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ORIGINAL ARTICLE

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Response strategies and the Simon effect

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Abstract The study investigated whether the Simon effect, and its facilitation and interference components, shows up in reaction time (RT) or in movement time (MT), depending on the response strategy. Experiment 1 replicated a study by Hietanen and Rämä. Subjects had to press one of two lateralised keys in response to one of two stimuli. The stimuli were presented in the center (neutral condition) or to the left or right side (corresponding or non-corresponding conditions). To press the response key, a reaching movement was necessary, and both RT and MT were recorded. One group of subjects showed an RT facilitation effect and an MT interference effect. Another group of subjects showed both MT facilitation and MT interference effects. It was hypothesized that the two groups used different response strategies. In Exps. 2 and 3, the subjects were explicitly instructed to use the two strategies that were hypothesized for Exp. 1. The results showed that whether facilitation and interference manifest themselves in RT or MT depends on the response strategy adopted by the subjects.

Introduction

The Simon effect arises when subjects are required to make a rapid left or right motor response on the basis of a stimulus dimension other than position (e.g., form), and the stimulus appears in one of two lateralised positions, that is, on the left or on the right (Simon, 1969; for reviews, see Lu & Proctor, 1995; Umiltà & Nicoletti, 1990). For example, in a typical Simon task subjects are required to respond with the left-side key to one stimulus (e.g., a square) and with the right-side key to a different stimulus (e.g., a circle). Although subjects have to perform a shape-discrimination task, and thus stimulus position is task irrelevant, response are faster when the position of the stimulus and the position of the response correspond (corresponding S-R pairings) than when they do not correspond (non-corresponding S-R pairings).

Because the Simon effect is not affected by factors that influence response execution (Hasbroucq, Guiard, & Kornblum, 1989; Spijkers, 1990), it is considered to be a response selection phenomenon (e.g., Lu & Proctor, 1995). The only dissenting opinion is that of Hasbroucq and Guiard (1991), who ascribe the Simon effect to an earlier stage, that is, to stimulus encoding.

The response selection view maintains that the stimulus position code automatically activates its spatially corresponding response. On trials in which the automatically activated response corresponds to the response signalled by the relevant stimulus feature, there is no competition at the response selection stage, but facilitation. Hence, reaction times (RTs) are comparatively fast. On trials in which the automatically activated response does not correspond to the one signalled by the relevant stimulus features (i.e., on non-corresponding trials), competition must be resolved before the correct response is executed. This competition causes interference. Hence, RTs are comparatively slow on non-corresponding trials.

The activation of the corresponding response by the spatial stimulus code, for which there is behavioral and psychophysiological converging evidence, is often incorporated in a dual-route model (De Jong, Liang, & Lauber, 1994; Eimer, 1995; Eimer, Hommel, & Prinz, 1995; Kornblum, 1994; Kornblum & Lee, 1995; Proctor, Lu, Wang, & Dutta, 1995). According to this model, a

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stimulus automatically activates its spatially corresponding response through an automatic route. Through a non-automatic route, the relevant stimulus dimension activates the correct response on the basis of task instructions.

All versions of the dual-route model predict that RT for corresponding S-R pairings is faster and RT for non-corresponding S-R pairing is slower than RT for a neutral, non-lateralized condition. This is because on neutral trials speed of response is not affected by either the automatic fast activation of the correct response, as occurs on corresponding trials, or by the conflict between the wrong but automatically activated response and the correct response, as occurs in non-corresponding trials. Therefore, the presence of both facilitation and interference is a crucial prediction of the dual-route models.

In a study by Hietanen & Rämä (1995), on each trial subjects started holding a central pad with their right hand until a visual stimulus appeared in one of three possible locations (that is, left, central, and right, in relation to the body midline). They were instructed to release the central pad and, with the same hand, to reach and press one of the two lateralized response pads (left or right), depending on the color of the stimulus and irrespective of its location. The central stimulus location was the neutral condition and was considered a baseline to be compared with the corresponding and the non-corresponding pairings. A lateralized stimulus that required an ipsilateral response produced a corresponding trial, whereas it produced a non-corresponding trial when a contralateral response was required. RT was computed from stimulus onset to release of the central pad, whereas movement time (MT) was measured from release of the central pad to contact with the response pad.

