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S–R Compatibility Effects Without Response Uncertainty

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Five experiments investigated whether cognitively based spatial S–R correspondence effects or "compatibility" effects can occur in simple reaction time (SRT) tasks and if so, which factors might be responsible for their occurrence and size. In Experiment 1, responses were cued before each trial, but made only after presentation of a Go signal. There were considerably faster responses with spatial correspondence of Go signal and response, demonstrating that response certainty does not prevent a compatibility effect. Experiment 2, a SRT task with "extra" trials requiring responses with the same or the opposite hand, indicated a major determinant of this effect to be the keeping of two task-relevant responses in a state of readiness. Experiment 3 provided preliminary evidence for "inertia" effects—that is, for stronger correspondence effects with frequent than with infrequent alternations between left-hand and right-hand blocks. Experiment 4 showed that correspondence effects can be obtained by using a within-hand response repertoire. Experiment 5, a replication of Experiment 3 with within-hand responses, found further evidence for inertia effects. For all experiments, reaction time distribution analyses were carried out to gain insight into the temporal dynamics of correspondence effects. Altogether the results strongly suggest that most if not all correspondence effects had a cognitive rather than an anatomical origin. This raises some doubts about conclusions from prior attempts to measure interhemispheric transmission costs by means of SRT tasks.

In choice reaction time (CRT) tasks, response speed is known to depend on the spatial relationship between stimulus and response. Consider, for instance, a standard spatial compatibility task, where subjects press a left- and a right-hand key in response to left- or right-side stimuli. With an ipsilateral mapping (i.e. left stimulus to left response and right stimulus to right response), reaction times (RTs) are shorter than with a contralateral mapping (e.g. Broadbent & Gregory, 1962). Likewise, spatial stimulus–response (S–R) correspondence speeds up performance as compared to non-correspondence even if stimulus position is not relevant for the task (e.g. Simon & Rudell, 1967). Notably,

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studies comparing performance with uncrossed and crossed hands showed that such correspondence effects do not depend on the anatomical identity of the hand but on the location of the response key (Simon, Hinrichs, & Craft, 1970; Wallace, 1971). This demonstrates that, in CRT tasks, correspondence effects must be (at least mainly) attributed to cognitive not anatomical factors. Consequently, most explanations focus on the match or mismatch between cognitive spatial stimulus and response codes (Eimer, Hommel, & Prinz, 1995; Fitts & Seeger, 1953; Kornblum, Hasbroucq, & Osman, 1990; Prinz, 1990; Umiltà & Nicoletti, 1990; Wallace, 1971).

With simple reaction time (SRT) tasks, where there is complete spatial response certainty, matters are not that clear. Hasbroucq, Kornblum, and Osman's (1988) review of relevant SRT studies reveals that reliable S–R correspondence effects were found in only 13 out of 21 studies. Assuming that significant results are more likely to be submitted and published than null effects, Hasbroucq et al. seriously doubt the existence of correspondence effects in SRT tasks. In contrast, Bashore (1981) in an earlier and more comprehensive review, and Marzi, Bisiacchi, and Nicoletti (1991) more recently, were more optimistic. More important for the moment, however, is that even studies reporting correspondence effects with SRT tasks found much smaller correspondence effects than those commonly observed in CRT tasks. With choice tasks, typical compatibility effects are in the range of about 50–150 msec with relevant stimulus position (e.g. Broadbent & Gregory, 1962; Nicoletti, Umiltà, & Ladavas, 1984), and about 20–70 msec with irrelevant stimulus position (e.g. Callan, Klisz, & Parsons, 1974; Simon & Rudell, 1967). In contrast, SRT tasks produce correspondence effects of about 2–6 msec, clearly a different order of magnitude.

Both theoretical considerations and this difference in size have led to the widespread opinion that correspondence effects in SRT and CRT tasks have a different origin. Effects in CRT tasks are thought to be of a cognitive origin, due to compatibility between spatial stimulus and response codes, whereas the small effects in SRT tasks are commonly attributed to anatomical factors. Following Poffenberger (1912), it is assumed that, with ipsilateral S–R pairings, the input is projected up to the same hemisphere as that controlling the response, such as a left or right index-finger movement. With contralateral pairings, in contrast, input and output are processed by different hemispheres (at least with visual inputs), so that interhemispheric transmission is required. As this transmission takes time, non-correspondence must produce longer RTs than correspondence, for simple anatomical reasons. The difference in RTs for correspondence and non-correspondence can, in turn, be taken as an estimate of the interhemispherical transmission time.

Presumably due to the straightforward logic of the interhemispheric transmission cost hypothesis, surprisingly little effort has been invested in developing strict, agreed-upon criteria to distinguish anatomical from cognitive effects. Among the suggestions for measuring pure interhemispheric transmission time are recommendations not to use CRT or Go/No-go tasks, because of their "cognitive" bias (Bashore, 1981), to avoid stimulus position uncertainty, and to compare performance with uncrossed and crossed hands (Bradshaw, Nettleton, & Spehr, 1982; Bradshaw & Umiltà, 1984). However, these guidelines are not generally followed, and they can also be questioned on both theoretical and empirical grounds:

First, though it seems to be a convincing strategy to minimize the involvement of cognitive processes in dealing with anatomical issues, it is difficult to imagine that one can get rid of any cognitive activity during an intentional action such as a simple reaction. So, the finding that correspondence effects decrease from CRT to SRT tasks might not indicate different origins, but simply reflect that less cognitive processing is involved in the latter, thus producing smaller compatibility effects. The usual line of argumentation, however, runs in the opposite direction: The fact that an observed correspondence effect is small is taken as (at least additional) evidence that it is of anatomical origin (e.g. Berlucchi, Crea, Di Stefano, & Tassinari, 1977; Verfaellie, Bowers, & Heilman, 1990). This comes close to circularity.

Second, the relevance of constant stimulus position is more than questionable. Not only is there evidence that (cognitively based) compatibility effects in CRT tasks can occur even without uncertainty about stimulus position—that is, if stimulus position is blocked (Simon & Rudell, 1967) or known in advance (Van der Molen & Keuss, 1981)—but there is also nothing in the reviews of Bashore (1981), Hasbroucq et al. (1988), and Marzi et al. (1991) to indicate any systematic difference between the outcomes of SRT experiments with blocked and random stimulus positions.

Third, comparing conditions with arms uncrossed and crossed does not really provide an unequivocal test of the origin of correspondence effects. The empirical evidence as such is undisputed: In the standard experimental setup, where a left and a right key are pressed with the corresponding index finger, relative position and anatomical identity of the effectors are confounded. This problem can be, and has been, solved by having subjects cross their arms, so that left and right key are operated by right and left hand, respectively. As pointed out, in CRT tasks this manipulation reveals a dominant influence of hand position over identity. With SRT tasks, however, responses are faster with correspondence of stimulus and anatomical identity of the effector—that is, if stimulus and response are processed within the same hemisphere (e.g. Anzola, Bertoloni, Buchtel, & Rizzolatti, 1977; Berlucchi et al., 1977). In other words, in CRT tasks the correspondence effect goes with effector position, whereas in SRT tasks it goes with anatomical identity. Furthermore, (additive) effects of anatomical identity can be observed even in more complex CRT tasks if the necessary control conditions are included (e.g. Hommel, 1993a).

