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Onset and offset as determinants of the Simon effect

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We investigated the presence and the characteristics of the Simon effect for onset and offset targets when these stimuli are randomly intermixed. In Experiment 1, two possible target locations were occupied by an occluder. On onset trials, a target appeared above an occluder, while on offset trials one of the occluders disappeared, revealing the target underneath. In Experiment 2, four stimuli appeared randomly in six possible locations. On onset trials, a new stimulus appeared in an empty location while on offset trials, one of the initial stimuli disappeared. In both experiments, the Simon effect for onset and offset targets was characterized by similar size, time course and sequential modulation, suggesting similar sensorimotor interactions between target and response locations. However, the Simon effect in the current trials was more evident when the same type of target (onset or offset) was repeated on successive trials demonstrating the role of stimulus category in its modulation.

In many situations we are to respond to stimuli with either the hand of the same or the opposite side. We are better responding with the ipsilateral foot or hand, an effect that has been investigated in Cognitive Psychology under the domain of the Simon effect. In the typical Simon task (Simon & Rudell, 1967) participants are instructed to respond to a non-spatial stimulus feature (e.g., shape or colour) using horizontally arranged keys. For instance, they are asked to respond with their left or right response key to the shape (e.g., either a square or a diamond) of a stimulus presented on the left or right side of the screen, where the square is associated with the left response and the diamond is associated with the right response. Typically,

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responses are faster and more accurate when stimulus and response are located on the same side (corresponding trials) than when they are located on opposite sides (non corresponding trials). The Simon effect shows that even if stimulus location is completely task-irrelevant, this stimulus feature is processed and interferes with task performance (e.g. Fitts & Seeger, 1953; Teichner & Krebs, 1974; Tsal and Lavie 1993).

Cognitive dual-route models (e.g. De Jong, Liang & Lauber, 1994; Kornblum, Hasbroucq & Osman, 1990; see also Metzker & Dreisbach, 2011, for a recent further development of the model) postulate that the presentation of the stimulus activates two parallel response-activation routes. The conditional route activates a response according to the task-relevant stimulus dimension as indicated by the S-R pairings specified by the instructions. The unconditional route activates a response on the basis of the location of the stimulus so that the response which spatially corresponds to stimulus location is automatically primed irrespective of task instructions (De Jong et al., 1994). While the conditional route is assumed to be slow and under intentional control, the unconditional one is considered fast and automatic. Importantly, both routes converge at response selection stage. When the conditional and the unconditional routes activate the same response (corresponding trials), this is quickly executed resulting in efficient performance. However when the two routes activate different responses (non corresponding trials), a conflict arises at response selection stage which must be solved before the correct response can be executed. This process takes times, increasing RTs and error rates.

The time-course of the Simon effect is considered a demonstration of the automaticity of the unconditional route activation. In the classic Simon task, where both stimuli and responses are horizontally arranged, a sizable Simon effect is found for the fastest responses but it tends to decrease over time with null or even an inverted effect for the slowest responses (e.g., De Jong et al., 1994; Hommel, 1993). This is considered an indication that the automatic activation of the ipsilateral response via the unconditional route by stimulus position is immediate and does not require time. When this automatic activation is no longer present the Simon effect disappears. However this decreasing time-course of the Simon effect is not always observed. For instance, when stimuli and responses are arranged in the vertical dimension (e.g., Proctor, Vu & Nicoletti, 2003), for central stimuli (e.g., Ansorge, 2003) or with crossed hands (Wascher, Schatz, Kuder & Verleger, 2001), the Simon effect tends to remain relatively constant or to show an opposite trend, i.e., being small with fast responses and increasing with slow responses. Wascher et al. (2001) postulated that increasing and decreasing time-courses are associated to different mechanisms underlying the Simon effect and that only under specific conditions, i.e., with visual stimuli and hands in anatomical locations, the standard decreasing Simon effect is found.

In almost all studies on the Simon effect the target stimulus requiring a response is characterized by its abrupt onset on the screen. Such stimulus could then disappear or remain on the screen until the execution of the response. Thus the offset of the stimulus from the screen is also used in the Simon task. However, only recently this stimulus feature has been investigated as an independent variable and compared to onset events (Riggio, Lagravinese, Patteri, Buccino & Umiltà, 2003; Wühr & Kunde, 2006). While an onset stimulus is characterized by the appearance of a new object in the visual field and the observer can rely on continuously available visual information to respond to it, an offset stimulus is characterized by the disappearance of an object already present on the screen. In this case, the observer needs to retrieve the stimulus representation held in working memory in order to respond to the stimulus identity.

One relevant question is whether the empty location created by stimulus offset is able to activate automatically the spatially corresponding response, thus producing a Simon effect. To answer this question, Riggio et al. (2003) instructed participants to respond to the identity of the target that was, in different blocks, the appearance or the disappearance of one of the two geometrical shapes in the onset or in the offset conditions, respectively, along the horizontal meridian. Onset and offset stimuli were also used by Wühr and Kunde (2006) in different experiments, where they were presented on the corners of an imaginary square, centered on the fixation point (one stimulus appearing in one of the four locations in the onset experiment, and one stimulus disappearing from one of the four locations after four stimuli had previously occupied such locations in the offset experiment). The results of both studies showed that the location of an offset event primes the corresponding response like the location of an onset event, confirming that both stimulus onset and offset are able to produce a Simon effect. This suggests that the spatially corresponding response is automatically activated regardless of the physical presence of the stimulus. When the size of the Simon effect for onset and offset trials was directly compared, different results emerged between the two studies mentioned above. Wühr and Kunde (2006) showed a larger Simon effects for onset than offset stimuli, whereas similar Simon effects for both stimulus types were found in Riggio et al.' study (2003). Further differences emerged in the time-course analysis where Wühr and Kunde found that both onset and offset Simon effects were characterized by a decreasing time-course, while

Riggio et al. (2003) found a decreasing time-course for the onset Simon effect and an increasing time-course for the offset Simon effect.

Two relevant differences characterize onset and offset events. First, in onset trials the target is presented in an empty location, whereas in offset trials a location becomes empty. Second, in onset trials participants are able to process the identity of the target stimulus only after its appearance whereas in offset trials they have to process the target before its disappearance. Therefore only in offset trials there is a temporal dissociation between perceptual processing and the dynamic event. Since in the previous studies (Riggio et al., 2003; Wühr & Kunde, 2006) onset and offset trials were presented separately in different blocks or in different experiments, it is possible that at least part of the differences observed between onset and offset Simon effects are due to the anticipation of the type of event and to the different processing strategies that participants might have adopted on the different blocks of trials or experiments to cope with the type of event being presented.

In the present study we directly manipulated the differences between onset and offset trials to investigate their selective effects on the Simon effect, while controlling for the use of different processing strategies. To this aim we run two experiments using a Simon-like paradigm in which onset and offset target events were randomly intermixed within the same block of trials, so that participants were unable to anticipate the following type of event (onset vs. offset). In the first experiment we eliminated both features that were previously associated with offset events. First, two objects (one to the left and one to the right of fixation) were always present throughout the task (see Figure 1A). Thus both locations were always occupied by the same set of stimuli. Importantly, the task relevant features of these objects were initially masked by an occluder that covered their identity. Thus no processing of the stimuli identity was possible during the initial display (1000 ms duration), eliminating any preprocessing difference between onset and offset trials. On onset trials a new stimulus appeared above one of the occluder while on offset trials one of the occluder disappeared revealing the identity of one of the initial stimuli. In the second experiment, we reintroduced the main feature of offset events, that is, target location is empty when the response is selected. On onset trials a new object appeared in an empty location while on offset trials an old object disappeared from the screen rendering its location empty (see Figure 1B). Because participants were unaware of the type of stimulus presented on the following trial (onset vs. offset), they were forced to treat the initial display in analogous way on every single trial, thus eliminating any difference between onset and offset events at least until the dynamic event.

