preceding x current correspondence interaction [$F(1, 17) = 51.21$, partial $\eta^2 = .75$, $p < .001$] indicates that the Simon effect was significant only after a $C_{n-1}$ trial (45 ms, $p < .01$), whereas it was reversed, although not significantly so, after a $NC_{n-1}$ one (-20 ms). This effect confirms previous results (Stürmer et al., 2002; Stürmer & Leuthold, 2003).

The 3-way interaction [$F(3, 51) = 5.64$, partial $\eta^2 = .25$, $p < .01$] indicated that the Simon effect was modulated by the precue duration only after a $C_{n-1}$. With a $C_{n-1}$ trial, the Simon effect decreased when the precue was presented in advance (32, 37 and 39 ms, for the 200, 400 and 600 ms precues, respectively) with respect to when it was absent (72 ms). This was confirmed by polynomial contrasts demonstrating that the Simon effect with the no spatial precue condition was larger than with all the other precue conditions (all $p < .01$, see Figure 2). Conversely, with an $NC_{n-1}$ trial, the Simon effect was significantly reversed with a no precue condition (-26 ms, $p < .01$) and absent after any spatial precue.

---*Insert Figure 2 about here* ---

*Accuracy.* Responses faster than 100 ms were 0.7%, responses slower than 1500 ms were 0.03%, and anticipations given before the go-signal were 0.07%. Accuracy data are reported in Table 1. The current correspondence effect [$F(1, 17) = 4.4$, partial $\eta^2 = .21$, $p = .05$] mirrored the Simon effect found in the RT analysis, indicating that percentage of correct responses was higher for $C_n$ trials (93.3%) than for $NC_n$ trials (91.1%). The spatial precue x preceding correspondence interaction [$F(3, 51) = 2.8$, partial $\eta^2 = .14$, $p = .05$] suggested that accuracy was higher after an $NC_{n-1}$ than after a $C_{n-1}$ trial in the no precue condition. This pattern was reversed in the 200 ms precue condition and absent with longer precues. However, no post-hoc comparison was significant.

The preceding x current correspondence interaction [$F(1, 17) = 46$, partial $\eta^2 = .73$, $p < .001$], similarly to the RT analysis, indicated that the Simon effect was present only after $C_{n-1}$ trials (accuracy Simon effect = 6.7%; $p < .05$) while it was reversed after $NC_{n-1}$ trials (accuracy Simon effect = -3.2%; n.s.). The precue x preceding correspondence x current correspondence interaction [$F(3, 51) = 5.8$, partial $\eta^2 = .25$, $p < .01$] indicated that, after $C_{n-1}$ trials, the Simon effect was observed for all but the 600 ms precue (10.6%, 8.4% and 5.3%, for the no precue, 200- and 400 ms precues, respectively; all $p < .05$). In contrast a non significant reverse effect was observed after $NC_{n-1}$ trials for any precue, apart for the 400 ms precue condition, for which the reverse Simon effect reached significance (-5.1%, $p < .05$).

*Vertical Task*

*RTs.* As for the horizontal task, the effect of the spatial precue [$F(3, 51) = 12$, partial $\eta^2 = .41$, $p < .001$] was due to the RT decreasing as a function of precue duration (448, 436, 411 and 405 ms). Polynomial contrasts showed a significant linear trend for this factor [$F(1, 17) = 26.43$, $p < .001$]. The correspondence effect [$F(1, 17) = 28.6$, partial $\eta^2 = .63$, $p < .001$] demonstrated a Simon effect between $C_n$ and $NC_n$ conditions (435 vs. 415 ms). The preceding x current correspondence interaction [$F(1, 17) = 38.5$, partial $\eta^2 = .69$, $p < .001$] was due to the Simon effect being significant only after a $C_{n-1}$ trial (48 ms, $p < .001$), whereas it was absent after an $NC_{n-1}$ trial (-7 ms).