However, the critical question is whether an effect of anatomical identity should be interpreted as an effect of the anatomical hardware, as Poffenberger's hypothesis suggests, or as a cognitive effect. Of course, human actors have knowledge about the anatomical identity of their effectors and may, under some circumstances, tend to code their actions in these terms instead of using position codes. Actually, there is evidence that subjects have some choice about which of the several features of their actions becomes effective in cognitive response coding (Guiard, 1983; Hommel, 1993a; Riggio, Gawryszewski, & Umiltà, 1986). Especially in the absence of environmental spatial reference points, subjects can be shown to code their responses in terms of spatio-anatomical relationships, this yielding effects of sizes far beyond the scope of anatomical accounts (e.g. Heister, Schroder-Heister, & Ehrenstein, 1990; Klapp, Greim, Mendicino, & Koenig, 1979; Lippa, in press). So, as Heister et al. (1990) have argued, an empirical effect of anatomical identity may well be a cognitive effect—that is, an effect of cognitively represented anatomy. And it is difficult to see how to exclude the possibility that it is that kind of effect—but not interhemispheric transmission costs—that shows up in hand-crossing studies.

A further problem one faces in trying to tell cognitive from anatomical effects has to do with processing speed. In a CRT or Go/No-go task, stimuli must be identified to a certain extent in order to determine the correct response. Elsewhere (Hommel, 1993b), I have argued that the temporal relationship between identification and localization (i.e. formation of the spatial stimulus code), determines the size of the correspondence effect in tasks like these, at least if stimulus location is irrelevant: As an irrelevant spatial stimulus code can be assumed to decay over time, so its impact on response selection (i.e. the compatibility effect) should be smaller, the slower identification is. And in fact, compatibility effects decrease with increasing identification difficulties (Hommel, 1993b, 1994a, 1994b).

In a SRT task, however, stimulus detection (or event registration) is required instead of identification. Unlike identification, detection can be assumed to precede localization in time. This means that fast, detection-based responses might be emitted before the spatial stimulus code is formed. If so, it is not surprising that stimulus location has little or no effect on RT. Again, this could mean that the different order of magnitude of correspondence effects in SRT and CRT tasks is not due to differing origins. Instead, differing sizes may be a rather trivial result of task-specific temporal relationships between spatial stimulus coding and responding.

In sum, it appears that the question of whether correspondence effects in SRT and CRT are caused by qualitatively different mechanisms or processes is far from settled. Although the idea of interhemispheric transmission costs could account for a large body of data, it is not clear whether it is needed at all. Alternatively, correspondence effects in SRT tasks may be explained in purely cognitive terms. Unfortunately, however, little is known about the theoretically relevant differences between CRT and SRT tasks. Therefore, the present study investigates some that may be relevant.

The tasks used in the five experiments of this study are very similar to standard SRT tasks in providing the subject with full, valid pre-knowledge about the upcoming response. However, they deviate from the classical design in one or another theoretically interesting way. In Experiment 1, the role of response (un)certainty itself is tested, the critical question being whether this factor can eliminate compatibility effects. A further difference between CRT and SRT tasks concerns response readiness. In CRT tasks, two responses are held in readiness, but in SRT tasks only one. Whether this is relevant for the emerge of correspondence effects is investigated in Experiment 2. Another factor that may affect the size or occurrence of correspondence effects is the frequency of response alternations—that is, the number of trials passed since the last alternative response; this is tested in Experiment 3. Experiment 4 is a control experiment that uses within-hand, instead of between-hand, response alternatives. Finally, Experiment 5, using the same response repertoire, examines the role of the unused response finger and also provides a further test of the alternation frequency hypothesis.

In all five experiments, RT distribution analyses were carried out in order to investigate the impact of temporal factors. As demonstrated by Grice, Boroughs, and Canham (1984) or De Jong, Liang, and Lauber (1994), the temporal dynamics of correspondence effects can be analysed by fractionating the RT distribution into quantiles (quintiles were used here) to compare the size of effects in different parts of the RT distribution. According to the relative-speed account of the small size of correspondence effects in SRT tasks outlined above, cognitively based correspondence effects should increase with increasing RT. This is because, under the (perhaps not entirely realistic) assumption of a relatively invariant temporal relationship between stimulus detection and localization, the formation of a spatial stimulus code is more likely to affect the response the later the response is emitted.

EXPERIMENT 1

According to Berlucchi et al. (1977), cognitively based correspondence effects depend on selecting one response against another: "the relationships of spatial compatibility between the stimulus and the response device become important for reaction time only when there is more than one response device, and the subject must choose between them before responding" (p. 516). If this were true, it would make little sense to attempt to account for SRT effects in terms of cognitive factors. So, the first experiment was conducted to test whether correspondence effects with a likely cognitive origin can be obtained if no "selecting-against" is required.

Strictly speaking, the proposition of Berlucchi et al. would mean that no compatibility effect should be observed in a Go/No-go task: As the response is constant throughout a particular block, there is no response selection process, hence there should be no compatibility effect. Yet, though Berlucchi and colleagues themselves found no correspondence effect in a Go/No-go task, there is evidence that such effects can be obtained (Broadbent & Gregory, 1962; Callan et al., 1974; Hommel, 1995). However, consider the possibility that Go/No-go tasks can be handled in different ways. To gain response speed, subjects might always hold their response in a state of high preparation. This, on the other hand, pays off only on Go trials—that is, in 50% of the cases. This would mean a great deal of wasted energy in No-go trials, so that subjects may, instead, prepare the response only after successful identification of a Go signal (Hackley, Schäffer, & Miller, 1990). If the first strategy is used, a Go/No-go task would produce outcomes similar to a SRT task; the second strategy, on the other hand, would make the task similar to a CRT task. So, the assumption of Berlucchi et al. may hold, but only if subjects prepare prior to stimulus onset. This should be very likely with 100% Go trials, as in a SRT task, but may or may not occur with the usual 50:50 Go/No-go task.

Support for this reasoning might be drawn from the fact that the largest correspondence effect with Go/No-go responses was found in the experiment with the lowest likelihood of full response preparation (Hommel, 1995; Experiment 1): In this experiment, a response cue signalled the next response with 100% validity. About 1 sec later, a green Go signal or a red No-go signal appeared on the left or right side, and the subjects were to press the cued key in case of a Go signal. Not only were responses required on only 50% of the trials, but they could also change from trial to trial, and the preparation time was rather short. So, one might argue that it would have been a reasonable strategy to withhold response preparation until a Go signal had been identified, at least on a considerable number of trials. Consequently, response selection would often have followed stimulus presentation, which is exactly what Berlucchi et al. assume to be responsible for correspondence effects to occur. Therefore, it is hardly surprising that Hommel (1995) obtained a 43-msec correspondence effect—more than observed in any other Go/No-go task and in many other studies with choice tasks and irrelevant stimulus position.

An obvious implication of these considerations is that correspondence effects should disappear if No-go trials are removed—that is, with 100% Go trials. In that event, preparation would always pay, just as in a standard SRT task. Such a condition was provided in Experiment 1 of the present series. It was a replication of the relevant experiment of the Hommel (1995) study, except that only Go signals were used and, in order to prevent anticipations, the range of the randomly determined interval between response cue and Go stimulus was also extended.

Method

Subjects

Ten adult volunteers (right-handed except for one who was ambidextrous) served as paid subjects in single sessions of about 15 min. They had normal or corrected-to-normal vision and were naive as to the purpose of the experiment.[1]

Apparatus and Stimuli

Stimulus presentation and data collection were controlled by a Hewlett Packard Vectra QS20 computer, interfaced to an Eizo Flexscan 9070s monitor. Subjects responded by pressing the left- or right-hand shift key on the computer keyboard with the corresponding index finger. From a viewing distance of about 60 cm, they saw a gray rectangular frame of $1.2° \times 1.2°$ at the centre of a black screen. The response cue was three white arrows pointing to the left or right side displayed always at the same central location inside the frame. The go signal was a green $1.0° \times 1.8°$ patch, whose centre appeared 1.2° to the left or right of the frame.