In both experiments, we compared onset and offset events in relation to the presence of the Simon effect, its relative size, and its time-course. In addition, an important aspect of the Simon effect is its dependency on the sequence of corresponding or non corresponding trials. Previous studies have shown that the Simon effect is reduced (e.g. Praamstra, Kleine & Schnitzler, 1999; Ridderinkhof, 2002), absent (e.g. Stürmer, Leuthold, Soetens, Schröder & Sommer, 2002) or even inverted (Hommel, Proctor & Vu, 2004) after non corresponding trials, whereas a regular Simon effect (i.e., faster and more accurate responses to corresponding trials than non corresponding ones) is observed after corresponding trials. Although specific to each conflict type (Funes, Lupiáñez & Humphreys, 2010a; 2010b), analogous sequential modulations have been also found in other well known conflict paradigms, such as the Flankers Compatibility Effect (e.g., Gratton, Coles & Donchin, 1992; Wendt & Luna-Rodriguez, 2009) or the Stroop effect (e.g., Fernandez-Duque & Knight, 2008; Logan & Zbrodoff, 1979; Tzelgov, Henik & Berger, 1992) thus indicating broader generality of the underlying mechanisms.

One explanation for the sequential modulations of the Simon effects, the 'information/gating' account, maintains that the location-based response activation carried out by the unconditional route is under the control of a higher-order cognitive control process (Mordkoff, 1998; Stürmer et al., 2002). Such cognitive control mechanisms can modify, increasing or decreasing, the flow of activation of the unconditional route from the stimulus location to the response codes. In corresponding trials, this flow of activation is useful for selecting the correct response, so that it is increased, leading to larger benefits in subsequent corresponding trials and larger costs in subsequent non corresponding trials (i.e., resulting in a larger Simon effect). In non corresponding trials, however, the flow of information is misleading for response selection, and it is therefore decreased or blocked, leading to smaller or absent benefits for subsequent corresponding trial and smaller or absent costs for subsequent non corresponding trials (i.e., reduced or inverted Simon effect). This explanation of the sequential modulation of the Simon effect is consistent with the influential response conflict monitoring model, originally proposed by Botvinick and colleagues to explain the sequential modulation of the Flanker effect (Botvinick, Braver, Barch, Carter, & Cohen, 2001). According to this model, preceding response conflict triggers stronger top-down control, leading to performance improvements on subsequent trials of similar context.

Since the onset-offset features have never been directly manipulated, previous sequential analyses were not suited to investigate the role of these features. In both experiments of this study, the present trial N and the preceding trial N-1 are both characterized not only by the repetition or alternation of the S-R correspondence but also by the repetition or alternation of the dynamic feature of the trial (onset – offset). Therefore we carried out a sequential analysis in which reaction times were analyzed as a function of the S-R correspondence and type of trial (onset – offset) in the present trial N and in the preceding trial N-1. Thus, we are able to investigate independently the effects of both variables to uncover whether the sequential modulation of the Simon effect is affected by the repetition vs. alternation of different types of trial (onset vs. offset) when these trials are randomly intermixed. If the unconditional activation of spatially corresponding responses operates on an abstract level, little or no differences should be expected between onset and offset trials on the general aspects of the Simon effect such as its size and time-course. Therefore, analogous sequential modulation should emerge after the repetition/alternation of onset and offset events. In contrast, if the unconditional route treats differently onset and offset events not only the Simon effects on trial N should be different but also cognitive control processes should affect differently the unconditional route generating a specific modulation according to the type of trial. In this case a different sequential modulation will be observed on consecutive trials, depending on whether the type of event (onset – offset) is repeated or alternated.

EXPERIMENT 1

In the present experiment we compared the Simon effect for onset and offset events in which task set and processing conditions were similar between these two types of events. Here, two stimuli, a red rectangle and a grey bar, were always presented at the beginning of each trial, to the left and to the right side of the fixation cross (see Figure 1A). Thus both locations were always occupied by the same set of stimuli. Importantly, the grey bar had in its middle the critical figure (either square or circle) that participants would have to discriminate, responding with the appropriate left-right key. However, this critical feature was always masked by an occluder (the rectangle) that covered their identity and only the end of the grey bars was visible (see Figure 1A). Thus no processing of the stimuli identity was possible during the initial display (1000 ms duration). On onset trials a new stimulus appeared above one of the occluder, while on offset trials one of the occluder disappeared revealing the identity of one of the initial stimuli. Furthermore, to compare directly the Simon effect for onset and offset events, we presented onset and offset targets in a random way within the same block of trials so that participants were not able to predict the following type of event (onset vs. offset). Participants were instructed to respond to the identity of the stimulus presented on the screen after the dynamic event (either onset or offset).

The aim of the present experiment was to assess the Simon effect for onset and offset stimuli under conditions where the only difference between onset and offset trials was the type of dynamic event (onset vs. offset).

METHOD

Participants. Twenty-four right-handed (Oldfield, 1971) students from the University of Parma, 6 males and 18 females, between 21-31 years of age, volunteered to take part in the experiment. They had normal or corrected-to-normal vision and were naive as to the purpose of the experiment.

Apparatus. The experiment took place in a sound-attenuated room, dimly illuminated by a halogen lamp directed towards the ceiling. Stimuli were displayed on a VGA monitor with P22 phosphor driven by an IBM-compatible PC, running E-PRIME software that generated the stimuli, controlled timing operations, and recorded the responses. The experimental monitor was mounted in a wooden frame and was covered by a grey cardboard, except for an 18 x 13 cm window in which the stimuli were displayed. Participants sat in front of the monitor with the head positioned in an adjustable head-and-chinrest, so that the distance between the eyes and the screen was approximately 57 cm. Eye height was adjusted to the level of fixation.

