Perception & Psychophysics
1987, 42 (2), 195-201

Spatial S-R compatibility with unimanual two-finger choice reactions: Effects of irrelevant stimulus location

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Spatial stimulus-response (S-R) compatibility was investigated for two-finger choice reactions with irrelevant stimulus location. Subjects responded with either their index or their middle finger of one hand to a bicolor diode emitting either green or red light in the right or left visual field. Three conditions were tested, in which subjects responded (1) with palms facing down; (2) with palms facing up, alternating the hands between blocks of trials; and (3) again with palms facing down, but using the same hand throughout an experimental session. For all three conditions, results show a strong S-R compatibility effect for fingers. In addition, a small S-R compatibility effect for hands (especially for the left) was obtained in experimental Condition 3 (nonalternating hands), but not in Conditions 1 and 2 (alternating hands). In general, the results strongly support the coding hypothesis of spatial S-R compatibility. A modified attentional hypothesis is proposed to supplement the coding hypothesis to account for the results obtained in Condition 3.

In studies of spatial stimulus-response (S-R) compatibility, distinctions are made between relevant and irrelevant stimulus location. With relevant stimulus location, subjects have to perform a *spatial* task; for example, for an arrangement of stimuli and responses along the right/left dimension, they have to press the right key as response to the right light and the left key as response to the left light (compatible condition), or the left key for the right light and the right key for the left one (incompatible condition). With irrelevant stimulus location, the task concerns properties of the stimulus independent of its location (such as size, color, or shape) and is thus *nonspatial*; for example, again for a right/left arrangement, subjects have to press the right key when the stimulus is red and the left key when it is green, or, conversely, the right key when the stimulus is green and the left key when it is red. Although the spatial positions of the stimuli are irrelevant to the task, data are nevertheless evaluated according to the spatial (compatible vs. incompatible) relationship between stimuli and responses (see, e.g., Craft & Simon, 1970; Hedge & Marsh, 1975). The spatial S-R compatibility effect for irrelevant location has also been called the "Simon effect" by Hedge and Marsh (1975), which, however, does not imply that this effect is explained by Simon's (1969) theory (see Faber, van der Molen, Keuss, & Stoffels, 1986; Heister, Ehrenstein, & Schroeder-Heister, 1986, especially Note 1). With respect to bimanual responses, spatial S-R compatibility effects could be demonstrated repeatedly both for relevant and irrelevant stimulus location under various arrangements of the stimuli and responses (see Brebner, Shephard, & Cairney, 1972; Nicoletti & Umiltà, 1984; Umiltà & Nicoletti, 1985, and references therein).

Whereas up to now spatial compatibility was almost exclusively investigated for bimanual reactions, Heister et al. (1986) obtained a spatial S-R compatibility effect with relevant stimulus location for unimanual two-finger choice reactions. Subjects responded with their index and middle fingers to lights in the right or left visual field, pressing the spatially same (compatible) or the spatially different (incompatible) key. The hand used for response was held in the normal right or left position (i.e., the right

The experimental work reported here was carried out at the Institut für Arbeitsphysiologie, Dortmund. We are grateful to Jeff Miller for his comments on our preceding article (Heister, Ehrenstein, & Schroeder-Heister, 1986), which motivated us to set up Condition 3 of the experiment described in this paper. We would also like to thank the reviewers for helpful comments and suggestions; Armin Bozek, Sibylle Marquard, and Wilfried Runte for technical assistance; and David Emmans for revising the English text.

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hand on the right side and the left hand on the left side of the body midline). In order to discriminate between a "genuine" spatial S-R compatibility effect and an effect that is bound to the anatomical order of fingers, two experimental conditions were chosen. Subjects responded (1) with a palm-down hand position (which is the standard position in reaction time tasks) and (2) with a palm-up position (leading to a reversal of the spatial ordering of the anatomical fingers). A reaction time advantage for spatially compatible stimulus-response associations was obtained under both conditions, which was even more pronounced under the palm-up condition. This result gave strong support for the coding hypothesis of spatial compatibility, according to which the translation and comparison of the spatial relationships on the stimulus and response side are responsible for the observed effect. It ruled out rival hypotheses that would predict either no effect at all (such as attentional or neurological pathway hypotheses) or an effect related to the fingers instead of their positions (like the mapping hypothesis). For a more detailed description of these hypotheses and relevant literature, see Heister et al. (1986).

The present study investigated whether the theoretical conclusions of our previous study (Heister et al., 1986) also extend to the case of irrelevant stimulus location. For this purpose we used red and green lights as stimuli, let the subjects decide about the color of the light, and let them give their reactions with their index or middle fingers. As in the first study, both prone and supine hand positions were tested. Since, for bimanual reactions, the basic results are essentially the same for relevant and irrelevant location (see Nicoletti, Anzola, Luppino, Rizzolatti, & Umiltà, 1982; Umiltà & Nicoletti, 1985), we may expect that the finger compatibility effect applies to the relevant as well as to the irrelevant case.