Procedure and Design

The experiment took place in a dimly lit room. The sequence of events in each trial was as follows: After an intertrial interval of 2000 msec, the response cue appeared for 500 msec. A randomly determined interval of 400 to 1400 msec followed, before the Go signal appeared for 100 msec. The program waited until a response was given, but not longer than 1000 msec. In case of a key error (i.e. wrong keypress), an anticipation (RT < 140 msec), or missing response (RT > 1000 msec), the trial was recorded and then repeated at some random position in the remainder of the block. Subjects could delay the next trial by keeping the key depressed if they felt confused or inattentive.

[1] All subjects were randomly selected from the same file. To avoid carry-over effects between experiments, we block our subjects about one month from participation in similar experiments. As most experiments of this study were carried out with longer intervals in-between, four subjects participated in more than one experiment: one subject in Experiments 2 and 3, the second in 2, 4, and 5, the third in 2 and 5, and the fourth in 4 and 5. Control analyses with these subjects excluded were run for all respective experiments. With one minor exception (the main effect of stimulus location in Experiment 5 disappeared), all effects were virtually identical in direction and significance level to the effects reported here.

Subjects worked through 2 warm-up blocks and 40 experimental blocks. Blocks were presented continuously—that is, without breaks or other obvious demarcations. Each block was composed of 4 randomly mixed trials, whose type resulted from the factorial combination of stimulus type or response location (left or right) and Go signal location (left or right).

Results

Mean reaction times (RTs) and percentages of key errors, anticipations, and missing responses for each combination of Go signal location and response location are presented in Table 1 (top row) and Table 2 (top row), respectively. A 2 × 2 ANOVA for repeated measures on the RTs produced a significant main effect of response location, $F(1, 9) = 7.21$, $p < .05$, due to faster responses with the left than the right key, and a highly significant interaction, $F(1, 9) = 39.44$, $p < .001$, indicating faster responses to corresponding than to non-corresponding Go signals (see Table 1, rightmost column, for effect sizes). Planned comparisons (criterion: $p < .05$, one-tailed) showed that the correspondence effect was present in both hands. The analysis of key errors also yielded a significant interaction, $F(1, 9) = 10.33$, $p < .05$, which was due to smaller error rates with correspondence than with non-correspondence.

The RT distribution was analysed by using the individual means for the 1st to 5th fifth of the rank-ordered RTs from correspondence and non-correspondence conditions (see Ratcliff, 1979, for procedural details) as input into a 2 (correspondence) × 5 (quintile) ANOVA (see Figure 1 for means). Apart from significant (but, given the outcome of the mean RT analysis, expected) main effects for correspondence and quintile, the analysis produced a highly significant interaction, $F(4, 36) = 14.95$, $p < .001$. Planned comparisons revealed that the correspondence effect was significant for all quintiles, though its size increased steadily from the faster to the slower responses.

TABLE 1
Mean RTs[a] in Experiments 1–5 as a Function of Stimulus Location (or Go Signal Location) and Response Location

		Left Response		*Right Response*		
Exp.	*Condition*	*Left Stimulus*	*Right Stimulus*	*Left Stimulus*	*Right Stimulus*	Δ^b
1		258	292	299	271	31
2	1 response	287	284	296	287	3
2	2 responses	302	321	332	311	20
3	low freq.	275	275	282	274	4
3	high freq.	281	288	294	287	7
4		292	303	320	300	16
5	low freq., no cap	279	276	295	290	1
5	low freq., cap	280	281	298	289	4
5	high freq., no cap	274	278	296	287	6
5	high freq., cap	279	281	301	283	10

[a] In msec. [b] Effect sizes (mean of non-correspondence conditions minus mean of correspondence conditions).

TABLE 2
Mean Error Rates[a] in Experiments 1–5 as a Function of Stimulus Location (or Go Signal Location) and Response Location

		Left Response						*Right Response*					
		Left Stimulus			*Right Stimulus*			*Left Stimulus*			*Right Stimulus*		
Exp.	*Condition*	*K*[b]	*A*[c]	*M*[d]	*K*	*A*	*M*	*K*	*A*	*M*	*K*	*A*	*M*
1		0.2	1.9	2.1	2.5	0.8	2.0	3.5	0.8	1.3	1.4	1.6	1.3
2	1 response	0.4	1.4	0.0	1.2	0.6	0.0	0.0	0.8	0.0	0.0	0.4	0.0
2	2 responses	0.6	0.8	0.0	1.6	0.6	0.2	1.2	0.4	0.0	0.0	1.1	0.2
3	low frequency	0.6	2.1	0.0	0.3	1.4	0.0	0.2	1.4	0.0	0.0	1.9	0.1
3	high frequency	0.6	1.6	0.3	1.2	1.6	0.0	0.8	1.2	0.4	0.0	0.9	0.0
4		0.0	2.2	0.0	0.3	1.8	0.0	0.2	1.3	0.3	0.0	1.8	0.0
5	low freq., no cap	0.0	1.1	0.4	0.0	1.5	0.0	0.0	1.0	0.0	0.0	2.6	0.2
5	low freq., cap	–	1.5	0.0	–	1.6	0.0	–	1.1	0.2	–	2.5	0.0
5	high freq., no cap	0.0	1.9	0.0	0.2	1.9	0.0	0.5	2.2	0.0	0.0	1.8	0.0
5	high freq., cap	–	2.7	0.2	–	2.0	0.0	–	2.3	0.2	–	0.8	0.0

[a]In percentages. [b]K = key errors. [c]A = anticipations. [d]M = missing responses.

Note. Key errors were impossible in cap conditions of Experiment 5. Rates for anticipations (A) and missing responses (M) refer to all trials actually run in the respective condition. Rates for key errors (K) refer to trials with in-time responses only (i.e. after excluding trials with anticipations or missing responses).

Discussion

The results are clearly inconsistent with the assumption of Berlucchi et al. (1977), that compatibility effects occur only if response selection follows the relevant stimulus or Go signal. The fact that the pre-cued response always had to be performed should have given the subjects strong motivation to prepare the response immediately after the response cue onset. Consistent with that, responses were about 130 msec faster than in the original experiment of Hommel (1995), suggesting a much higher degree of preparation. Yet the correspondence effect was only slightly smaller (31 msec versus 43 msec) and highly significant. This suggests that the degree of response preparation—or the timepoint of response selection—is not a critical factor in the emergence of correspondence effects in no-choice tasks. As a 31-msec effect in a simple task can hardly be attributed to interhemispheric transmission costs, we have the first evidence that compatibility effects can be obtained even without response uncertainty.