The results showed a Simon effect for both RT and MT. However, in the two measures, the Simon effect had different components. In RT there was only facilitation, corresponding trials being faster than neutral trials. In MT there was only interference, non-corresponding trials being slower than neutral trials.

To explain their results, Hietanen & Rämä (1995) suggested that when the imperative stimulus appeared in the periphery, a movement in the direction of the stimulus was immediately programed. If the trial happened to be a corresponding one, then the movement could be executed without delay. If the trial happened to be a non-corresponding one, then a new program had to be prepared after stimulus discrimination. Also on neutral trials, that is, when the stimulus appeared in the center, the new motor program could be prepared only after stimulus discrimination. This would explain why RT was faster on corresponding than on neutral trials (facilitation) and why RT was not faster on neutral than on non-corresponding trials (lack of interference).

Also, Hietanen and Rämä (1995) suggested that, on non-corresponding trials, the program triggered by the stimulus was changed during the movement phase of the response. In contrast, on neither corresponding or neutral trials did the change in program occur. This would explain why in MTs there was interference but no facilitation.

Hietanen and Rämä's (1995) results are at odds with the dual-route model on two accounts. First, as just noted, the presence of both facilitation and interference in the RT measure is crucial for every version of the model. Second, because the model assumes that the Simon effect occurs at response selection, rather than at response execution, it should manifest itself in RT but not in MT.

However, the experimental procedure adopted by Hietanen and Rämä (1995) was markedly dissimilar from that of a regular choice RT task, of the sort normally used to produce the Simon effect. In the task, two different strategies could be adopted. (For response strategies when response alternatives are aimed movements, see Proctor & Wang, 1997, pp. 33–34.) The subject could release the central pad as soon as the stimulus appeared and then reach for one of the two lateralized pads to press the response key (see, e.g., Smith & Carew, 1987). This way, the directional (i.e., left or right) component of the response would be programed after RT. In other words, a simple RT would be measured, which includes the stages preceding response selection, but not the response selection stage. If one considers that the Simon effect originates at the response selection stage (see, e.g., Lu & Proctor, 1995), it is clear that, when subjects initiate the response before they make the decision about its direction, an effect related to response selection cannot show up in RT. The time needed to select the left or right response should instead be included in MT, which thus should show the Simon effect.

Alternatively, subjects could withhold releasing of the central pad until the whole response, including its directional component, was programed. This way, the response selection stage would be included in RT, thus rendering it sensitive to the Simon effect.

Note that the two strategies can be empirically distinguished. If response selection occurs in MT, comparatively fast RTs and comparatively slow MTs should be observed. If response selection occurs in RT, comparatively slow RTs and comparatively fast MTs should be observed.

The experiments of the present study explored if these two response strategies can determine whether the Simon effect will show up in RT or in MT. Also, they explore whether the facilitation and interference components are differentially affected by whether the effect shows up in RT or MT.

Experiment 1

The aim of Exp. 1 was to test whether the task developed by Hietanen and Rämä (1995) could be performed in two manners. As was mentioned earlier, these two strategies can be indexed by different RT and MT patterns. One strategy consists in releasing the central pad only after the whole movement has been programed. It should yield slow RTs and fast MTs. We will term it sRT/fMT startegy. The other strategy consists in releasing the central pad as soon as the stimulus appears and then deciding which response pad to reach for. It should yield fast RTs and slow MTs. We will term it fRT/sMT strategy. In the present experiment, we try to differentiate the two strategies by asking the subjects to perform a task very similar to the one used by Hietanen and Rämä and then dividing the subjects into two groups on the basis of the relative speed of their RTs and MTs.

Method

Subjects. Twenty-four students of the University of Modena volunteered to participate in the experiment. They were right-handed, had normal or corrected-to-normal vision, and were not aware of the purpose of the experiment.