Each trial began with the presentation of the fixation cross (0.4° x 0.4°) along with two red rectangles (2.7° x 1.3°, Figure 1A), one on the left and one on the right field, each partially covering a gray object (4.2° x 0.4°) located underneath. After 1000 ms one of two events could happen. In the onset condition a new gray object was presented in one of the two marked locations, above one of the two red rectangles. In the offset condition, one of the two red rectangles disappeared revealing the background object. Red objects and target objects (gray objects) could have one of two orientations (vertical or horizontal). Target objects had either a square (side: 1°) or a

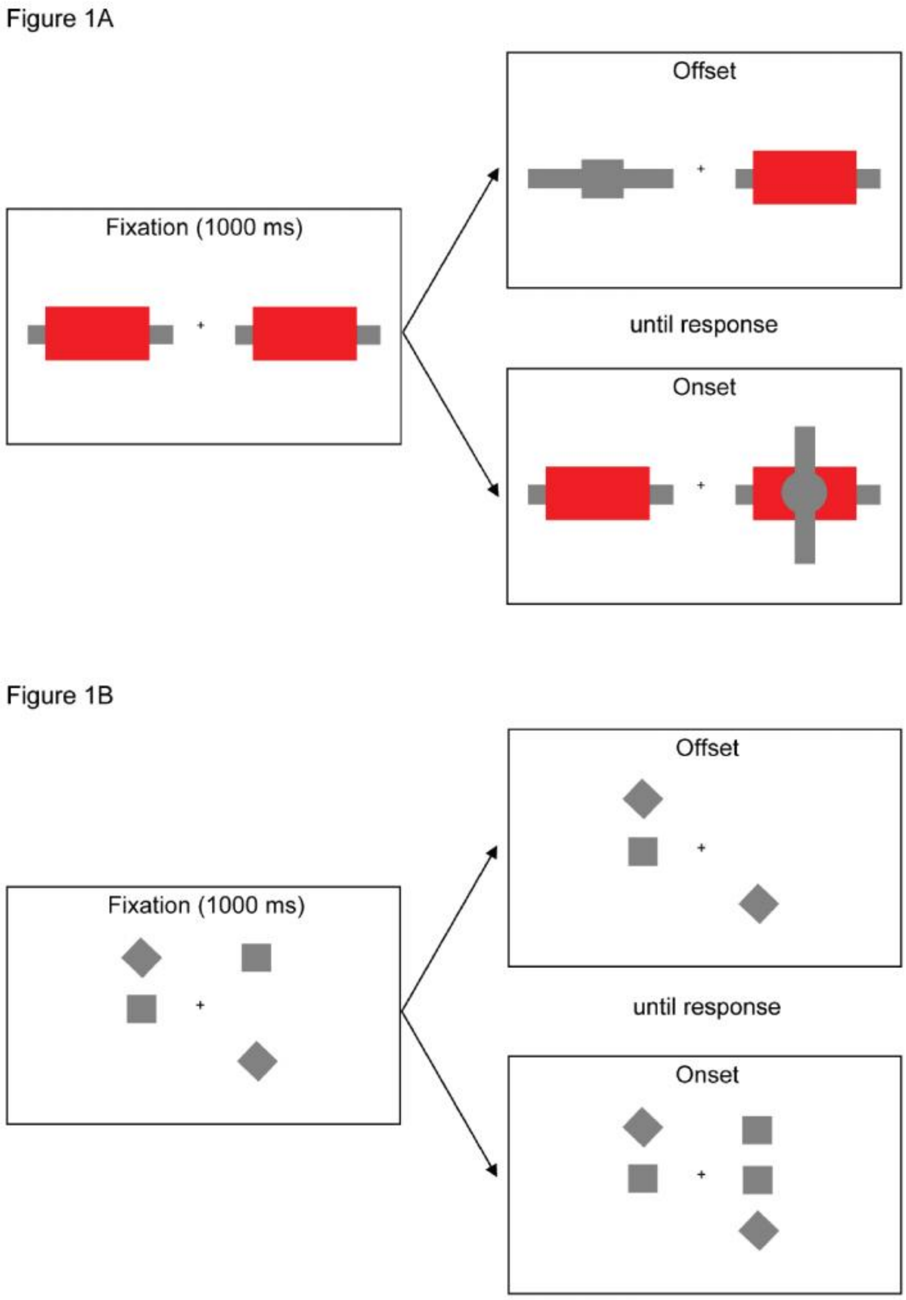

Figure 1. Stimuli used in Experiment 1 (Figure 1A) and in Experiment 2 (Figure 1B).

circle (diameter: 1°) in the center (Figure 1A). Onset targets always had a different orientation to the fixation objects, to emphasize their perceptual interpretation as new objects. In both onset and offset trials the target display was presented until the response, but anyway no longer than 1500 ms. The screen was cleared immediately after subjects' responses and a blank screen was shown for 1000 ms. Therefore, the interval between successive stimuli was variable.

Response keys were the Z and M letter keys of a standard QWERTY keyboard, aligned with the center of the screen; in this way one key was located to the right of the body midline and was pressed by the right index finger, whereas the other key was located to the left and was pressed by the left index finger. During the experiment each index finger was held on the corresponding response key (i.e., the left index on the left key).

Eye position was monitored using 10-mm electrodes located at the outer canthus of each eye. The electrodes were referred to an electrode attached to the right ear-lobe. Electro-oculographic (EOG) signals were digitized (sampling rate of 100 Hz) after filtering (0.5-2.0 Hz, 12 dB octave) and high gain amplification (10^4). Data acquisition was controlled by an IBM-compatible PC. Before the experiment, participants had to execute some calibration trials, which consisted in the 2°-pursuit-movements, in both horizontal directions, of a moving spot stimulus on the computer screen. This procedure allowed us to determine, for each participant, the baseline of 2°-movements. The output of the EOG, after on-line smoothing, which used a three-points moving average, was displayed on the monitor of an IBM-compatible PC, were two horizontal lines indicated the extent of 2°-movement to the right and to the left of the fixation point. The experimenter, the apparatus to monitor eye movements and the computer that controlled the experiment were located in a room next to the experimental room. During the experiment, an EOG signal that reached or overcame the baselines indexed eye movements equal or greater than 2° led to the on-line rejection of the corresponding trial.

Procedure. The experiment consisted of 144 trials for the onset condition and 144 for the offset condition, subdivided into six blocks of 48 trials, ran in one session and participants were allowed to take a short break between successive blocks. Onset and offset trials were randomly presented during the same blocks of trials and they occurred according to a random sequence, with the constraints that both the two target stimuli and the two orientations were presented half the time to the right, and half the time to the left of the fixation cross. The experimental trials were preceded by 20 practice trials.

In both the onset and the offset conditions, participants were instructed to respond to the identity of the target stimulus (square or circle). Half of the participants pressed a right key for the square and a left key for the circle, while the other half of the participants had the opposite rules. Trials for which RT was less than 150 ms (anticipations) or more than 1200 ms (missing responses) were discarded from the RT analyses, as well as trials in which participants pressed the wrong key or made an eye movement.

RESULTS

Overall errors (anticipation, missing response, key error and eye-movement) were 7.6% of all trials. Key error percentages were arcsine-transformed and entered into an analysis of variance (ANOVA) with type of Target (onset vs. offset), and target-response Correspondence (corresponding vs. non corresponding trials), as within-subjects variables. The main effect of Correspondence [$F(1, 23)=17.1$, $p<0.001$] was significant with more errors in non corresponding than in corresponding trials (7.3% vs. 3.2%). Neither the Target main effect nor the Target x Correspondence interaction emerged to be significant [both $F(1, 23)<1$].

Time-course analysis. The time course of the Simon effect was investigated by applying the Vincentization procedure introduced by Ratcliff (1979)) which consists of dividing the RT distributions for each participant and each level of Target type (onset vs. offset) and Correspondence (corresponding vs. non corresponding) variables into quintiles (bins) and computing mean RTs for each quintile.