More evidence comes from the distribution analysis, which gives some support to the idea that compatibility effects tend not to occur in SRT tasks only because responses are usually emitted before the spatial stimulus code is formed. In the first quintile—that is, with RTs around 210 msec—the correspondence effect is at a minimum. Considering that most true SRT tasks can be performed with an overall mean of this magnitude or even faster, it is clear that compatibility effects are not very likely to appear in the data. Thus,

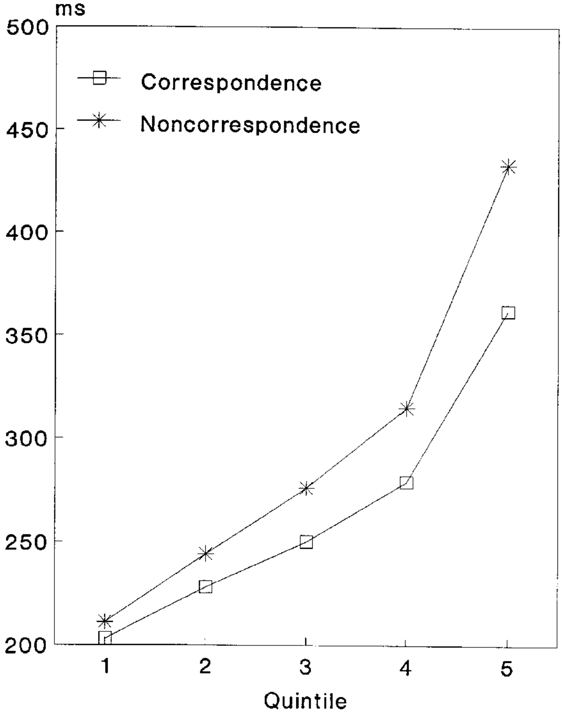

FIG. 1. Experiment 1: Means of individual mean RT quintiles (see Result section for calculation procedure) as a function of spatial S–R correspondence or non-correspondence.

the mere absence of (large) correspondence effects in such tasks does not prove that spatial response codes are not formed and would not be matched to spatial stimulus codes if only time allowed.

EXPERIMENT 2

The major difference between the conditions of Experiment 1 (or Hommel, 1995) and a standard SRT task is that the two responses can change from trial to trial in the former. It is reasonable to assume that, as a result, both responses were constantly held in some state of readiness, although the degree of preparation should vary with the information given by response cues. In contrast, only one response should be held in readiness in a standard SRT task.

Experiment 2 was designed to test the relevance of this difference for the occurrence of compatibility effects by combining a standard SRT task with a secondary task that rendered a second, alternative, response relevant or did not do so: In some trials, an "extra" signal appeared immediately after the simple reaction proper was executed—or, more precisely, after the key was released. Upon presentation of that signal, subjects had to press the same or the opposite key, depending on the experimental condition or group. Thus, in the first case there was only one relevant response in a block, but two were relevant in the second case, even though they did not represent real response alternatives that had to be "selected-against". If task relevance of a response played a role in the emergence of correspondence effects, such effects should be observed with two relevant responses but not—or not as pronounced—with only one relevant response.

Method

Subjects

Twenty-four adult volunteers (all right-handed except for one who was left-handed and one who was ambidextrous) served as paid subjects in single sessions of about 15 min. They fulfilled the same criteria as in Experiment 1. Twelve subjects were assigned randomly to each experimental group.

Apparatus and Stimuli

The experiment was controlled by a Hewlett Packard Vectra QS20 computer, interfaced to an Eizo Flexscan F550i-W monitor. Response keys were two microswitches, mounted 11.5 cm apart on a flat board in front of the subject. A white asterisk served as central fixation mark. The reaction stimulus was a green patch, like the Go signal in Experiment 1. The "extra" signal was a red patch of the same size, which always appeared at the centre of the screen.

Procedure and Design

At the beginning of each block of 90 trials, the subject was informed about which key to use for the standard SRT response and which for the extra response. Following an intertrial interval of 1500 msec, the fixation mark appeared. After a randomly determined interval of 100 to 1100 msec, the stimulus was presented until a response was given, but not for longer than 1000 msec.

In an "extra" trial, the red signal was presented as soon as the subject released the response key, in which event the predesignated key was to be pressed. In the *1-response* group, this key was identical to the currently valid response key—that is, a repetition of keypresses was required. In the *2-response* group, the extra-trial key was the opposite response key—that is, an alternation of keypresses was required. To minimize the differences between groups, subjects of both groups were asked to place both index fingers on the corresponding keys throughout all blocks. The remaining details were as in Experiment 1, except that the criterion for anticipations was lowered to 120 msec.

Subjects worked through two blocks of 90 standard trials each, one for each response (2 stimulus locations × 40 replications, plus 10 extra trials, 1 within every 8 standard trials). Trial order was random, except that the maximum repetition of the same condition was limited to three. Block order was balanced across subjects.

Results

An analysis of extra-trial RTs did not reveal any reliable difference between the two groups, though RTs tended to be lower with one than with two prepared responses (402 versus 449 msec). After excluding the rare key errors, anticipations, and missing trials (see Table 2, Rows 2–3), mean RTs were calculated for each combination of stimulus location, response location, and number of task-relevant responses (see Table 1, Rows 2–3).

In an ANOVA on mean correct RTs, there was only a highly significant interaction of stimulus location and response location, $F(1, 22) = 27.07$, $p < .001$, modified by a three-way interaction with response number, $F(1, 22) = 14.33$, $p < .001$. As confirmed by separate ANOVAs, the 20-msec correspondence effect with two relevant responses was significant, $p < .001$, but the 3-msec effect with one relevant response was not, $p > .2$.

In the distribution analysis (see Figure 2 for means), nearly all terms were significant, including the three-way Correspondence × Response Number × Quintile interaction, $F(4, 88) = 4.01$, $p < .005$. Planned comparisons showed that, with one relevant response, a significant correspondence effect occurred at the second quintile only, whereas with two responses a (continuously increasing) effect was present at all but the first quintile.

Discussion

The results demonstrate a critical role of the number of task-relevant responses for the emergence of correspondence effects. With two relevant responses, the outcome is similar to that of Experiment 1, in terms of both mean RTs and RT distributions, even though responses did not change from trial to trial and there were no real response alternatives. That is, pronounced correspondence effects occur as soon as more than one response has to be held in a state of some readiness, regardless of whether this is due to an alternation of true response alternatives throughout the task or the introduction of a simple second-

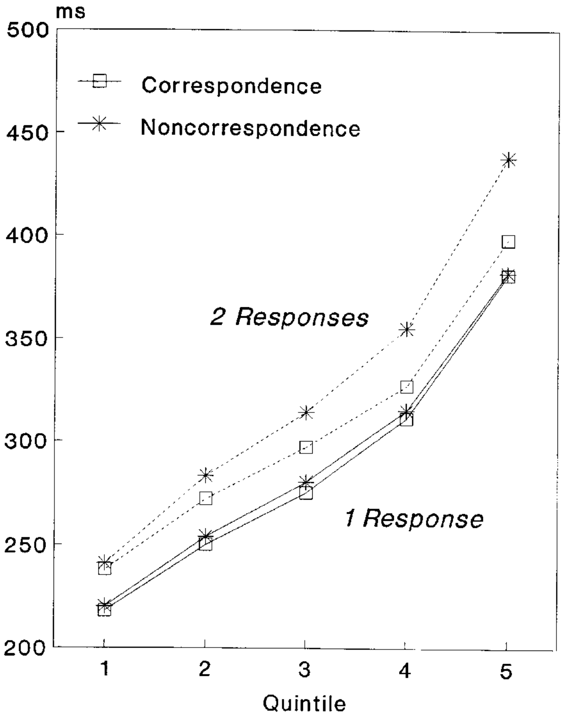

FIG. 2. Experiment 2: Means of individual mean RT quintiles as a function of number of relevant responses and spatial S–R correspondence or non-correspondence.

ary task. The effect's size and dependence on relative response speed renders an anatomical account unlikely.

In contrast, no reliable correspondence effect was obtained with only one response held in readiness. Although this is in line with the task relevance hypothesis under test, it might seem somewhat surprising from an anatomical point of view: As corresponding—but not non-corresponding—S–R pairings should have been processed by the same hemisphere, there should have been some small effect due to interhemispheric transmission time. However, there was an effect of the expected magnitude, albeit not statistically reliable, and the conditions were admittedly suboptimal for obtaining such an effect (e.g. small number of subjects with little practice, randomized stimulus location, extra trials). So the present results alone should not be taken as strong evidence against the common idea of interhemispheric transmission costs.