Apparatus and display. The experiment took place in a dimly lit and noiseless room. Subjects were seated facing a cathode-ray tube screen driven by a Tulip dt 386sx computer. The subject's head was positioned in an adjustable head-and-chin rest. The distance between the eyes and the screen was about 45 cm. The visual display comprised the following items (see Fig. 1): three empty boxes, 3.8° × 2° in size; a 1° × 1° cross, which was shown 1.9° up or down from the geometrical center of the screen and positioned 8.3° up or down from the geometrical center of the central box; one 3.8° × 1° filled rectangle and one 2° × 2° filled square (i.e., the stimuli), which were shown, one at a time, centered in one of the three boxes. The space bar of the computer keyboard served as central pad, and the characters "Z" and "\", were the two (left and right) response keys, respectively. Response timing and data collection were controlled by the Micro Experimental Laboratory software system (MEL 1.0; Schneider, 1988).

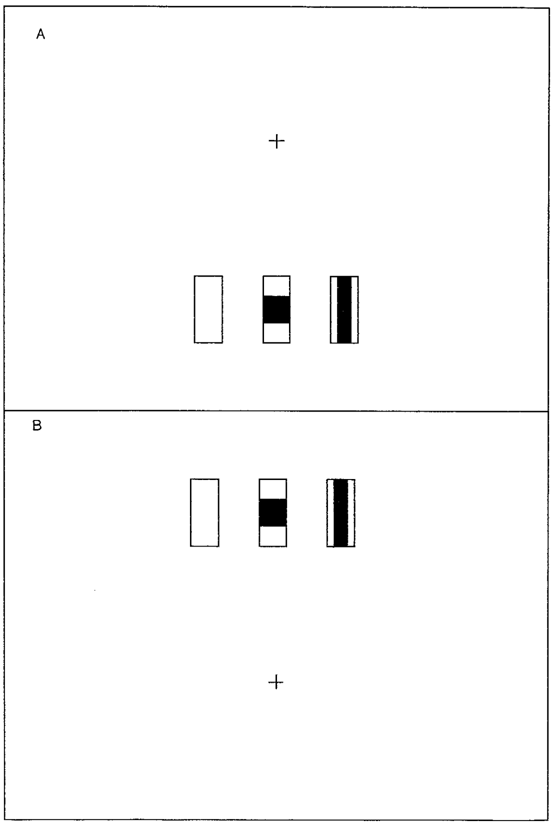

Fig. 1 Schematic drawing of the displays used in Exp. 1

Procedure. On each trial, the sequence of events was a follows. The subjects held down the space bar with their right index finger to start the trial. The bar was pressed roughly at its center. The fixation cross and the three boxes were visible on the screen throughout the trial. On each trial a warning tone (25 ms in duration) was delivered. Subsequently, after an interval of 300 ms, one stimulus (either the square or the rectangle) appeared for 100 ms inside one of the three boxes.

Subjects were instructed to maintain fixation, release the space bar, and press as fast as possible upon stimulus presentation one of the two keys, depending on stimulus shape, with their right index finger. RT was measured from stimulus onset to release of the space bar. MT was measured from release of the space bar to depression of one of the two lateralized keys. Half of the subjects used the right-side key for the square and the left-side key for the rectangle, whereas the other half had the reverse assignment. At the end of each trial, subjects were informed about RT and accuracy through feedback shown below the fixation cross, followed by a 1-s intertrial interval.

Every subject was tested individually in one experimental session, which comprised 240 trials, split into two equal blocks. In one block the fixation cross was up and the three empty boxes were down from the geometrical center of the screen (Fig. 1, Panel A), whereas the other block had the reverse arrangement (Fig. 1, Panel B). The order of blocks was counterbalanced across subjects. This experimental manipulation was introduced to control for possible asymmetries in visual acuity between the upper and the lower hemifield. However, preliminary analyses showed that it was immaterial.

The first experimental block was preceded by a block of practice trials. Stimulus presentation occurred according to a quasi-random sequence, with the constraints that both the square and the rectangle appeared equally often in the three boxes, thus requiring a right-hand response half of the time and a left-hand response the other half.

Results

The present and all subsequent analyses were conducted after discarding those trials in which an error occurred (about 1.5%) in which RT was faster than 100 ms or slower than 900 ms, or in which MT was slower than 900 ms. Using the Vincentization procedure introduced by Ratcliff (1979), we calculated the mean RT for the first through the fifth bin, that is, for the 20% fastest RTs through the 20% slowest RTs. This was done because the magnitude of the Simon effect is known to vary as a function of response speed (e.g., Eimer et al., 1995; Rubichi, Iani, Nicoletti, & Umiltà, 1997).