Resulting means were entered into an ANOVA with three within-subjects variables: type of Target (onset vs. offset), target-response Correspondence (corresponding vs. non corresponding) and Bin (first trough fifth*).* The main effects of Target [$F(1, 23)=9.9$, $MSE=813.4$, $p<0.005$], Correspondence [$F(1, 23)=27$, $MSE=4699.9$, $p<0.001$], and Bin [$F(4, 92)=290.6$, $MSE=3166$, $p<0.001$], were significant. Onset trials were 8 ms slower than offset trials (505 vs. 497 ms). A normal Simon effect emerged with corresponding trials being 33 ms faster than non corresponding ones (484 vs. 517 ms). Of course RT lengthened from the first to the fifth bin (392, 444, 485, 533, 649 ms).

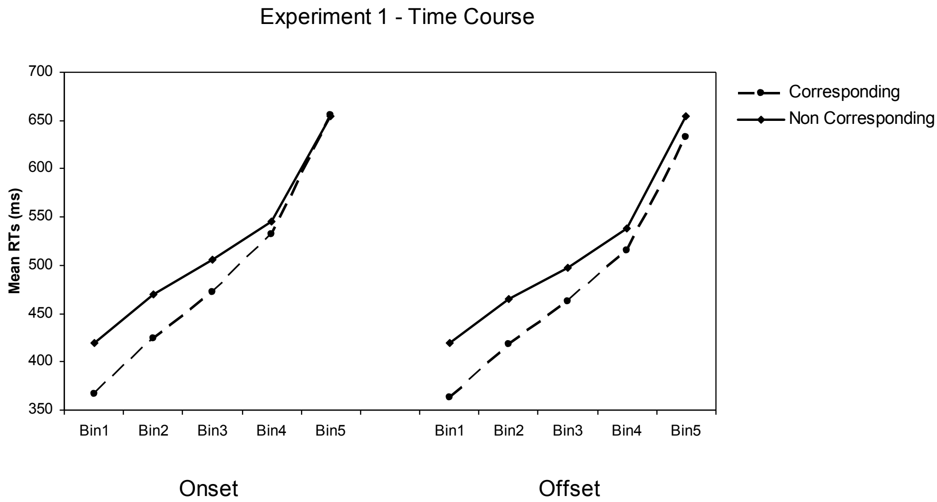

Figure 2. Time course analysis in Experiment 1. Mean reaction times (RTs) for each bin are represented for corresponding and non corresponding trials (dashed and solid lines, respectively), separately for onset and offset target types.

The Target x Correspondence interaction was not significant [F(1, 23)=1.9, MSE=936.3, p=0.17], suggesting that a Simon effect of similar size was present in both onset and offset trials (28 ms and 37 ms, respectively). The Correspondence x Bin interaction [F(4, 92)=17.9, MSE=474.7, p<0.001] showed that the size of the effect decreased from fast to slow responses (e.g., De Jong et al., 1994; Hommel, 1993), while the Target x Correspondence x Bin interaction [F(4, 92)=3, MSE=207.1, p<0.03] indicated that the Simon effect decreased more in onset than in offset trials for the last bins (Figure 2, for onset trials the Simon effect was highly significant in the 1^{st} to 3^{rd} bins, it was also significant in the 4^{th} bin but not in the 5^{th} whereas for offset trials it remained highly significant from the 1^{st} to the 5^{th} bin, as indicated by post-hoc analyses with the Newman-Keuls method).

Sequential analysis. A further ANOVA was conducted with Previous Target (onset vs. offset) x Present Target (onset vs. offset) x Previous Correspondence (corresponding vs. non corresponding trial) x Present Correspondence (corresponding vs. non corresponding trial) as within-subjects factors. Present Target was significant [F(1, 23)=7.4, MSE=751.3, p<0.012], confirming slower responses for onset than for offset trials. Previous Correspondence [F(1, 23)=20.6, MSE=670.4, p<0.001], showed that trials preceded by corresponding trials were 12 ms faster than those preceded by non corresponding trials (494 vs. 506 ms for trials preceded by corresponding and non corresponding trials, respectively) and Present Correspondence [F(1, 23)=28.7, MSE=3960.1, p<0.001], confirmed the Simon effect described above. More importantly, the interaction between Previous Correspondence and Present Correspondence was significant [F(1, 23)=62, MSE=1311.3, p<0.001]. As shown in Figure 3, the Simon effect depended on the correspondence of the previous trial. It was significant (64 ms with 462 vs. 526 ms for corresponding and non corresponding trials, respectively, p<0.001) when the previous trial was a corresponding one; whereas it was absent on trials following non corresponding trials (5 ms with 503 vs. 508 ms for corresponding and non corresponding trials, respectively, p=0.3). The factor Present Target (onset vs. offset) did not interact with Previous Target [F(1, 23)=0.7, MSE=794, p=0.4] or with Present Correspondence [F(1, 23)=1, MSE=686, p=0.3]. The Present Target x Previous Target x Present Correspondence interaction failed to reach significance [F(1, 23)=2, MSE=410.8, p=0.17]. Figure 4 shows the data for the Previous Target, Present Target and Present Correspondence interaction.

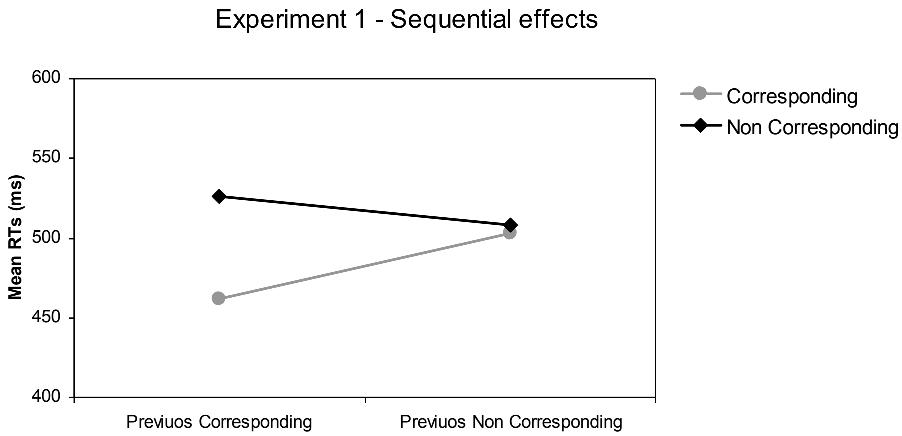

Figure 3. Sequential analysis in Experiment 1. Mean reaction times (RTs) for corresponding and non corresponding trials in the present trial (present correspondence) are represented as a function of correspondence in the preceding trial (previous correspondence).

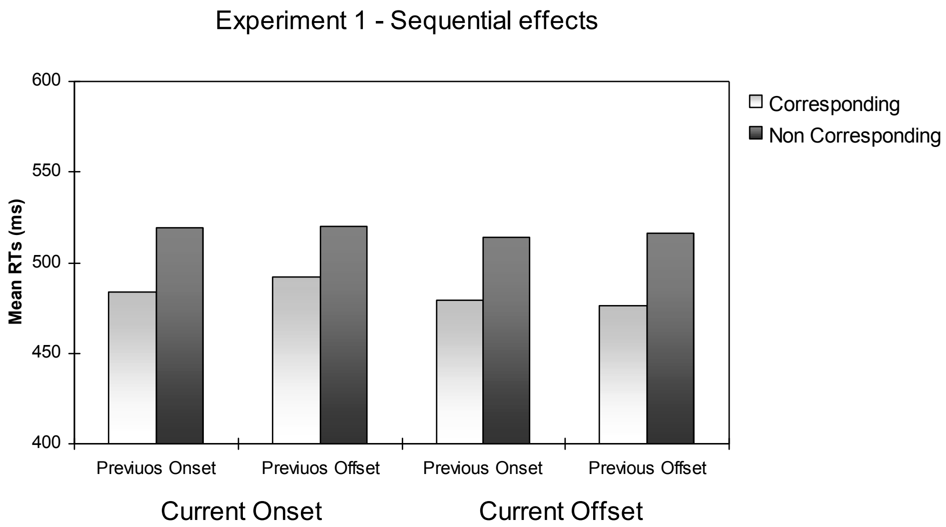

Figure 4. Sequential analysis in Experiment 1. Mean reaction times (RTs) for corresponding and non corresponding trials (grey and black bars, respectively) in the present trial (present correspondence) are represented as a function of the type of target (onset vs. offset) in previous and present trials.