EXPERIMENT 3

The preceding experiments strongly suggest that the mere activation of the internal code of an alternative response is sufficient to bring about substantial compatibility effects. Such an activation can be induced by a trial-to-trial variation of responses, as in Experiment 1, or by means of a secondary task, as in Experiment 2, but there are other potential sources as well. Consider, for instance, a standard SRT task, where only one response is relevant and active throughout a block of a certain number of trials. With large blocks, the situation is similar to that in the 1-response group of Experiment 2: Subjects are likely to hold only one response in readiness, and consequently a negligible impact of activation from the alternative response is expected. With smaller blocks, however, the situation becomes similar to that in Experiment 1 or to the 2-response group of Experiment 2: Subjects switch frequently from one response to the other, so that after a switch some activation of the last response may show some "inertia" and transfer to the new block, even though, objectively, this response is no longer valid.

In prior studies on interhemispheric transmission time, the number of trials per block has been quite variable, ranging from 15 (Berlucchi et al., 1977) to 50–100 (Anzola et al., 1977). Transfer seems to be unlikely in the second case, but considerable inertia effects could have been present in the first. To test this idea, the frequency of switches between responses—and hence block size—was varied in Experiment 3. If the inertia hypothesis is valid, larger correspondence effects should be observed with high than with low switch frequency.

Method

Subjects

Sixteen adult volunteers (right-handed except for one who was left-handed and two who were ambidextrous) served as paid subjects in single sessions of about 25 min. They fulfilled the same criteria as in Experiment 1.

Apparatus, Stimuli, Procedure, and Design

These were as in Experiment 2, with the following exceptions: There were no catch trials, but nevertheless both the finger that was used and the one that was not were placed on the corresponding key. The experiment was divided into two sections. The *low-switch-frequency* section consisted of 2 long blocks of 80 trials each (2 stimulus locations × 40 replications), 1 for each response. The *high-switch-frequency* section consisted of 20 short blocks of 8 trials each (2 stimulus locations × 4 replications), 10 for each response. Each subject started with one response and switched to the other with every new block. The starting key as well as the order of the two frequency sections were balanced over subjects.

Results

After exclusion of error trials (see Table 2, Rows 4–5), mean RTs were calculated for each combination of switch frequency, stimulus location, and response location (see Table 1, Rows 4–5). The analysis yielded a significant main effect of frequency, $F(1, 15) = 9.52$, $p < .01$, owing to faster responses with low than with high switch frequency (276 versus 287 msec), and a Stimulus Location × Response Location interaction, $F(1, 15) = 5.76$, $p < .05$, indicating faster responses to corresponding than to non-corresponding stimuli with left (278 versus 282 msec) and right responses (280 versus 288 msec). Importantly, the interaction was not modified by frequency ($p > .4$). A further analysis with order-of-frequency sections as an additional factor showed that this lack of a modifying frequency effect did not depend significantly on order, as indicated by the absence of a four-way interaction, $p > .9$.

The distribution was analysed by means of a 2 (frequency) × 2 (correspondence) × 5 (quintile) ANOVA (see Figure 3 for means). In addition to significant main effects of frequency, correspondence, and quintile, the analysis produced significant interactions of frequency and quintile, $F(4, 60) = 6.72$, $p < .001$, and of correspondence and quintile, $F(4, 60) = 3.10$, $p < .05$. Most important, there was also a three-way interaction that at least approached significance, $F(4, 60) = 2.36$, $p < .07$. Planned comparisons confirmed that, with low frequency, the correspondence effect was significant for the first two quintiles only, whereas high frequency produced significant, and steadily increasing, correspondence effects for the 3rd to the 5th quintile.

Discussion

On the one hand, the analysis of mean RTs does not show any reliable evidence for a dependence of correspondence effects on the frequency of switches between response alternatives, which is inconsistent with an inertia hypothesis as outlined above. On the other hand, however, the insignificant increase of 4 to 7 msec from low to high frequency goes in the expected direction, and, furthermore, more reliable support of the inertia hypothesis is provided by the distribution analysis: Though of a completely different order of magnitude than in the preceding experiments, there is a similar, negative relationship between correspondence effect and relative response speed with high, but not with low switch frequency. That is what one would expect if spatial response codes were formed with high frequency but come into play only if responses are emitted after

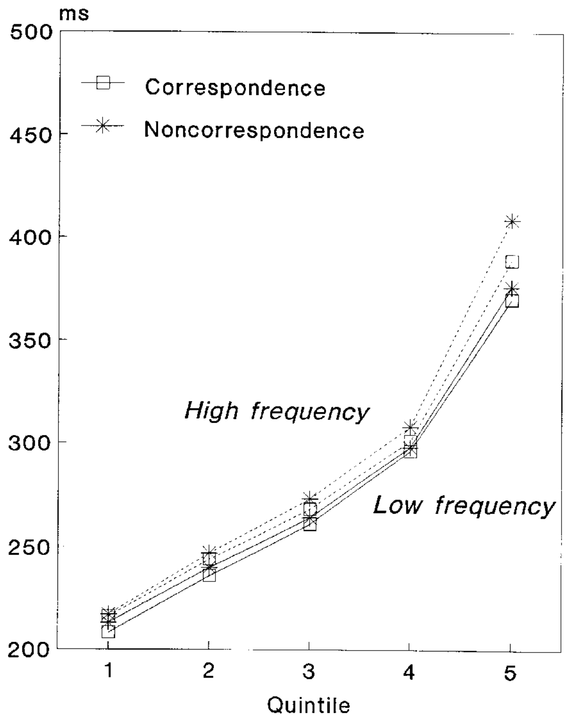

FIG. 3. Experiment 3: Means of individual mean RT quintiles as a function of response switch frequency and spatial S–R correspondence or non-correspondence.

stimulus location is coded. So, there is some (though certainly preliminary) evidence for the existence of inertia effects in SRT tasks.

The second important result is that, unlike in Experiment 2, a reliable correspondence effect could be observed even under low frequency conditions. The size of this effect is of the same order of magnitude as in the 1-response group of Experiment 2, which warrants our cautious interpretation of the failure to find an effect there. However, it is not clear which kind of effect that is. On the one hand—and this is certainly the most common interpretation—it might reflect interhemispheric transmission costs; on the other hand, it might be a compatibility effect that is small only because spatial response coding is minimal with low response switch frequency. These two hypotheses were pitted against each other in the next two experiments.

EXPERIMENT 4

Logically, delays due to interhemispheric transmission can occur only if the two alternative responses are controlled by different cortical hemispheres, as with movements of the left versus the right hand. In contrast, compatibility effects resulting from a match or mismatch between spatial stimulus and response codes also occur if the alternative responses are controlled by the same hemisphere, as in the case of two fingers of the same hand (Arend & Wandmacher, 1987; Heister, Ehrenstein, & Schroeder-Heister, 1986, 1987). This suggests a means to test between an anatomical and a cognitive interpretation of the correspondence effects observed with a low response switch frequency in Experiment 3: According to an anatomical interpretation, these effects should disappear if we use two fingers of the same hand instead of two fingers of different hands for responding. In contrast, the cognitive interpretation would predict basically the same kind of effect as in Experiment 3. Actually, one might expect even larger effects, because there is some evidence that response competition is stronger within than between hands (Kornblum, 1965; Reeve & Proctor, 1988). More competition should delay the selection of the response and hence increase RT, a condition that, as we know now from the distribution analyses, produces larger correspondence effects. Alternatively (or in addition), inasmuch as response competiton reflects a conflict between spatial response codes, using fingers of the same hand may increase the need for (or tendency towards) spatial response coding. If so, this may also bring about larger effects of correspondence or compatibility than found with between-hand responses in Experiment 3.