To establish whether two patterns for RT and MT data were present, the subjects were rank-ordered on the basis of these measures and were accordingly divided into three groups (see Table 1). Group 1 comprised nine subjects for whom average RT fell into the slower half of the group RT distribution, whereas average MT fell into the faster half of the group MT distribution. They

Table 1 Mean reaction time (RT) and mean movement time (MT) in milliseconds for each subject in Exp. 1

Group 1		Group 2		Group 3	
RT	MT	RT	MT	RT	MT
380	304	189	642	259	456
383	388	194	620	276	457
391	370	202	532	330	457
393	394	207	540	367	532
409	405	217	667	394	590
420	389	231	568	452	494
432	420	259	575		
454	314	278	565		
514	281	331	609		
420	363	234	591	346	498

presumably used the sRT/fMT strategy. Group 2 comprised nine subjects for whom average RT fell into the faster half of the group RT distribution, whereas average MT fell into the slower half of the group MT distribution. They presumably used the fRT/sMT strategy. Group 3 comprised six subjects who did not fit either pattern.

Two preliminary omnibus ANOVAs were conducted on RT and MT data. Group (group 1 or group 2) was the between-subjects factor, and condition (corresponding, neutral, non-corresponding) was the within-subjects factor. The interaction was significant for either the RT or the MT analysis, $F(2, 32) = 5.20, p < 0.015$, and $F(2, 32) = 3.98$, $p = 0.03$, respectively.[1] Therefore, further ANOVAs were conducted, separately for the two groups. They had two within-subjects factors: condition (corresponding, neutral, non-corresponding), and bin (first through fifth). When appropriate, pairwise comparisons were conducted with the Newman-Keuls method.

Group 1: RT analysis. The bin main effect was of course significant. However, it merely reflected the way data were grouped. Therefore, it will not be discussed here or in the following experiments. Of the other sources of variance, only the main effect of condition was significant, $F(2, 16) = 4.86$, $p = 0.022$. It indicated a 19-ms Simon effect, with corresponding trials producing faster RTs than non-corresponding trials (410 vs. 429 ms). Compared to neutral trials (421 ms), corresponding trials showed a significant ($p < 0.05$) facilitation effect of 11 ms, whereas non-corresponding trials did not show a significant interference effect (8 ms). The interference effect reached significance with an a-priori *t*-test ($p < 0.05$, one-tailed).

Group 1: MT analysis. All sources of variance were significant: $F(2, 16) = 30.09$, $p < 0.001$ for the condition main effect, and $F(8, 64) = 7.41$, $p < 0.001$ for the interaction.

There was an MT Simon effect of 34 ms, with corresponding trials being faster than non-corresponding trials (353 vs. 387 ms). Corresponding and neutral (348 ms) trials did not significantly differ. Thus, there was no facilitation effect. In contrast, there was a 39-ms interference effect, neutral trials being significantly ($p < 0.05$) faster than non-corresponding trials.

Pairwise comparisons, performed on the interaction means, showed that the Simon effect was significant at every bin and increased as a function of bin (15, 17, 27, 36, and 71 ms, from the first through the fifth bin).

Group 2: RT analysis. With the obvious exception of the bin main effect, no source of variance was significant.

Group 2: MT analysis. Only the two main effects of condition, $F(2, 16) = 16.41$, $p < 0.001$, and bin were significant. The former showed an MT Simon effect of 47 ms, with corresponding trials yielding MTs significantly ($p < 0.01$) faster than non-corresponding trials (568 ms vs. 615 ms). Neutral trials yielded MTs (590 ms) that were significantly ($p < 0.05$) slower than those of corresponding trials and significantly ($p < 0.05$) faster than those of non-corresponding trials. Therefore, there was a 22-ms facilitation effect and a 25-ms interference effect.

Discussion

The results of Exp. 1 gave some support to the notion that response strategies can determine whether the Simon effect occurs in RT or in MT. We had predicted that the Simon effect would manifest itself in MT but not in RT when RT was fast and MT was slow. This is because this pattern would index that the response selection stage, that is, the stage at which the Simon effect occurs, contributes to the duration of MT rather than RT. This prediction was upheld by the results of subjects belonging to group 2 (i.e., those who presumably used the fRT/sMT strategy). They showed a substantial MT Simon effect and no RT Simon effect.