DISCUSSION

In this experiment we compared the Simon effect for onset and offset events when differences in stimulus processing requirements between these types of targets were eliminated. In fact, thanks to the use of the two occluders no stimulus location was left empty after an offset event. Furthermore, both onset and offset targets could be processed for the same amount of time (and no pre-processing of the offset target was possible during the initial display). Under these conditions, both onset and offset events are able to generate a response code responsible for a Simon effect, although the onset event refers to the appearance of a new object in an already occupied location and the offset event is characterized by the offset of the occluder, not the target, which identity is revealed by the disappearance of the occluder. It seems therefore that any lateralized dynamic event is sufficient to prime corresponding responses. In this experiment, the size and time course of the Simon effect were very similar for onset and offset targets.

Moreover, the sequential analysis suggested that when the differences between onset and offset events were reduced, no difference emerged between the sequential modulations of the Simon effect for onset and offset trials.

EXPERIMENT 2

The aim of the present experiment was to assess the Simon effect for proper onset and offset events under conditions where these types of event are randomly presented within the same blocks of trials. Therefore, in contrast to experiment 1, the onset target is presented in an empty location, whereas the offset target makes a location empty. To this aim, four stimuli (two squares and two diamonds) were presented at the beginning of each trial for 1000 ms. These stimuli randomly occupied four of six possible locations (three positions vertically arranged on the left and three on the right side of the fixation cross - top, central and bottom positions - see Figure 1B) with the constrain that two different stimuli (one square and one diamond) were always located on each side. On onset trials a new stimulus (either a square or a diamond) appeared in one of the two empty locations while on offset trials one of the four initial stimuli (either one of the squares or one of the diamonds) disappeared leaving its location empty. Participants were instructed to respond to the identity of the stimulus (square or diamond) that appeared on the screen (onset trials) or disappeared from the screen (offset trials) after the initial display. Importantly, because participants could not predict the sequence of onset and offset events they were forced to process the initial display on every single trial in the same way thus reducing any set differences between onset and offset trials.

METHOD

Participants. Forty right-handed (Oldfield, 1971) students from the University of Parma, 17 males and 23 females, between 19-35 years of age, volunteered to take part in the experiment. They had normal or corrected-to-normal vision and were naive as to the purpose of the experiment.

Apparatus. Stimuli were black geometrical figures, squares and diamonds of the same area (1 square degree), displayed on a grey background. These figures were displayed in six possible locations, three in each field, along a vertical line situated 5° to the right or to the left of the fixation cross (0.4° x 0.4°). The central location was 3.5° far from the top and the bottom location.

Each trial began with the presentation of the fixation cross, shown at the geometrical center of the screen along with four objects (see Figure 1B) with the constraints that a square and a diamond were randomly presented in each field in two of the three possible locations. After 1000 ms, one of two events could happen. In the onset condition a new object (square or diamond) was presented in one of the two empty locations. In the offset condition one of the four objects, already presented, disappeared. In both onset and offset trials the target display was presented until the response, but anyway no longer than 1500 ms. The screen was cleared immediately after subjects' responses and a blank screen was shown for 1000 ms. Therefore, the interval between successive stimuli was variable.

The same response keys as in experiment 1 were used.

Procedure. The experiment consisted of 144 trials for the onset condition and 144 for the offset condition ran in one session. Onset and offset trials were randomly presented during the same block of trials. They occurred according to a quasi-random sequence, with the constraints that both the two types of geometrical figures and events were presented half the time to the right, and half to the left of the fixation cross. The experimental trials were preceded by 20 practice trials.

Participants were instructed to respond to the identity of the target event (square or diamond). Half of the participants pressed the right key for the square target and the left key for the diamond target, while the other half of the participants had the opposite rules.

As in experiment 1, trials for which RT was less than 150 ms (anticipations) or more than 1200 ms (missing responses) were discarded from the RT analyses, as well as trials in which the wrong key was pressed and where eye movements were made. Horizontal eye movements were monitored with the same EOG system used in experiment 1 and the same exclusion criteria were applied.

RESULTS

Overall errors (anticipation, missing response, key error and eye-movement) were 15.6% of all trials. Key error percentages were arcsine-transformed and entered into an ANOVA with type of Target (onset vs. offset), and target-response Correspondence (corresponding vs. non corresponding trials), as within-subjects variables. The main effect of Correspondence failed to reach significance [$F(1, 39)=2.5$, $p=0.12$], 11% in corresponding trials and 13% in non corresponding trials. The main effect of Target type emerged to be significant [F(1, 39)=134, p<0.001] with more errors in offset than in onset trials (18% vs. 6%, respectively). Type of Target x Correspondence was not significant [F(1, 39)<1].

Time-course analysis. As in Experiment 1 an ANOVA was conducted with Target, Correspondence and Bin as within-subjects variables. All the three main effects were significant. The significance of Target [F(1, 39)=136.7, MSE=10185, p<0.001], was due to faster responses to onset than to offset trials (611 vs. 695 ms), suggesting that the appearance of a new object in an empty location was more salient than the disappearance of an old object which left its location empty (as further confirmed by the error analysis). In fact, the same difference was not present in Experiment 1 where both the possible target locations were always occupied by one object. The main effect of Correspondence [F(1, 39)=6.1, MSE=3979.8, p<0.02], showed a Simon effect of 11 ms (647 vs. 658 for corresponding and non corresponding trials). The significant main effect of Bin [F(4, 156) =779.5, MSE=3541.9, p<0.001] was linked to a progressive slowing-down of responses across bins (497, 580, 639, 705 and 844 ms from the first to the last bin, respectively).

The two-way interaction Target x Bin [F(4, 156)=58.8, MSE=556.3, p<0.001], indicated the presence of a response disadvantage on offset trials with respect to onset ones that increased across bins (42, 72, 87, 103 and 116 ms from the first to the last bin, respectively). Furthermore, the significant Correspondence x Bin interaction [F(4, 156)=8.4, MSE=474.5, p<0.001] showed that the Simon effect decreased steadily across bins (24, 18, 9, 3 and 2 ms from the first to the last bin, respectively).

Both types of events showed a Simon effect of similar magnitude (9 vs. 13 ms for onset and offset events, respectively) as demonstrated by the absence of a Target x Correspondence interaction [F(1, 39)=0.3, MSE=1885, p=0.6]. In the same way, the analysis of the time-course of the Simon effect showed that the spatial information about stimulus location provided by onset and offset events is treated in the same manner in the S-R translation. No Target x Correspondence x Bin interaction was found [F(4, 156)=0.6, MSE=322.6, p=0.6] indicating similar time courses characterized by a large difference between corresponding and non corresponding trials with fast RTs which decreased with slow RTs (Figure 5).