Method

Subjects

Sixteen adult volunteers (all right-handed) served as paid subjects in single sessions of about 15 min. They fulfilled the same criteria as in Experiment 1.

Apparatus, Stimuli, Procedure, and Design

These were exactly as in the low-frequency section of Experiment 3, except that responses were made by pressing two keys with the index and middle finger of the right hand. The keys were mounted 0.3 cm apart on a board with a tilt slightly ascending towards the screen. The board was positioned in front of the subject at a distance that allowed placement of the hand perpendicular to the screen. As in the preceding experiments, both the finger that was used and the one that was not were placed on response keys.

Results

After exclusion of error trials (see Table 2, Row 6), mean RTs were calculated for each combination of stimulus location and response location (see Table 1, Row 6). In the analysis, the main effects of stimulus location and response location were not significant ($p > .23$ and $p > .15$, respectively), but there was a significant interaction, $F(1, 15) = 16.31$, $p < .001$. A comparison with the low-frequency blocks of Experiment 3 yielded a significant interaction of stimulus location, response location, and experiment, $p < .05$, due to a larger correspondence effect with the present within-hand response repertoire.

The RT distribution analysis (see Figure 4 for means) yielded significant main effects of correspondence and quintile, and a highly significant interaction of correspondence and quintile, $F(4, 60) = 5.84$, $p < .001$. Planned comparisons showed that the correspondence effect was significant for all quintiles, but its size increased continuously from the faster to the slower responses.

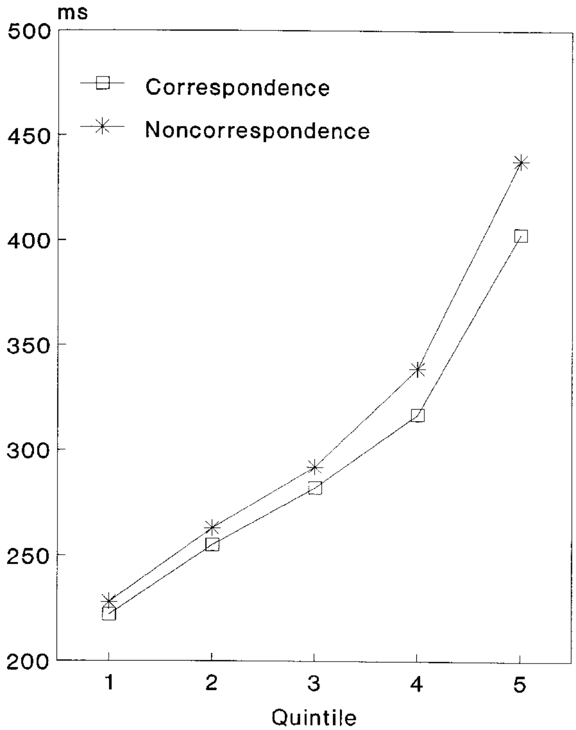

FIG. 4. Experiment 4: Means of individual mean RT quintiles as a function of spatial S–R correspondence or non-correspondence.

Discussion

The results demonstrate again that spatial compatibility effects can be obtained in a pure SRT task without any kind of spatial response uncertainty. Although the finding of a similar effect in Experiment 3 is open to an anatomical interpretation, anatomical factors can be excluded with the present effect. Interestingly, the effect is even stronger than in Experiment 3 and shows a pronounced increase with decreasing response speed, just as observed in Experiments 1 and 2 and in the high-frequency condition of Experiment 3. There can therefore be little doubt that it is a pure compatibility effect. Moreover, the observation that it is larger than in the comparable low-frequency condition of Experiment 3 is consistent with the speculation that the stronger competition of within- than between-hand finger pairs (as reported by Kornblum, 1965, or Reeve & Proctor, 1988) may produce larger correspondence effects, either by fostering spatial response coding or simply by delaying response selection and thus raising the RT level.

EXPERIMENT 5

Although only one response was made on a certain trial in the preceding experiments, subjects always had to place both fingers on the response keys. So, in some sense, the subject's task was not only to press the correct key, as in a standard SRT task, but also to inhibit responding with the incorrect key, as in a CRT task. A look at Table 2 suggests that this was a problem indeed, albeit mild: Even when the response key was unchanged throughout a large block of trials, there were cases of incorrect keypressing. Possibly preventing such errors on valid trials required discriminating between the two response alternatives, requiring attention to and coding of relative response location. Thus, in addition to the readiness of other task-relevant responses shown to be critical in Experiment 2, the mere availability of task-irrelevant response opportunities may also play a role in producing corresponding effects.

To test this idea, two conditions were compared in Experiment 5. The same within-hand repertoire and spatial finger placements were used as in Experiment 4. There was one condition in which each finger directly touched an active response key and one in which the invalid key was covered by a cap. If the available-response hypothesis is valid, the correspondence effects obtained in Experiment 4 should be replicated in the no-cap condition, but not in the cap condition.

A second objective of Experiment 5 was to provide a further test of the role of response switch frequency. Although the statistical outcome of Experiment 3 can certainly not be rated as strong support for a critical role, some evidence did point in that direction. Unfortunately, the overall correspondence effect was very small, so that there was not much room for an interaction to become evident. As indicated in Experiment 4, the correspondence effect might be somewhat larger with within-hand response alternatives, which would provide a better opportunity for detecting a statistical interaction with switch frequency. For this reason, Experiment 5 also replicated Experiment 3 with within-hand responses.

Method

Subjects

Sixteen adult volunteers (right-handed except for one who was ambidextrous) served as paid subjects in two sessions of about 15 min each. They fulfilled the same criteria as in Experiment 1.

Apparatus, Stimuli, Procedure, and Design

These were as in Experiment 3, with two exceptions: First, as in Experiment 4, responses were made by pressing two keys with the index and middle fingers of the right hand. Second, subjects worked through two sessions of the same type as in Experiment 3. In the *no-cap session*, both the finger that was used and the one that was not were placed on response keys, as in the preceding experiments. In the *cap session*, the currently invalid response key was covered by a round, hard plastic cap, on which the unused finger was placed. This meant that used and not used response fingers were positioned as in the no-cap session, but the unused finger could not operate the response key, so that no inhibition of a keypressing response should be required. The starting key (left in the first session, right in the second, or vice versa), the order of switching frequency in each session, and the order of cap and no-cap sessions, were balanced over subjects.

Results

After the exclusion of error trials (see Table 2, Rows 7–10), mean RTs were calculated for each combination of cap (present versus absent), response switch frequency, stimulus location, and response location (see Table 1, Rows 7–10). In the RT analysis, the main effects of stimulus location, $F(1, 15) = 6.49$, $p < .05$, and of response location, $F(1, 15) = 28.82$, $p < .001$, were significant, indicating that responses were faster to right than to left stimuli and faster with the left than the right response key. More important, there was a highly significant Stimulus Location × Response Location interaction, $F(1, 15) = 12.74$, $p < .005$. The three-way interaction with frequency only approached the significance criterion, $F(1, 15) = 3.51$, $p < .08$. Importantly, there was a small numerical decrease rather than an increase in the correspondence effect from the cap to the no-cap conditions from 7 to 4 msec (see Table 1, rightmost column), though all effects involving the cap factor were far from significance ($.27 < p < .93$).