Also in the vertical task, the 3-way interaction [$F(3, 51) = 4.14$, partial $\eta^2 = .2$, $p < .05$] was due to the Simon effect being modulated by precue duration only after $C_{n-1}$ conditions (see Figure 2). After a $C_{n-1}$ trial, indeed, the Simon effect decreased when the precue was presented at least 400 ms in advance (28 and 40 ms for the 400 and 600 ms precues, respectively) with respect to when it was presented 200 ms before the stimulus or was absent (67 and 58 ms, for the 200 ms and no precue, respectively). Planned comparisons corroborated this observation, demonstrating that the Simon effect with no precue was larger than with any precue (all $p < .001$) apart from the 200 ms precue (n.s.). Moreover, the Simon effect with the 200 ms-precue was larger than with the 400 and 600 ms precues (all $p < .01$). Conversely, after an $NC_{n-1}$ trial the Simon effect was always absent independently of precue duration (-6, -14, -1, -10, for no precue and 200, 400 and 600 ms precues, respectively; n.s.).

*Accuracy*. Responses faster than 100 ms were 0.5%, responses slower than 1500 ms were 0.02%, and anticipations given before the go-signal were 0.03%. Accuracy data are reported in Table 1. The current correspondence effect [$F(1, 17) = 8.9$, partial $\eta^2 = .34$, $p < .01$] was due to the percentage of correct responses being higher for $C_n$ (93.6%) than for $NC_n$ trials (90%). The spatial precue x current correspondence interaction [$F(3, 51) = 5.9$, partial $\eta^2 = .26$, $p < .01$] was due to the Simon effect being present only with no precue condition (9.7%, $p < .01$). The preceding x current correspondence interaction [$F(1, 17) = 8.9$, partial $\eta^2 = .34$, $p < .01$] was in the same direction as the RT results, since it indicated a regular Simon effect after $C_{n-1}$ trials (4%), and an inverted Simon effect after $NC_{n-1}$ trials (-4%), but post-hoc comparisons were non-significant.

## Discussion

In experiment 2, a slight reduction in the size of the Simon effect was evident only when the preceding correspondence factor was considered, even with the horizontal task. A precue-latency shift was observed in the occurrence of this reduction from the horizontal to the vertical task. With the horizontal Simon task, when the preceding trial had a corresponding condition, a reduction of the Simon effect was observed after a precue-target delay of 200 ms or longer. In contrast, with the vertical Simon task, a delay of 400 to 600 ms was necessary to observe a comparable decrease.

However, the failure to find clearer evidence for the decay of the Simon effect might be attributed to the nature of the experimental manipulation. Perhaps the spatial code decays soon after the onset of the spatial precue but it is again formed when the stimulus appears, as its abrupt onset in the peripheral visual field would produce a new automatic shift of attention. Note that an attentional shift is indeed thought to cause the Simon effect (e.g., Melis, 2001; Nicoletti & Umiltà, 1994; Rubichi et al., 1997; Stoffer & Umiltà, 1997). This second attentional shift, and the re-activation of the spatially compatible response, would prevent the Simon effect from completely disappearing even after a precue of 600 ms. A new paradigm was then adopted in the experiment 3, in which the automatic attentional re-orienting is avoided, but formation of the stimulus spatial code and the response selection stage still remain separated.

## Experiment 3

In experiment 3, stimulus discriminability was manipulated through an image processing procedure, which made the identification of the stimulus relevant feature (i.e., colour) more difficult, and therefore delayed the stimulus discrimination stage. With the horizontal Simon task, similar experiments have already been conducted. As a typical result, RTs are delayed by about 100 ms and the Simon effect is reduced from high to low discriminability (e.g., Hommel, 1994). This pattern has been held to indicate a spontaneous decay of the automatic response-code activation. To our knowledge, no study has adopted a similar manipulation directly to compare the decay of the compatibility effect in the horizontal and vertical versions of the Simon task. This was the aim of experiment 3.