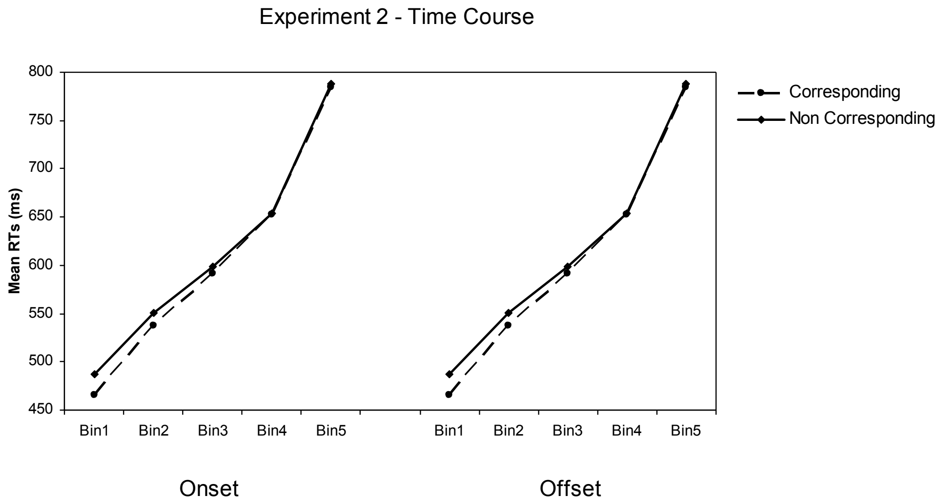

Figure 5. Time course analysis in Experiment 2. Mean reaction times (RTs) for each bin are represented for corresponding and non corresponding trials (dashed and solid lines, respectively), separately for onset and offset target types.

Sequential analysis. As in Experiment 1, a further ANOVA was conducted with Previous Target x Present Target x Previous Correspondence x Present Correspondence as within-subjects factors. The main effect of Present Target [$F(1, 39)=131.4$, $MSE=8682.7$, $p<0.001$], confirmed slower responses for offset than for onset trials and the main effect of Present Correspondence [$F(1, 39)=5.7$, $p<0.03$], confirmed the presence of the Simon effect described above. The significance of the interaction between Previous Correspondence and Present Correspondence [$F(1, 39)=5.8$, $MSE=2024.5$, $p<0.02$], showed the dependence of the Simon effect on the correspondence of the previous trial (see Figure 6): when the previous trial was corresponding a 20 ms Simon effect emerged (644 vs. 664 ms for corresponding and non corresponding trials, respectively, $p<0.003$), while no effect was found after non corresponding trials (652 vs. 654 ms for corresponding and non corresponding trials, respectively, $p>.6$).

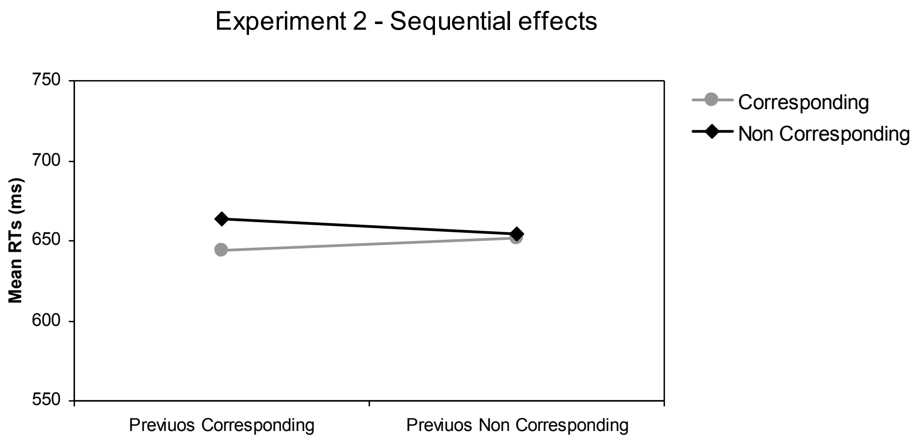

Figure 6. Sequential analysis in Experiment 2. Mean reaction times (RTs) for corresponding and non corresponding trials in the present trial (present correspondence) are represented as a function of correspondence in the preceding trial (previous correspondence).

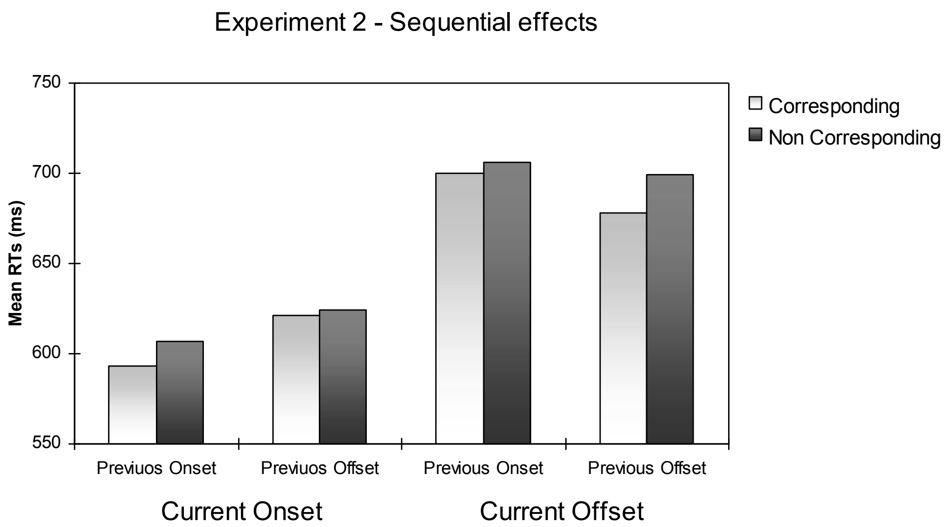

Figure 7. Sequential analysis in Experiment 2. Mean reaction times (RTs) for corresponding and non corresponding trials (grey and black bars, respectively) in the present trial (present correspondence) are represented as a function of the type of target (onset vs. offset) in previous and present trials.

The Simon effect on the present trial depended on the correspondence of the previous trial regardless of the type of target (onset vs. offset), as indicated by the fact that the factor Present Target (onset vs. offset) did not modulate the Previous Correspondence x Present Correspondence interaction ($p>0.1$).

The interaction Previous Target x Present Target [$F(1, 39)=33.8$, $MSE=1666.9$, $p<0.001$], emerged to be significant. While responses to offset targets were always slower than responses to onset targets, the size of this effect was modulated by the preceding type of target, with a larger difference after an onset target (103 ms, $p<0.001$) than after an offset target (65 ms, $p<0.001$).

Finally, the three-way interaction Previous Target x Present Target x Present Correspondence [$F(1, 39) =5.1$, $MSE=1205.2$, $p<0.03$] revealed that the Simon effect was significant only when the same type of target was repeated in the previous and present trial (14 ms Simon effect after two successive onset targets, $p<0.02$; 21 ms Simon effect after two consecutive offset trials, $p<0.001$), but not when they were alternated (3 ms Simon effect for offset preceded by onset trials, $p=.53$; 6 ms Simon effect for onset preceded by offset event, $p=0.27$, Figure 7).