It is likely that on most trials these subjects started moving before selecting the direction of the movement. Therefore, RT did not reflect response selection time. Response selection time was instead reflected, along with the Simon effect, in MT. Note that the MT Simon efect had both facilitation and interference components, as happens with the RT Simon effect when more typical tasks are used (e.g., Hommel, 1993; Kornblum, 1994; Kornblum & Lee, 1995; Lu & Proctor, 1994; Simon & Acosta, 1982; Wallace, 1971).

Subjects in group 1 (i.e., those who presumably used the sRT/fMT strategy) exactly replicated the results of Hietanen and Rämä (1995). In RTs they showed a facilitation effect in the absence of a significant interference effect. In MTs they showed the opposite pattern,

[1] The correlation between RTs and MTs from Table 1 is −0.75. That is unusual, because normally these correlations are small and positive. As was noted by Herbert Heuer, the rather high negative correlation may be evidence that subjects indeed traded RT for MT.

that is, an interference effect in the absence of a facilitation effect. It is interesting to note that Hietanen and Rämä's subjects behaved like our group-1 subjects, that is, they had slow RTs and fast MTs. (Overall, RTs were about three times slower than MTs.) Apparently, most of Hietanen and Rämä's subjects adopted the sRT/fMT strategy, that is, they programed the reaching response before releasing the central pad.[2]

As may be remembered, we had predicted that a pattern of slow RTs and fast MTs (i.e., the sRT/fMT strategy) would emerge when the movement was initiated only after the directional component of the response was computed. This way, the response selection stage should be included in RT, thus rendering it sensitive to both the facilitation and the interference components of the Simon effect. No Simon effect was instead predicted for MT. No doubt, the results of the present group 1 did not uphold this prediction.

The Simon effect decays, or even disappears, when RT is delayed (e.g., Eimer et al., 1995; De Jong et al., 1994; Lu & Proctor, 1994). Perhaps, in group 1, in which RT was slow, the Simon effect decayed. One might even argue that the interference components decayed faster than the facilitation component. That would explain why in group 1 the Simon effect was small and comprised only the facilitation component. However, this hypothesis cannot explain the presence of the Simon effect, or at least its interference component, in MT. In addition, whereas it is known that the RT Simon effect decreases in magnitude at the longest bins (Eimer et al., 1995; De Jong et al., 1994; Lu & Proctor, 1994), the interference component of the MT Simon effect increased as a function of bin. Possibly, comparatively long MTs are more likely to reflect the time for response selection.

The results of group 1 are no doubt puzzling. However, they cannot be considered as definitive because of two problems. The strategy was not explicitly manipulated; thus, one cannot be certain that what differentiated the two groups was the strategy adopted by the subjects. In addition, the central box was closer to fixation than the lateral boxes, which could have increased speed of response on neutral trials because of higher acuity near the fovea.[3] Therefore, we conducted two additional experiments in which subjects were explicitly instructed to use one of the response strategies and the eccentricity problem was eliminated.

Experiment 2

In the present experiment subjects were explicitly required to adopt the sRT/fMT strategy. The prediction was that the Simon effect, with both facilitation and interference components, should be present in RTs and absent in MTs.

Method

Subjects. Ten students of the University of Urbino, selected as before, participated in the experiment.

Apparatus, display and procedure. They were the same as in Exp. 1, except for the following aspects. The laboratory was different, and a Zenith Pentium computer with a VGA monitor was used. The fixation point was shown at the center of the screen. On half of the trials the three empty boxes, which marked stimulus positions, were to the right of fixation, whereas on the other half they were to the left (about 4°, 8°, and 12°, respectively, from fixation to the center of the box). The effect of visual acuity was counterbalanced across conditions and trials. In addition, the MEL Professional serial response box, with three pads, one central and one for each target location, was utilized as response device. The two lateral response pads were plugged into the response box, at the same distance as in Exp. 1. Subjects performed 300 experimental trials, split into three equal blocks, preceded by a block of practice trials. They were instructed to release the central pad only after the whole movement had been programed (the sRT/fMT strategy). That is, they were explicitly asked not to try to speed up RT by starting the response before deciding where to direct the aimed movement. Also, they were informed that the feedback was on MT. That should have led them to try to perform the time-demanding operation of response selection before MT was measured.