### Method

*Participants*

Fifteen volunteers that did not overlap with the samples of the two previous experiments participated in experiment 3. They were 24 years old on average (range = 18-29; 5 females). All the participants were right-handed (writing hand), and had normal or corrected-to-normal vision. All were naïve about the aim of the study.

*Apparatus and Materials*

In order to increase the interval between formation of the task-irrelevant stimulus spatial code and of the task-relevant stimulus feature, a number of changes were introduced in experiment 3. For the high-discriminability blocks, the target stimuli were 4x4 bright red-and-black or green-and-black checkboards subtending a visual angle of 1.4°. For the low-discriminability blocks, 90% of the pixels forming the squares of identical checkboards were randomly replaced by black and white pixels. In the horizontal task, the stimuli were presented one at a time and in random sequence, approximately 3.3° to the right or left of a central fixation cross on a constantly light grey background. In the vertical task, the same stimuli were presented approximately 3.3° above or below fixation. A 4x4 black-and-white checkboard was also used as contralateral filler. The stimulus and filler were displayed for 176 ms, and then replaced by a grey blank screen for 1327 ms. The fixation cross was constantly displayed against the background. The time for the response was 1500 ms. The inter-trial interval was 1000 ms.

*Procedure and Task*

Participants were encouraged to maintain fixation, and to react to the stimuli as fast and accurately as possible. There were 2 tasks (horizontal vs. vertical) x 2 discriminability (high vs. low) combinations, administered in four separate blocks. The order of presentation of the blocks was chosen randomly, provided that each given order would occur for one participant only. The associations between stimulus colours and response keys and the way they were counterbalanced were the same as in the previous experiments. For each experimental block, a practice run of 10 trials and 2 experimental runs were administered. During each experimental run, each colour x position combination was presented 25 times in a randomized sequence, for a total of 100 trials per experimental run (200 in total). After the first experimental run, a short rest was allowed.

*Data Analysis*

Responses faster than 100 ms or slower than 1500 ms and anticipations led to the exclusion of the current trial. The design of experiment 3 was simpler than that of the previous experiments. Consequently RTs and errors were analysed through single omnibus 2x2x2x2 repeated measures ANOVAs, with tasks (horizontal vs. vertical), colour discriminability (high vs. low), current correspondence ($C_n$ vs. $NC_n$) and preceding correspondence ($C_{n-1}$ vs. $NC_{n-1}$), as within-subject factors.

## Results

*RTs.* RT results are shown in Figure 3. The discriminability main effect [$F(1, 14) = 71.1$, partial $\eta^2 = .84$, $p < .001$] indicated that RTs in the low-discriminability condition were longer than those in the high-discriminability condition (550 vs. 435 ms). The presence of the Simon effect (i.e., current corresponding main effect: $F(1, 14) = 59.6$, $p < .001$) was better qualified by the preceding x current correspondence interaction [$F(1, 14) = 40.4$, partial $\eta^2 = .81$, $p < .001$], which confirmed that the Simon effect is present only after corresponding trials (47 ms, post-hoc test, $p < .01$) and not after non-corresponding trials (4 ms, post-hoc test, n.s.). The task x current correspondence interaction [$F(1, 14) = 5.4$, partial $\eta^2 = .28$, $p <$

.05] indicated that the Simon effect was larger in the vertical task than in the horizontal one (32 vs. 19 ms, respectively).

More relevant for the present purposes, the task x discriminability x current correspondence interaction [$F(1, 14) = 6$, partial $\eta^2 = .3$, $p < .05$] indicated that the Simon effect was modulated by stimulus colour discriminability, for the horizontal tasks only (29 vs. 9 ms, for high and low-discriminability, respectively). Conversely, no change was observed in the magnitude of the Simon effect for vertical tasks (29 vs. 35 ms, for high and low-discriminability, respectively). This was statistically corroborated through planned comparisons, indicating that the Simon effect was significantly reduced from the high- to the low-discriminability condition in the horizontal task [$F(1, 14) = 6.2$, partial $\eta^2 = .31$, $p = .05$], but not in the vertical task ($p = .43$).