DISCUSSION

In Experiment 2 participants responded to the identity of a dynamic event: the appearance of a new object or the disappearance of an old object, randomly presented during the same block of trials. Under these conditions in which a direct comparison between the two events is possible, onset and offset events showed a Simon effect of similar magnitude (9 vs. 13 ms for onset and offset events, respectively). In the same way, other aspects of the Simon task, such as its time-course and the sequential effects, contributed to show that the spatial information about stimulus location provided by onset and offset events is treated in the same manner in the S-R translation as demonstrated by the similar time-course of the Simon effect for onset and offset events.

The results of the time-course analysis suggested that both the appearance and the disappearance of the target generated a response code that facilitated or interfered with the selection of the task-relevant response in a similar way. The decreasing pattern of the Simon effect found with both targets indicates that the automatic, transient information processing takes place within privileged visuomotor pathways when an object appears on the screen as well as when it disappears from it.

The sequential analysis revealed that the Simon effect of the present trial N depended on the type of target (onset or offset) presented on trial N and N-1. A significant Simon effect emerged only when the same type of target (either onset or offset) was repeated on two successive trials. In contrast, no effect was found when different types of targets were presented on two successive trials.

GENERAL DISCUSSION

Previous studies (Riggio et al., 2003; Wühr & Kunde, 2006) suggested that offset events are able to produce a spatial code that can facilitate or interfere with the selection of the correct response, similarly to onset events. However, in previous studies when the offset Simon effect is compared to the onset Simon effect important differences emerged. It is feasible that some of these differences were due to the fact that previous research investigated onset and offset events separately with the possibility that participants applied different task-set for one or the other target property. The aim of the present work was to compare the Simon effect for onset and offset targets under conditions in which these stimuli features were simultaneously manipulated. Two experiments were conducted in which onset and offset targets were randomly presented during the same block of trials, that is, in situations in which participants were not able to predict the sequence of successive type of targets.

By definition offset targets involve the disappearance of old objects. This implies two outcomes: 1 target location is empty after the offset event, and 2. target processing and dynamic event are temporally dissociated only in offset trials. These two features of offset trials are eliminated in Experiment 1 whereas they are present in Experiment 2. In Experiment 1 the target locations were always occupied by objects occluding the potential target underneath. The onset target was a new object that appeared in one of those locations above one of the occluder, while the offset target consisted of the disappearance of one of the occluders that made visible the target object underneath. Here both onset and offset targets remained on the screen until response after the dynamic event. In Experiment 2 a 'proper' onset target consisting in the appearance of a new object in an empty location and a 'proper' offset target consisting in the disappearance of an old object rendering its location empty were used, within the same blocks of trials.

Overall our results demonstrate not only that 'proper' onset and offset events (Experiment 2) are able to generate a Simon effect but also onset and offset events in Experiment 1. Furthermore, in both experiments the sizes of the Simon effect were very similar for onset and offset targets suggesting abstract stimulus-response codes. These similarities argue in favour of the importance of eliminating any task-set for one or the other target property by mixing the two types of events in order to prevent anticipation strategies for a specific type of event. Note that in Wühr and Kunde's study (2006) where the onset trials produced a larger Simon effect than offset trials, the two types of trials referred to different experiments.

To further investigate the mechanisms underlying the Simon effect for onset and offset events two distinct analyses were carried out: the time course and the sequential analyses. In the two following sections these findings will be discussed separately.

Time course

The Simon effect for onset and offset targets is larger in fast trials and smaller in slow trials in both experiments. These decreasing temporal courses of the Simon effect had been related to the bottom-up activation of sensorimotor networks (innate or overlearned in everyday life) that primes actions spatially corresponding with the stimulus location. This automatic activation is transient and decays over time, spontaneously or because of active inhibition (e.g., Hommel, 1994; Tagliabue, Zorzi, Umiltà & Bassignani, 2000), thus the Simon effect disappears with slow responses.

The present work shows that presenting a dynamic event is enough to activate natural connections between stimuli and responses. Wascher, Schatz, Kuder and Verleger (2001) postulated two prerequisites for the activation of these privileged connections: 1. presentation of stimuli in the visual modality because this is part of the grasping system and 2. the required movement has to be anatomical. It is interesting to note that actions like reaching, grasping and manipulating are directed towards objects that are located in space. In order to interact with these objects, they need to be localized first. In our paradigm the hands were in anatomical positions and visual stimuli were used. However it is not clear whether a disappearing stimulus is a natural stimulus for the grasping system; after all when a stimulus disappears (see offset condition in Experiment 2) there is nothing to be grasped. So the onset-offset manipulation shows, at least when simple key presses are used, that the sensorimotor interactions are less specific than it was previously proposed (see also Wühr, 2006). In agreement with Wühr & Kunde' results (2006), our findings show a decreasing time course for both onset and offset targets, thus suggesting abstract interactions between stimuli and responses.

In the two previous studies that compared the Simon effect for onset and offset stimuli (Riggio et al., 2003; Wühr & Kunde, 2006) the observed time course for offset stimuli was not consistent. Wühr and Kunde found that both onset and offset targets show slightly decreasing Simon effects. In contrast, Riggio et al. (2003) found decreasing and increasing effects for onset and offset targets respectively. Thus it remains to be explained why in Riggio et al. (2003) a different time course was obtained with offset stimuli. In a previous study, Hommel (1996, see also Buetti & Kerzel, 2009 for a similar result) found an increasing time-course of spatial S-R Simon effect in simple reaction time tasks. In Experiment 1 of that study a central cue indicated the response to be executed before each trial, but the response was made after the presentation of a lateral go signal. A spatial Simon effect between go signal and response was found even if participants had a strong motivation to prepare the response after the presentation of the central cue. Moreover the size of the Simon effect increased steadily from the faster to the slower responses. Since in Riggio et al.' offset condition, the initial display was formed by only two figures participants could pre-process each figure, and perhaps associate it with the corresponding right or the left response before the offset event. In other words, participants could prepare for example the right response for the figure on the left, and the left response for that in the right even if the selection of the response was of course possible only after the offset event. Therefore, the increasing time-course pattern of the Simon effect in this condition could be a consequence of the use of only two figures with the possibility that the response code activated by the conditional route could be many times faster than the response code activated by the unconditional route. As said in the introduction, the Simon effect is considered the result of a conflict of two different response codes formed during the selection of the response. Tipically, the activation of the correct response derived from the instructions is slower than the activation of the response derived from the unconditional route. This generates a strong interference between the two response codes in the first bins when the automatic response activation is still available and a weaker interference in the last bins when the activation of the automatic response tends to decay, with the result of a decreasing Simon effect. But when the instructed response is faster than the automatic response (because it is prepared in advance), interference is larger later, in the last bins, when the automatic response becomes active leading to an increasing pattern of the Simon effect (Hommel, 1996). When only two figures are presented in the offset condition, as in Riggio et al., it might be possible to associate and held in some state of readiness the corresponding responses for the figure on the left and right location, rendering very fast the selection of the correct response when a figure disappears with the result of an increasing Simon effect. In contrast, when the initial display contains more than two figures (as in Wühr & Kunde, 2006, and in the present study) these processes are not possible, thus leading to a decreasing Simon effect with both onset and offset events.