Results and discussion

Errors were 1.8%. Correct RTs with the same cut-offs as before were analyzed by applying the same ANOVAs as in Exp. 1 to RTs and MTs, separately.

RT analysis. Only the two main effects of condition, $F(2, 18) = 7.56$, $p = 0.004$, and bin were significant. There was an overall Simon effect of 17 ms. Pairwise comparisons showed that RT for corresponding trials was significantly ($p < 0.05$) faster than RT for neutral trials (347 ms vs. 357 ms; a facilitation effect of 10 ms), which in turn was not significantly faster than RT for non-corresponding trials (364 ms). The 7-ms interference effect was only close to significance with an a-priori t-test ($p < 0.1$, one-tailed).

MT analysis. The main effects of condition, $F(2, 18) = 5.92$, $p = 0.011$, and bin, and the interaction $F(8, 72) = 4.49$, $p < 0.001$, were all significant. There was an overall MT Simon effect of 31 ms. Corresponding trials were significantly ($p < 0.05$) faster than neutral trials (264 vs. 278 ms), thus producing a 14-ms facilitation effect. Also, the difference between non-corresponding (295 ms) and neutral trials, that is, the interference effect, was significant (17 ms; $p < 0.05$).

Pairwise comparisons, computed on the interaction means, showed that the MT Simon effect was small and non-significant at the first two bins (4 and 8 ms), near to significance at the third bin (18 ms; $p = 0.056$), and

[2] Perhaps this was because in their experiment the response pads were much larger than the regular key of a computer keyboard (see Fig. 1 in Hietanen & Rämä, 1995) and thus were much easier to reach for.

[3] We thank Bernhard Hommel for pointing out this possible confounding.

significant at the other bins (51 and 70 ms; $p < 0.01$). At the two slower bins, both facilitation and interference were significant (facilitation 20 and 36 ms, $p < 0.05$; interference: 31 and 34 ms, $p < 0.05$).

For RTs, in Exp. 2 we obtained results identical to those of group 1 in Exp. 1: a Simon effect with a facilitation component and a marginally significant interference component. Also, the MT results were similar: there was a Simon effect, which was comprised of both facilitation and interference and increased as a function of bin. As for group 1 in Exp. 1, one may suppose that the RT Simon effect was small because, due to the slow RT, it had time to decay, and that the interference component decayed faster than the facilitation component. Similarly, one may again suppose that the MT Simon effect was larger at the slowest MTs because the slowest MTs were more likely to comprise the response selection operation.

However, as for group 1 in Exp. 1, the puzzling aspect of the results was that there was an MT Simon effect, which if the sRT/fMT strategy was used, should not be present. The presence of an MT Simon effect suggests that, on at least some trials, the response selection stage was "moved" to MT. Because subjects were required to break down a single, coherent response (i.e., release the central pad to press one of two keys) into two separate stages, perhaps they occasionally did not comply with the instructions to use the sRT/fMT strategy, but used the fRT/sMT strategy instead. That is, they released the central pad before the whole movement was programed.

The idea that subjects can wait for initiating the movement until response selection is completed implies accepting a strict stage-like processing model. However, we believe that human performance is best described by cascade models (McClelland, 1979; see also Zorzi & Umiltà, 1995). In a cascade model, movement initiates as soon as sufficient activation reaches the level where the motor program is prepared; however, response selection might be still incomplete at that point in time. Thus, the motor program level can be engaged in the response selection process, and this will be reflected in the length of movement time.

This explanation predicts that, on those trials in which MT was comparatively fast, the Simon effect should be present in RT and absent in MT. In contrast, on those trials in which MT was comparatively slow, there should be a Simon effect for MT and no Simon effect for RT. To explore this possibility, we performed two post-hoc analyses on RT data, split into two blocks of trials for each subject. A block consisted of RTs that co-occurred with the 50% fastest MTs (fast MT trials). The other block consisted of RTs that co-occurred with the slowest 50% MTs (slow MTs trials). The two blocks of RT data were entered into two ANOVAs with an identical design, condition (corresponding, neutral, and non-corresponding) being the only within-subjects factor.