--- *Insert Figure 3 about here* ---

*Accuracy*. Responses faster than 100 ms were 0.07%, RTs longer than 1500 ms were 2.1%, and anticipations given before the stimulus onset were less than 0.02%. Accuracy data are reported in Table 1. Accuracy was higher for the horizontal task than for the vertical one [88.9 vs. 86%; task main effect: $F(1, 14 = 8.6$, partial $\eta^2 = .38$, $p = .01$], for high- than for low-discriminability [92.3 vs. 82.7%; discriminability effect: $F(1, 14) = 13.2$, partial $\eta^2 = .48$, $p < .01$], for corresponding than for non-corresponding trials [90.7 vs. 84.3%; correspondence effect: $F(1, 14) = 24.6$, partial $\eta^2 = .64$, $p < .001$].

Moreover, the task x discriminability interaction [$F(1, 14) = 9.5$, partial $\eta^2 = .4$, $p < .01$] indicated that accuracy was higher in the horizontal than in the vertical task, but only with low-discriminability (85.7 vs. 79.6%, but post-hoc test, $p = .06$), whereas no difference between the two tasks was observed with high-discriminability (92.1 vs. 92.5%). The accuracy Simon effect was significantly higher in the vertical task than in the horizontal one

[8.7% vs. 4.1%; task x current correspondence interaction: $F(1, 14) = 8.7$, partial $\eta^2 = .38$, $p = .01$]. The preceding x current correspondence interaction [$F(1, 14) = 28.5$, partial $\eta^2 = .6$, $p < .001$] parallels the RT results, as the Simon effect for accuracy was present after a $C_{n-1}$ trial (10.5%, $p < .01$) and disappeared after an $NC_{n-1}$ one (2.4%, $p = .36$).

## Discussion

In experiment 3, a lengthening of the stimulus discrimination stage was obtained by rendering stimulus discriminability more demanding. In this way, the stage of task-irrelevant spatial code formation and that of task-relevant stimulus color identification were temporally separated. As a result, with horizontal S-R arrangements, the magnitude of the Simon effect was reduced in this condition with respect to a high-discriminability condition. This effect replicates data from the literature (e.g., Hommel, 1994). The novel finding of experiment 3 is that, in the vertical task, the Simon effect did not decrease with stimuli that were difficult to discriminate.

This pattern can be accounted for by Wascher and colleagues' hypothesis (Wascher et al., 2001; Wiegand & Wascher, 2005; see also Vallesi et al., 2005), according to which, the horizontal and vertical Simon effects originate from two different mechanisms. The horizontal Simon effect is attributed to the automatic activation of the response corresponding to the stimulus spatial code, due to the presence of privileged visuomotor pathways. The automatic activation of this path, also called *unconditional way* (De Jong et al., 1994), is held to decay over time (e.g., Hommel, 1994). The Simon effect occurs only if this unconditional way is active, while it diminishes as its activation decays. The manipulation adopted in the present experiment 3 has conceivably prolonged the stimulus identification stage, thus allowing the automatic activation to decay.

This explanation does not apply to the results of the vertical Simon task, in which no decrease in the magnitude of the Simon effect was found as a function of stimulus discriminability. The results obtained for the vertical task can be explained by means of the translation account (e.g., Hasbroucq & Guiard, 1991), according to which, the conflict between the (irrelevant) stimulus spatial code and the response occurs in the stage in which the stimulus relevant feature (its colour, in the current experiment) is translated into a response. On this account, if the identification of the stimulus-relevant feature is delayed, the response selection is consequently postponed, thus moving the conflict between the relevant and irrelevant response codes forward in time, and still permitting the emergence of a Simon effect with longer RTs.