Sequential effects

In the sequential analysis the Simon effect is analyzed as a function of the spatial S-R correspondence of the present and preceding trials. Typically, a strong Simon effect is found after a corresponding trial but little or no effect emerges after a non corresponding trial (sequential modulation of the Simon effect). In the sequential analysis of the present study, not only we considered the correspondence of the present and preceding trial but also the type of target in the present and preceding trial, to uncover whether similar or different mechanisms for the Simon effect would emerge during onset and offset trials.

Results of this analysis in both experiments revealed the typical pattern of modulation of the Simon effect when the sequence of corresponding and non corresponding trial is considered. The Simon effect was increased when the preceding trial was corresponding while it was eliminated whenever the preceding trial was non corresponding. It is interesting to note that the same result was found for both onset and offset events thus demonstrating that the mechanisms responsible for the sequential modulation of the Simon effect do not depend on the specific perceptual characteristics of the stimuli (onset vs. offset). This observation is further confirmed by the fact that offset events in Experiment 1 and 2 were different. While Experiment 2 was characterized by a 'proper' stimulus offset which left the stimulus location empty, in the offset event of Experiment 1 the stimulus location was never empty, as it was the occluder which disappeared revealing the target underneath. Nevertheless, similar sequential modulations of the Simon effect were found. This implies in our opinion that cognitive control processes operate on a rather abstract representation of the S-R, or at least that the mechanisms triggered by onset and offset events are very similar.

An interesting finding of the sequential analysis is the fact that the Simon effect emerged to be significant in Experiment 2 only when the same type of target was repeated in the present and in the preceding trial as reflected by the significant interaction between previous target, present target and present correspondence. Thus, a significant Simon effect was found when the target was either an onset or an offset in two successive trials but not when these types of targets were alternated on successive trials. It should be noted that although in Experiment 1 the analogous interaction failed to reach significance, the data exhibited a similar trend (Figure 4) with larger Simon effects after the repetition of the same target type. Therefore we carried out a further ANOVA to directly compare the sequential effects of target type on the Simon effect under conditions in which onset and offset targets were characterized by a low (Experiment 1) or high (Experiment 2) degree of differences. While the three-ways interaction between Previous Target x Present Target x Present Correspondence emerged to be significant [$F(1, 62)=5.28$, $MSE=992.6$, $p<0.03$], confirming that the Simon effect was larger when the same type (onset or offset) of target was repeated, no difference was found between the two experiments [$F(1, 62)=0.58$, $MSE=992.6$, $p=0.40$].

The fact that no difference emerged between the two experiments indicates that the Simon effect was modulated in a similar way in both experiments by the sequential presentation of target type in the present and previous trials. However, this effect seems to be stronger in Experiment 2 where differences between onset and offset events were stronger. In Experiment 1 where for both onset and offset trials the response-relevant information was present until response execution and no spatial location remained empty after the offset event (although it is to note that the critical event, onset vs. offset, was still clearly different for the two target types), the sequential modulation appeared to be weaker failing to reach significance. In contrast, in Experiment 2 where on offset trials the spatial location remains empty as compared to onset ones, a clear sequential modulation was found. These results suggest that although there seems to be a general pattern in both experiments, the strength of this sequential effect depends on the differences between onset and offset targets with more sizable sequential modulations of the Simon effect when the differences between onset and offset trials are stronger.

Moreover it should be noted that the modulation of the Simon effect by the previous and present type of target only concerns the correspondence of the present trial. Thus, it is independent from the mechanisms responsible for the 'classic' sequential modulation of the Simon effect where the S-R correspondence of the present trial is modulated by the correspondence of the preceding trial. A further ANOVA was carried out in which the factors Present Correspondence x Previous Correspondence x Present Target x Target Type Repetition (same vs. different types in the previous and present trial), were considered. This was done to measure any dependency of the Simon sequential effects on similarity on consecutive trials as predicted by the Feature Integration Account (Hommel et al., 2004). If this is the case significant three ways interactions between Present correspondence x Previous correspondence x target type repetition should be expected. However, no such interaction emerged in Experiment 1 [F(1, 23)=1.1, p=0.299] nor in Experiment 2 [F(1, 39)=0, p=0.99], confirming the idea that the modulation of the Simon effect on trial N by repetition or alternation of the same type of target is independent of the correspondence of the trial N-1.

Taken together these results suggest that the Simon effect on a given trial is not only dependent on the spatial relation between stimulus and response but also on the repetition of different categories or features of stimuli. This is the first study directly manipulating the onset vs. offset feature as an independent variable. We were able to reveal its importance in the occurrence of the Simon effect by demonstrating that the Simon effect is present only when the same category of stimuli is repeated on two successive trials regardless of their correspondence status. Although the previous indexes of the time-course of the Simon effect showed no differences according to the type of trial, this result clearly demonstrated that at some level onsets and offsets affect Simon task performance in a specific way. Future research should investigate whether this sequential modulation of the Simon effect is specifically linked to the onset-offset dimension or it can be generalized to other categories or features of stimuli such as, for example, their modality of presentation (e.g. visual vs. auditory stimuli) suggesting the involvement of higher levels control processes.

In short, the present study has demonstrated that under conditions in which onset and offset events are randomly intermixed the Simon effects produced by these events are extremely similar. For instance, their size is of similar magnitude, their decreasing time course is comparable and they are characterized by similar sequential modulations (sizable Simon effect after corresponding trials and reduced Simon effect after non corresponding trials). However, the presence of the current Simon effect is modulated by the repetition of the same type of target (onset vs. offset) on successive trials. These results demonstrate for the first time, at least for the onset-offset dimension, how the Simon effect is affected by other task-irrelevant features of the target not just its spatial location.

RESUMEN

La aparición y desparición abrupta de objetos como determinantes del efecto Simon. En este trabajo investigamos las características del efecto Simon producido por la aparición vs. desaparición de objetos en escena, cuando los dos tipos de evento ocurren de forma aleatoria e impredecible. En el Experimento 1, las dos posiciones en las que podía presentarse el estímulo objetivo aparecían ocluidas por otro objeto. En los ensayos de *aparición de objeto*, el estímulo objetivo se presentaba encima del objeto presente; en tanto que en los ensayos de *desaparición de objeto*, el estímulo objetivo se revelaba por la desaparición del objeto presente. En el Experimento 2, se presentaban cuatro estímulos en cuatro de seis posiciones posibles. En los ensayos de aparición de objeto el estímulo objetivo aparecía de forma abrupta como un nuevo objeto en una de las dos posiciones vacías; mientras que en los ensayos de desaparición de objeto el estímulo objetivo estaba definido como el objeto de los cuatro objetos iniciales que desaparecía de la escena. En ambos experimentos se observó un efecto Simon similar para los dos tipos de evento (aparición y desaparición de objeto). Los dos efectos eran similares en tamaño, curso temporal y modulación por efectos secuenciales, lo que sugiere una interacción sensorio-motora similar entre el lugar del estímulo objetivo y el de la respuesta. Sin embargo, la magnitud del efecto Simon en un ensayo dado era mayor cuando el evento en el ensayo anterior era de la misma naturaleza (aparición o desaparición de objeto), lo que muestra un papel importante del tipo de evento en el efecto Simon.

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