Condition was significant for fast MT trials, $F = (2, 18) = 14.65$, $p < 0.001$. Pairwise comparisons showed that corresponding trials (346 ms) were significantly ($p < 0.01$) faster than neutral trials (361 ms), which in turn were significantly ($p < 0.01$) faster than non-corresponding trials (377 ms). Thus, there was an RT Simon effect of 31 ms. It was comprised of a 15-ms facilitation component and a 16-ms interference component (Fig. 2). In contrast, condition was not significant for slow MT trials. Therefore, there was no RT Simon effect for these trials.

The interpretation we propose is that when MT was fast, subjects were successful in withholding the movement until after response selection, and the time for response selection was reflected in RT. Consequently, there was an RT Simon effect. When MT was slow,

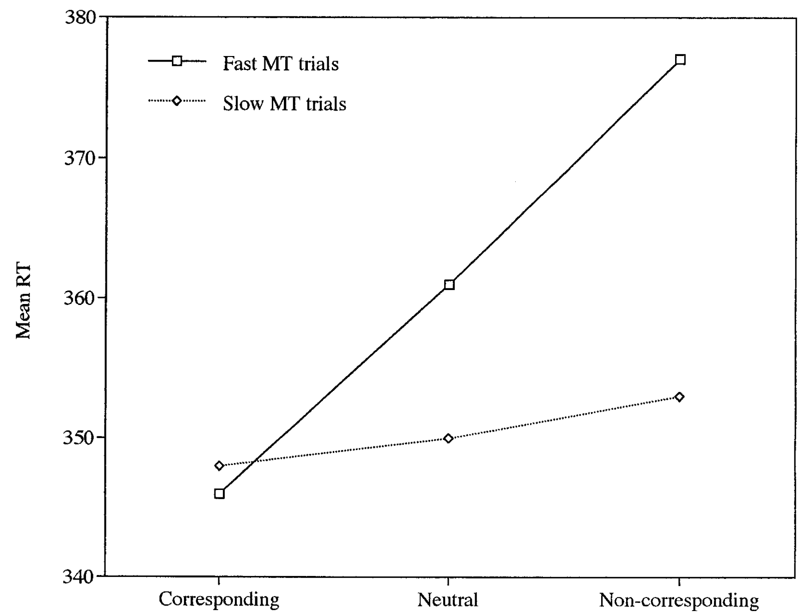

Fig. 2 Mean corresponding, neutral, and non-corresponding reaction time (RT) for slow and fast movement time (MT) trials in Exp. 2

subjects, in spite of instructions, could not with hold the movement, and the time for response selection was reflected in MT. Consequently, there was an MT Simon effect.

Experiment 3

In this experiments, subjects were explicitly instructed to use the fRT/sMT strategy. Thus, one should obtain no Simon effect in RTs and a Simon effect, with both facilitation and interference, in MTs.

Method

Subjects. Fourteen students of the University of Urbino, selected as before, participated in the experiment.

Apparatus, display and procedure. They were the same as in Exp. 2, except for instructions and feedback. The instructions were to release the central pad as soon as the stimulus appeared and then decide which response pad to reach for. In other words, they were explicitly asked to try to speed up RT by initiating the response before selecting its direction. To encourage the use of this strategy, subjects were informed that feedback was on RT.

Results and discussion

Errors were 2.4%. Correct RTs with the usual cut-offs were analyzed by applying to RTs and MTs, separately, the same ANOVAs that were conducted in the previous experiment.

RT analysis. Only the bin main effect was significant.

MT analysis. All sources of variance were significant: $F(2, 26) = 17.20$, $p < 0.001$ for the condition main effect, and $F(8, 104) = 2.47$, $p = 0.017$ for the interaction.