## General Discussion

The aim of this study was to discriminate between activation and translation accounts of the Simon effect obtained with the horizontal and vertical S-R arrangements. This issue has been addressed before by means of RT distributional analysis and electrophysiology. Some studies (e.g., Vallesi et al., 2005; Wascher et al., 2001) show evidence in favour of activation and decay accounts for the horizontal Simon effect, whereas translation accounts seem to be more suitable for the vertical Simon effect. However, this evidence is controversial (e.g., Praamstra, 2007; Roswarski & Proctor, 2003). Here we used a more traditional approach, namely the manipulation of stimulus and response parameters in order to influence the various processing stages involved in a Simon task.

In experiment 1, a go-signal was used to delay response execution by a variable interval. As a result, the Simon effect decreased as the delay increased, for both the horizontal and vertical Simon tasks. Thus, in both tasks, the irrelevant stimulus spatial code decays if response execution is delayed over time. In experiment 2, we investigated the hypothesis that, in either task, the spatial stimulus code decays before response selection. If that is the case, the Simon effect should not occur if the response selection stage is delayed with respect to the formation of the spatial stimulus code. To this aim, a spatial precue was shown with a variable interval before the stimulus, that is before any response could be selected.

However, this had only a small influence on the RT Simon effect, as the decrease could be detected only when the preceding trial was corresponding. In that case, the horizontal Simon effect decreased with a precue-target delay of 200 ms or longer, while the vertical Simon effect was reduced with a delay of 400 ms or longer. We interpret the result as due to the attentional shift towards the target after its abrupt onset, although its spatial position had been already signalled by the spatial precue. This interpretation derives from evidence showing that an attentional shift is a critical condition for the occurrence of the Simon effect (e.g., Rubichi et al., 1997).

In order to avoid a possible secondary shift of attention, in experiment 3 the time interval between the formation of the stimulus spatial code and the response selection was prolonged through a manipulation of the discriminability of the task-relevant stimulus feature, namely its colour. With low-discriminability, a reduction of the RT Simon effect was obtained for the horizontal version of the task only, replicating results obtained with comparable manipulations (e.g., Hommel, 1993; 1994). On the other hand, no change in the size of the Simon effect was observed for the vertical task. This finding fits well with Wiegand and Wascher's (2005) view that different mechanisms can explain the horizontal and vertical Simon effects.

Although analyses on accuracy data not always showed significant results, the effects found in accuracy were generally in the same direction as those found in RTs, thus ruling out any explanation of the present results in terms of speed-accuracy trade off.

The horizontal Simon effect has been traditionally accounted for by postulating an automatic activation of a visuo-motor pathway by the task-irrelevant spatial code, soon after stimulus onset. This activation has been demonstrated to decay over time (e.g., Hommel, 1994). The present results confirm this account, as increasing the interval between the formation of the stimulus spatial code and the response selection reduced the Simon effect. However, a different account should apply to the vertical Simon effect, as the same manipulation did not affect its size. As demonstrated in the current study, the locus of the vertical Simon effect follows the stage in which the stimulus spatial code is formed and probably precedes response preparation. A plausible stage for the vertical Simon effect is that of response selection, as predicted by the translation account put forward by Hasbroucq and Guiard (1991).

A possible limitation of the study is that the RT measure is not always as sensitive to capture response conflict as other measures (e.g., LRP). In a recent study, initial angle of pointing movements was recorded together with RTs in horizontal and vertical versions of the Simon task (Buetti & Kerzel, 2008). Results showed the classical pattern of decreasing Simon effect with longer RT bins in the horizontal Simon task, and a stable Simon effect across RT bins with the vertical Simon task. However, initial movement angles across RT-bins showed a similar pattern for vertical and horizontal Simon tasks, suggesting similar mechanisms. This possible dissociation between RTs and other measures was not investigated here. This prevents us from drawing strong conclusions about the divergence of results concerning the Simon effect in the two S-R sets, although the evidence presented here is in favour of the view that S-R correspondence in the Simon task may affect partially different processing stages depending on the spatial S-R arrangement.