As a test for the role of response repertoire (i.e. between- versus within-hand response set), an ANOVA was run on the RTs from Experiment 3 and the present no-cap condition. Apart from two two-way interactions with frequency, $p < .05$, and with response location, $p < .05$, response repertoire was not involved in any other interaction, $p > .4$, in all cases. That is, there was no indication of any reliable modification of correspondence effects by whether two fingers of the same hand or two of different hands were used for responding.

Apart from the effects already found in the analysis of the means, the RT distribution analysis produced only a significant Correspondence × Quintile interaction (see Figure 5 for means), $F(4, 60) = 3.99$, $p < .01$. There was no hint of any reliable modification of this effect by cap, frequency, or both, $p > .5$. Planned comparisons showed that with high switch frequency the correspondence effect was significant for all quintiles, its size increasing continuously from the faster to the slower responses. A similar increase was observed for low switch frequency, but reliable correspondence effects only occurred in the last two quintiles.

Discussion

Experiment 5 yielded three important outcomes. First, there is further evidence for a correspondence effect in a SRT task with within-hand response alternatives, thus replicating the basic finding of Experiment 4. However, in contrast to Experiment 4, the effect in the no-cap condition is rather small and is thus more comparable to that obtained with between-hand responses in Experiment 3. A within-hand repertoire does not therefore generally produce larger correspondence effects than does a between-hand repertoire, which seems to contradict an interpretation of the increased effect in Experiment 4 in terms of stronger response competition within than between hands. Note, however, that the RT level in the no-cap condition was comparable to Experiment 3, but it was lower than in Experiment 4, most probably due to the larger amount of practice. Through

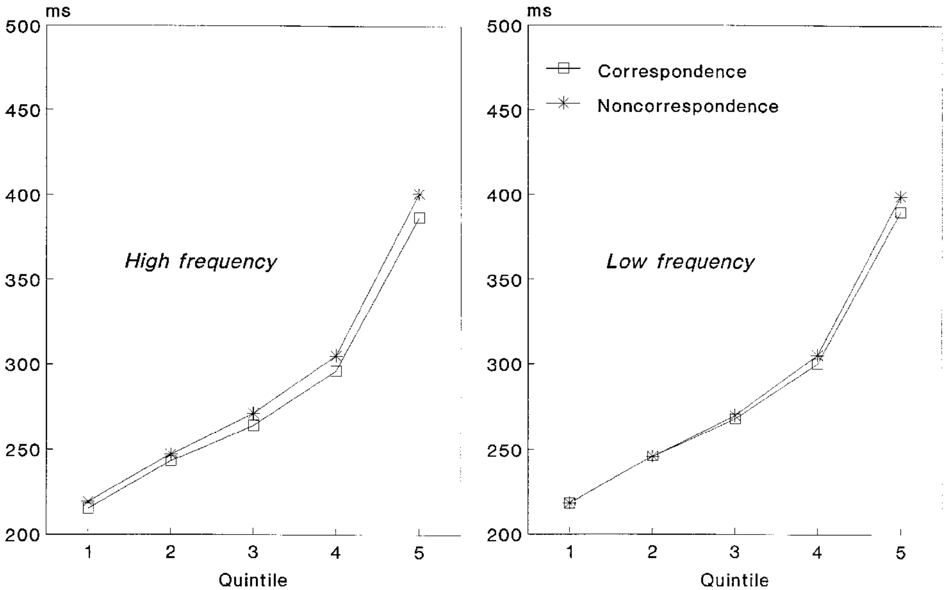

FIG. 5. Experiment 5: Means of individual mean RT quintiles as a function of response switch frequency and spatial S–R correspondence or non-correspondence.

practice, so one may speculate, response competition might have disappeared or at least been reduced to the same strength as between-hands competition. Consequently, response selection would have become easier, and/or spatial response coding less essential, so that a decreased correspondence effect would in fact be expected.

Second, although the relevant statistical effect is again far from impressive, Experiment 5 provides further evidence for response inertia. As in Experiment 3, correspondence effects tend to be larger with small than with large blocks, and hence with high rather than low response switch frequency.

Third, there was no indication of a reliable impact of the cap manipulation, and the small numerical difference observed was in the opposite direction to that predicted from the response-availability hypothesis. Thus, whether or not a response alternative is physically available does not change the picture. Interestingly, error rates in the no-cap condition were no higher than in the preceding experiments; wrong keypresses were observed even less often. Whatever process was therefore responsible for preventing incorrect keypresses in this condition, it worked at least as efficiently as in the preceding experiments. As there is no reason to assume that the same process was also active in a cap condition, the lack of a cap effect shows that processes having to do with preventing invalid, but physically possible, responses are unlikely to modulate, or even produce, S–R correspondence effects.

GENERAL DISCUSSION

The empirical aim of the present study was to investigate whether cognitively based S–R correspondence effects—and hence compatibility effects—can occur in SRT tasks, and if so, which experimental factors have an impact on their size or occurrence. Experiment 1 demonstrated that full response certainty does not prevent large correspondence effects if responses vary from trial to trial. Experiment 2 indicated that one major determinant of these effects was that two responses were task-relevant and thus presumably held in continuous readiness. Experiment 3 gave preliminary evidence for "inertia" effects—that is, for stronger correspondence effects with frequent than with infrequent alternations between left-hand and right-hand blocks. Furthermore, there was a small effect even with infrequent alternations. Experiment 4 tested an anatomical account of this effect by using a within-hand response repertoire. The result, a correspondence effect of presumably cognitive origin, is not consistent with such an account but points, rather, to a cognitive interpretation. Experiment 5, also using within-hand responses, provided further evidence for inertia effects. Moreover, it showed that placing the unused response finger on an active response key or a rigid plastic cap does not change the size of correspondence effects, thus ruling out a possible explanation of at least some of the present findings in terms of response inhibition processes.

What conclusions can be drawn from these results as to the theoretical aim of this study, which is to identify the origin of correspondence effects in SRT tasks? First, our findings clearly indicate that response uncertainty is not necessary for producing compatibility effects. If one follows the common practice and takes effect size as a criterion, at least the correspondence effects of Experiments 1, 2 (2-response group), and 4 are large enough to be counted as compatibility effects. Considering the distribution analyses, the high-frequency conditions of Experiments 3 and 5 may be added to this list. There is therefore ample evidence that SRT tasks can produce cognitively based effects.

Second, the major determinants of the size of compatibility effects in SRT tasks seem to be (a) response speed, and thus—according to the proposed assumption—the temporal distance between detection and localization of the stimulus, (b) response readiness—that is, whether more than one response is somehow relevant to, and used during, a task—and (c) response switch frequency—that is, the time or number of trials since the last performance of the alternative response. Although the evidence for a major role of the latter factor is weak, the overall pattern of correspondence effects across Experiments 2–5 is consistent with it. Table 3 shows the correspondence effects obtained in Experiments 2 and 4 and the comparable low switch-frequency conditions of Experiments 3 and 5 as a function of relative block position—that is, separately for the first and second 80-trial blocks of the experiment or condition. Ignoring the rather special 2-response condition of Experiment 2, all other experiments produced a numerical increase in correspondence effect from the first to the second block—that is, after responses were switched. Moreover, in only one case (Experiment 4) did the very first block of an experiment or session (see Rows 1, 3, 4, and 5 only) produce a numerical effect. Admittedly, there is no way to exclude the possibility that this is a pure chance finding: In an ANOVA on the data from large blocks only, with experiment as between-subjects factor and correspondence and block position as the within-subjects factors, all interactions involving block position

TABLE 3
Correspondence–Effect Sizes[a] for 80-Trial Blocks from Experiments 2[b] and 4, and from Low-Frequency Conditions of Experiments 3 and 5[c] as a Function of Relative Block Position

		Block Position	
Experiment	*Condition/Order*	*1st*	*2nd*
2	1 response	0	6
2	2 responses	24	16
3	low-high	0	2
3	high-low	5	9
4		11	21
5	low-high	− 1	0
5	high-low	5	8

[a] In msec. [b] Extra trials excluded. [c] Cap and no-cap data combined.