There was a 36-ms MT Simon effect, corresponding trials being faster than non-corresponding trials (538 and 574 ms). Neutral trials (551 ms) were significantly ($p = 0.04$) slower than corresponding trials and significantly ($p = 0.002$) faster than non-corresponding trials. Therefore, there was a facilitation effect of 13 ms and an interference effect of 23 ms. Pairwise comparisons, computed on the interaction means, showed that the Simon effect was present (ps < 0.05) from the first through the fifth bin (22, 47, 49, 38, and 22 ms). Facilitation was significant (ps < 0.5) from the second to the fourth bin (18, 18 and 15 ms), whereas interference was significant (ps $< .05$) from the first to the fourth bin (15, 29, 31, and 23 ms).

Consistent with the hypothesis, there was no RT Simon effect but there was an MT Simon effect. This means that, if the response selection stage takes place after RT, the Simon effect shows up in MT only. The interference component was greater than the facilitation component. This asymmetry was not predicted but is not without precedent in the literature on the RT Simon effect, which can be asymmetric, with interference exceeding facilitation (e.g., Craft & Simon, 1970; Simon & Acosta, 1982; Simon & Craft, 1970; Simon & Small, 1969).

Conclusion

The notion that the Simon effect originates at the response selection stage is widely accepted (see, e.g., a review in Lu & Proctor, 1995). In particular, the dual-route models (e.g., De Jong et al., 1994) are based on the notion of an interaction between the automatically activated spatially corresponding response and the response that is indicated by the task-relevant stimulus feature. This is supported by compelling empirical evidence (e.g., Eimer, 1995; De Jong et al., 1994) and by computational models (Zorzi & Umiltà, 1995).

On the basis of this notion, the Simon effect should occur at the response selection stage, regardless of whether the response is a keypress, as in typical Simon tasks, or an aimed movement, as in Hietanen and Rämä (1995). Therefore, regardless of the type of response modality, the Simon effect should manifest itself in RT and not in MT. In addition, as pointed out in the Introduction, the presence of both facilitation and interference components of the Simon effect is a crucial feature of dual-route models. This is because on neutral trials speed of response is not affected by either the automatic fast activation of the correct response or the conflict between the wrong but automatically activated response and the correct response. Instead, Hietanen and Rämä reported that, when subjects had to perform left-right aimed movements, the facilitation component showed up in RT, whereas the interference component showed up in MT. Therefore, their findings seem to be inconsistent with dual-route, response-selection accounts of the Simon effect.

We reasoned that an aimed movement response can be performed by using two strategies. Which strategy is used determines whether the Simon effect will show up in RT or MT. However, in either case, the Simon effect occurs at the response selection stage. The subject can start moving as soon as the stimulus appears and then reach for the target locations. If the movement is initiated before a decision is made about which response to execute, an effect related to response selection cannot show up in RT. Rather, the response selection operation would be put off to MT. Thus, there should be an MT Simon effect. Alternatively, the subject can start moving only after the response is programed. This way, RT would comprise the response selection operation. Therefore, there should be an RT Simon effect. If that is true, with either strategy the Simon effect would occur at the response selection stage.

We explored this possibility in three experiments. Experiment 1 replicated the study by Hietanen and

Rämä (1995). The logic used to examine the strategies that were adopted to perform the task was to separate subjects into a group with fast RT and slow MT and a group with slow RT and fast MT. Subjects in the former group showed an RT facilitation effect and an MT interference effect, as Hietanen and Rämä's subjects did. In contrast, subjects in the latter group showed both MT facilitation and MT interference effects. In the two subsequent experiments, explicit instructions to adopt one or the other of the strategies were provided. In Exp. 2, subjects were instructed to initiate the response only after the whole movement was programed. That should have led them to perform response selection in RT. Results indicated that, on condition subjects were successful in complying with instructions, the facilitation and interference components were present in RT. However, both components were present in MT, too. Perhaps that was because subjects, in spite of instructions, often could not withhold the movement, and the time for response selection was thus reflected in MT. In Exp. 3, subjects were instructed to initiate the response as soon as the imperative stimulus appeared and then select the direction of the response. They showed both the facilitation and interference components in MT and neither component in RT.

In conclusion, the findings of the present study confirm that the Simon effect is attributable to facilitation and interference components, which both occur at the response selection stage. In addition, our findings are generally consistent with the hypothesis that whether these components show up in RT or MT depends on the response strategy that is adopted by the subjects.

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