In summary, the findings of the present study go some distance towards a further understanding of the mechanisms underlying spatial attention, and in particular towards resolving the contradiction between translation and activation theories with regard to the Simon effect. As proposed by Wiegand and Wascher (2005), either account may well explain the Simon effect, depending on the task conditions such as, for instance, whether this compatibility effect has been obtained with the horizontal or vertical arrangements of stimuli and responses.

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# Tables

*Table 1. Percentage of correct responses in the 3 experiments of the study, according to task (horizontal, vertical), current correspondence condition (Cn = corresponding, NCn = non corresponding), preceding correspondence condition (Cn-1 = corresponding, NCn-1 = non corresponding), and manipulations specific to each experiment (first column on the left).*

| Experiment 1 | | Horizontal task | | | | Vertical task | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $C_{n-1}$ | | $NC_{n-1}$ | | $C_{n-1}$ | | $NC_{n-1}$ | |
| | | $C_n$ | $NC_n$ | $C_n$ | $NC_n$ | $C_n$ | $NC_n$ | $C_n$ | $NC_n$ |
| Go-signal delay (ms) | 0 | 98 | 90 | 94 | 95 | 99 | 86 | 92 | 94 |
| | 200 | 100 | 94 | 93 | 98 | 99 | 91 | 96 | 96 |
| | 400 | 97 | 94 | 95 | 95 | 99 | 96 | 96 | 99 |
| | 600 | 94 | 96 | 93 | 95 | 100 | 95 | 99 | 100 |
| **Experiment 2** | | | | | | | | | |
| | | $C_{n-1}$ | | $NC_{n-1}$ | | $C_{n-1}$ | | $NC_{n-1}$ | |
| | | $C_n$ | $NC_n$ | $C_n$ | $NC_n$ | $C_n$ | $NC_n$ | $C_n$ | $NC_n$ |
| Spatial precue duration (ms) | 0 | 95 | 85 | 90 | 94 | 98 | 84 | 95 | 90 |
| | 200 | 98 | 89 | 89 | 94 | 95 | 88 | 90 | 93 |
| | 400 | 96 | 91 | 90 | 95 | 92 | 88 | 90 | 91 |
| | 600 | 94 | 91 | 92 | 92 | 97 | 91 | 93 | 95 |
| **Experiment 3** | | | | | | | | | |
| | | Cn-1 | | NCn-1 | | $C_{n-1}$ | | $NC_{n-1}$ | |
| | | $C_n$ | $NC_n$ | $C_n$ | $NC_n$ | $C_n$ | $NC_n$ | $C_n$ | $NC_n$ |
| Color degradation | No | 95 | 88 | 94 | 92 | 96 | 87 | 94 | 92 |
| | Yes | 89 | 82 | 86 | 86 | 89 | 72 | 82 | 76 |

Figure Captions

*Figure 1.* Mean RTs as a function of correspondence in the current trial, correspondence in the preceding one, and the go-signal delay, in experiment 1. Upper panel A refers to the horizontal task, lower panel B refers to the vertical task. Vertical bars denote Standard Errors of the mean. $C_n$ and $NC_n$ = corresponding and non corresponding conditions in the current trial, respectively; $C_{n-1}$ and $NC_{n-1}$ = corresponding and non corresponding conditions in the preceding trial, respectively.