Note: Data from Experiments 3 and 5 are given separately for the two possible orders of frequency sections.

clearly failed to reach significance ($p > .6$). However, given the small correspondence effects obtained with large blocks, a hunt for significant interactions is hardly promising. So, even though there is ample reason not to overinterpret the present result pattern, it fits quite well with the switch-frequency hypothesis.

Third, even though multiple response readiness is presumably not present in SRT tasks such as used for measuring interhemispheric transmission costs, the evidence (albeit weak) for effects of response-switch frequency suggests that at least some reports about transcallosal transfer times may be inflated by inertia effects. Moreover, the important observation that compatibility effects were greater for slower responses raises some doubt about the common contention that small-sized effects must be of anatomical origin. In the absence of evidence from distribution analyses, one could also assume that most, but not all, responses were simply carried out before spatial stimulus codes had been formed.

Unfortunately, although Quantile × Correspondence interactions may serve as a diagnostic for the presence of compatibility effects, this diagnostic works only one way. As already mentioned in the introduction, an interaction can only be expected if the temporal relationship between stimulus detection and localization is relatively constant, whereas that between detection and responding is relatively variable. However, it is reasonable to assume that the latter source of variability vanishes with decreasing task complexity, increasing practice, and the like, so that the variance obtained would be produced mainly by sensory and motor processes. If so, the Speed × Correspondence interaction would disappear, even if some real compatibility effect remained. That is, the presence of an interaction indicates that a correspondence effect is presumably of cognitive origin, but its absence does not prove the opposite. With this in mind, it would be premature to draw conclusions from the absence of clear indications of compatibility effects in Experiment 3 (low frequency), or in any other SRT experiment, about the anatomical origin of the obtained correspondence effect.

In sum, then, the present study allows for two general conclusions, one regarding the issue of cognitive versus anatomical origin of correspondence effects in SRT tasks, and the other regarding the mechanism producing cognitively based effects. With regard to the first of these, the demonstration of cognitively based correspondence effects does not, of course, prove that all correspondence effects are cognitive. There is no way to exclude the possibility that the significant effect in Experiment 3 (low frequency) and the insignificant effect in Experiment 2 (1 response) were due to interhemispheric transmission costs. In fact, both their small size and their independence from relative response speed would be consistent with such an interpretation, which would also not be invalidated by the mere finding of an increased overall effect due to the introduction of cognitive factors. One may therefore understand the present findings as just another warning to avoid cognitive factors in the attempt to measure interhemispheric transmission costs.

On the other hand, however, Experiments 3 and 5 produced very similar results, suggesting that the anatomically important between-hand versus within-hand difference did not play a critical role here. Of course, similar effects may be produced by different factors, so that adherents of the anatomical view could still attribute the effect of Experiment 3 to interhemispheric transmission and the effect of Experiment 5 to cognitive factors. This is obviously not the most parsimonious interpretation, but it is hardly possible to settle this issue as long as definite criteria for distinguishing anatomical from cognitive effects are lacking. As already pointed out, stimulus uncertainty does not seem to be critical, and the hand-crossing procedure cannot serve as an unequivocal diagnostic. The present study shows that avoiding response uncertainty is also insufficient to justify inferring an anatomical basis. Moreover, subtle design features such as block size may produce unexpected cognitive effects. This, together with the numerous failures to find correspondence effects in SRT tasks at all, calls for a more cautious interpretation of existing correspondence effects than can be observed in recent studies on interhemispheric interactions. The outcome of this study does not therefore warrant the pessimistic view of Hasbroucq et al. (1988) that correspondence effects are unlikely to appear in SRT tasks, nor does it support the optimistic view of Bashore (1981) or Marzi et al. (1991) that those effects necessarily provide a good measure of interhemispheric transmission costs. Instead, it suggests that more empirical and theoretical work is needed to distinguish between anatomical and cognitive effects in SRT tasks.

The second general conclusion concerns the mechanism producing compatibility effects. Apart from perceptual approaches (Hasbroucq & Guiard, 1991; Stoffels, Van der Molen, & Keuss, 1989), which can be questioned for empirical and theoretical reasons (De Jong et al., 1994; Eimer, 1994; Hommel, 1995; Lu & Proctor, 1994; O'Leary, Barber, & Simon, 1994), most theories attribute correspondence effects to S–R translation or response selection problems (Eimer et al., 1995; Fitts & Seeger, 1953; Kornblum et al., 1990; Proctor, Reeve, & Van Zandt, 1992; Simon, 1990; Teichner & Krebs, 1974; Umiltà & Nicoletti, 1990; Wallace, 1971). As stimuli need not be translated and responses need not be selected in SRT tasks, the present findings seem to be a major challenge for these approaches. How could that be encountered?

For S–R translation models such as those of Fitts and Seeger (1953), Proctor et al. (1992), Simon (1990), Teichner and Krebs (1974), or Wallace (1971), SRT compatibility effects are difficult to handle. With CRT tasks, one may assume that, given identity of or similarity between stimulus and response elements, a match of those elements (e.g. left stimulus → left response) allows for the construction of a simpler rule than a non-match (e.g. left stimulus → right response) or speed-up translation by some other means. With SRT tasks, however, the only rule to be followed is to carry out the predetermined response if some above-threshold visual event takes place. It is difficult to see why following this rule should be easier in the presence of S–R correspondence.

In contrast, response-selection models like those of Eimer et al. (1995) or Kornblum et al. (1990) propose an automatic activation of responses by corresponding stimuli. Under the assumption that a response conflict arises if stimulus-induced activation adds to internal response priming as a result of response inertia or readiness, conflicts might be expected for all tasks in this study that produced compatibility effects (see Hommel, in press, for a more detailed discussion). So, some kind of response selection—that is, decision between concurrently activated response codes—may have occurred even without response uncertainty in the objective sense. And this process could be facilitated by S–R correspondence, and/or hampered by non-correspondence, provided that location-induced activation reaches the response selection stage before the response is carried out.

From this more dynamic view, the present findings can be put in a somewhat broader perspective. There is accumulating evidence that task performance is not only determined by the type and difficulty of the actual task, including stimuli, responses, and the mappings between them, but also a function of the preceding task set or the set adopted in the preceding trial. For instance, if subjects are asked to switch between two different tasks on successive trials, performance is worse than if no switch is required (Jersild, 1927; Spector & Biederman, 1976). More interesting in the present context is the finding that switching costs do not reduce to zero even if subjects have sufficient time to prepare the new task (Allport, Styles, & Hsieh, 1994; Los, 1995; Rogers & Monsell, 1995). This suggests that a preceding task set cannot simply be replaced by a new one; it still lingers on for some time. Consistent with this, alternative task sets impair performance only if they have already been used (Allport et al., 1994). Obviously, these task-set-related findings parallel what we have assumed and at least partially found for single responses (or their spatial codes). Task-set inertia (as Allport et al. call their effect), response inertia, and response readiness may, therefore, be only a few examples of a more general phenomenon that awaits further exploration.

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