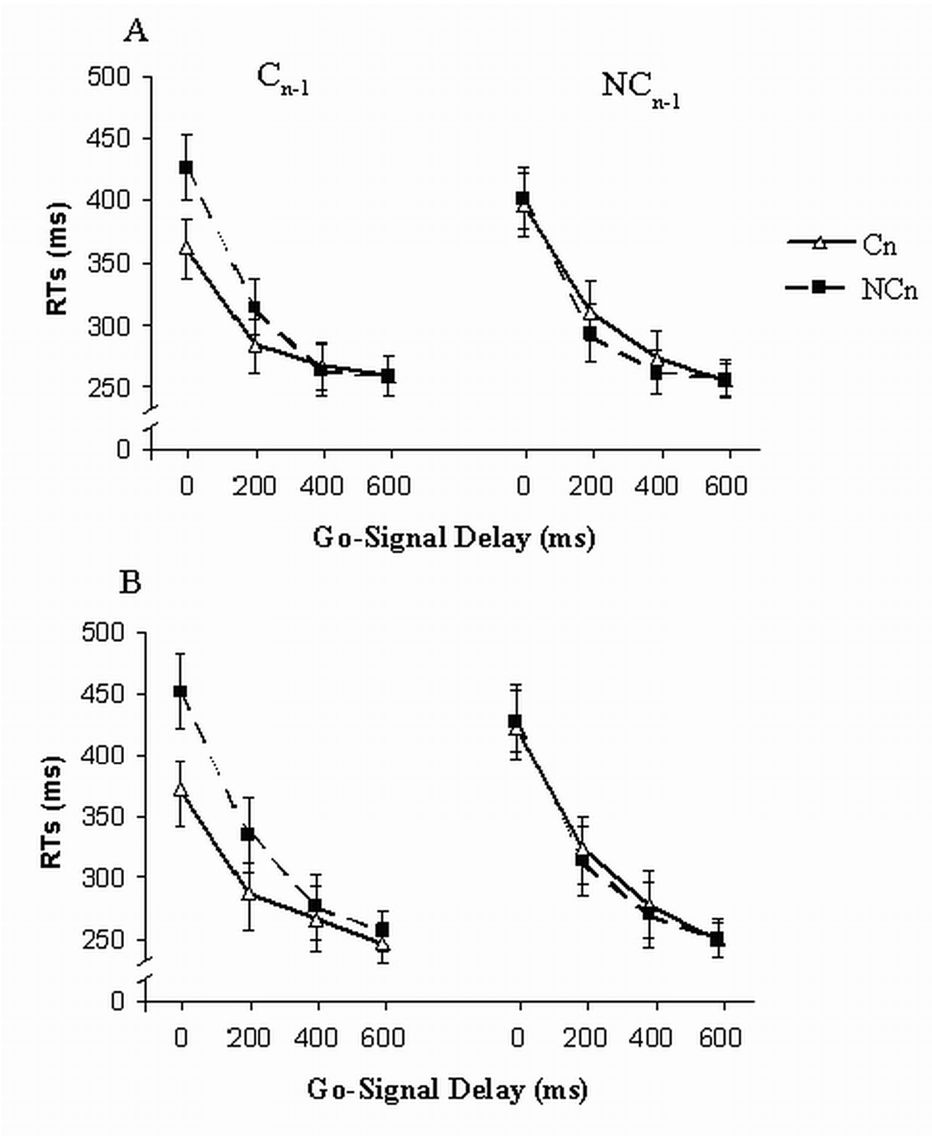

*Figure 2.* Mean RTs as a function of correspondence in the current trial, correspondence in the preceding one, and spatial precue duration, in experiment 2. Upper panel A refers to the horizontal task, lower panel B refers to the vertical task. Vertical bars denote Standard Errors. See Figure 1, for an explanation of the abbreviations used.

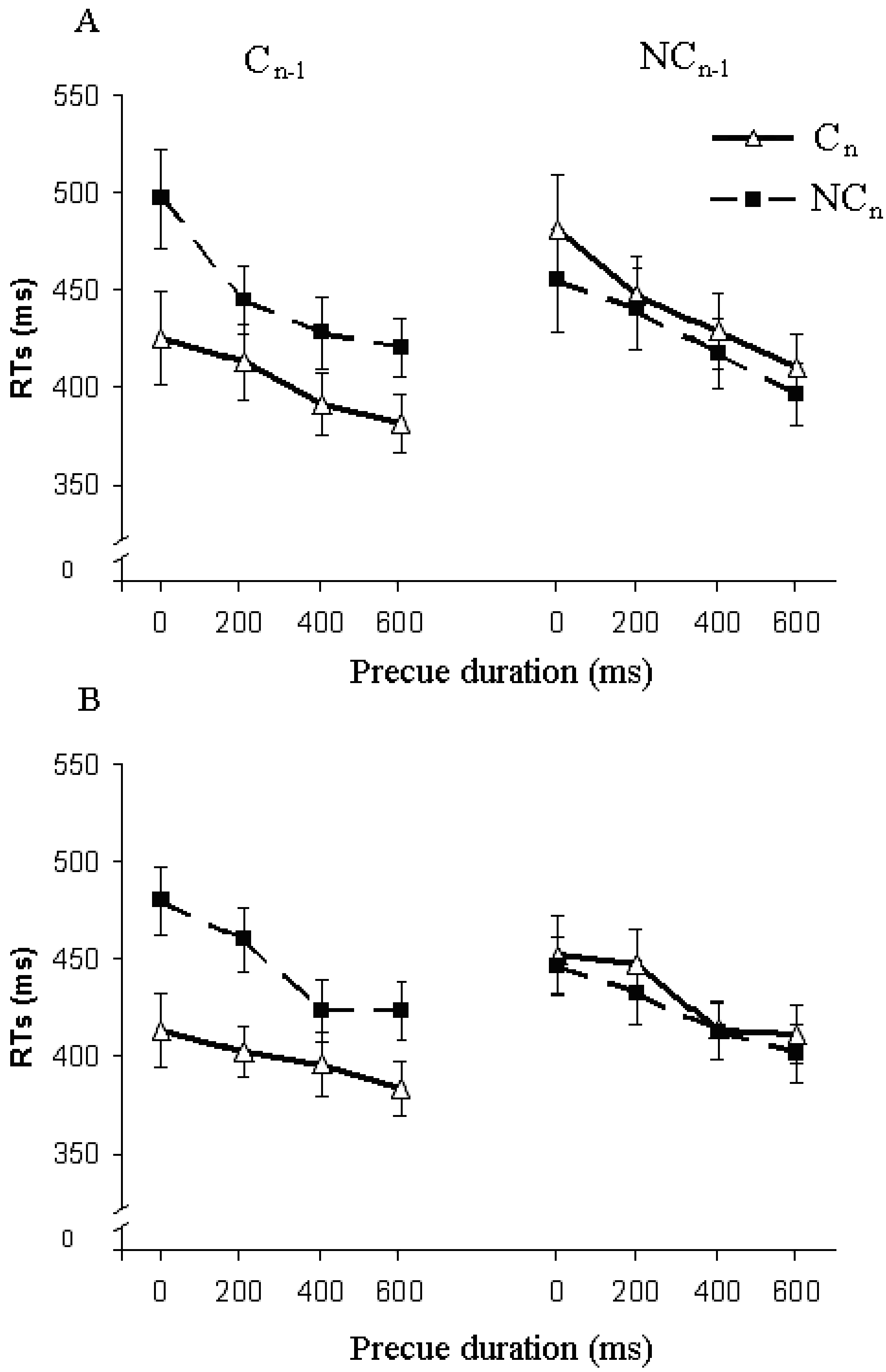

*Figure 3.* Mean RTs as a function of correspondence in the current trial and of colour discriminability, in experiment 3. Panels A and B refer to the horizontal and vertical tasks, respectively. Vertical bars denote Standard Errors. $C_n$ and $NC_n$ indicate corresponding and non corresponding conditions in the current trial, respectively.