For one aspect in our design, however, one may predict a different result in the irrelevant case. Since the (right or left) hand used for responding was not held in middle position (as in Katz, 1981), but on the right or left side of the body midline, respectively, we may ask if in addition to the finger compatibility effect a hand compatibility effect occurs. That means we would have to check to see if the right hand reacts faster to stimuli in the right than in the left field, and if the left hand reacts faster to stimuli in the left than in the right field, with the finger used for response being disregarded. In our first study on relevant stimulus location, no such hand compatibility effect was obtained. This supported the coding hypothesis of spatial S-R compatibility, according to which the observed effect depends on the *relative* spatial locations of the choice effectors with respect to each other. Since the choice was made between the two fingers of one hand and not between the two hands (i.e., since the hand used for response was fixed independent of the choice), the coding hypothesis predicts no hand compatibility effect.

Although in best accordance with the theory of spatial coding, the absence of the hand-compatibility effect in our first study was not in line with results obtained in other investigations. Heister and Schroeder-Heister (1987), using unimanual two-finger-choice reactions in an experiment with lexical decisions, found evidence for a hand compatibility effect. In an experiment by Umiltà and Nicoletti (1985, Experiment 3), a hand compatibility effect occurred when subjects reacted bimanually to green or red lights flashed to the same position in a single field (either to the right or to the left). Here, the position of the stimulus, not of the response, was fixed in advance. This procedure eliminated relative spatial differences between the possible stimuli, so that the coding hypothesis could not be applied. Since both of these studies used irrelevant stimulus location, we speculated that the incongruence between these results and our previous work might have to do with the difference between relevant and irrelevant stimulus location. If this is true, the present study with irrelevant stimulus location should demonstrate an S-R compatibility effect for hands in addition to the one for fingers. In this case, we would have to look for a theoretical explanation for the difference between relevant and irrelevant location. The coding hypothesis, at least in its present form (Nicoletti et al., 1982; Umiltà & Nicoletti, 1985), has no features that distinguish between relevant and irrelevant stimulus location.

Another difference between our previous study (Heister et al., 1986) and the other studies (Heister & Schroeder-Heister, 1987; Umiltà & Nicoletti, 1985, Experiment 3) was that we let the hands used for responding alternate between blocks of trials. In Heister and Schroeder-Heister (1987), the responding hand was fixed for the whole experimental session, and in Umiltà and Nicoletti (1985), the stimulus position was changed only once per session. Thus, one could hypothesize that a hand compatibility effect occurs only when the responding hand (or in Umiltà & Nicoletti's design, the stimulus position) remains constant for a sufficiently long period. In order to control for this possibility, in the present study we used a third experimental condition, in addition to the two experimental conditions corresponding to those of our previous study (i.e., prone and supine hand positions, hands alternating between blocks). This time, responding hands were held palm-down as in the first condition, but did not alternate between blocks. Therefore, the third condition consisted of two sessions: one for the right and one for the left hand. If a difference with respect to hand compatibility occurs between the first condition (pronation, alternating hands) and the third condition (pronation, fixed hands), this cannot be explained by the coding hypothesis. The coding hypothesis does not distinguish between degrees of constancy in spatial features, so that some alternative hypothesis would have to be looked for again.

In short, if the finger compatibility effect obtained in our previous study with relevant stimulus location pertains in general to irrelevant stimulus location, a significant reaction time advantage for compatible light-finger pairings should be obtained under all experimental conditions, independent of hand position (prone vs. supine) and of whether responding hands alternate or remain fixed. If the situation with respect to hand compatibility differs between relevant and irrelevant stimulus location, a reaction time advantage for compatible light-hand pairings should now be obtained for all experimental conditions. If having only the responding hands fixed influences hand compatibility, no such effect should be obtained for experimental Condition 1 (hands palm down, alternating) or Condition 2 (hands palm up, alternating), but it should occur under Condition 3 (hands palm down, fixed).

METHOD

Subjects

Eight female college or university students (aged 17 to 25 years) served as paid subjects. They were all right-handed according to a German adaptation of the Edinburgh Inventory (Oldfield, 1971), had normal color vision, and had no special training in visual reaction time tasks. All subjects served in each of the three experimental conditions and were naive as to the purpose of the task.

Apparatus

The subject sat in front of a modified Förster perimeter (Oculus). Her head position was fixed by a forehead- and chinrest; the distance between the subject's eyes and the perimeter plane was 45 cm. Two shielded lamps provided a dim and diffuse ambient illumination. Two bicolor (red/green) light-emitting diodes (LEDs; Telefunken CQX 95) produced circular lights of 560 and 630 nm peak wavelength subtending 38′ of arc. The centers of the stimuli were positioned at 5° of visual angle to the left and right of the fixation point. The fixation point consisted of a white circular field subtending a visual angle of .75° on a gray perimeter plane. Luminance (measured by a Hagner Universal Photometer S2) was 2.5 cd/m² for the perimeter background, 4.1 cd/m² for the fixation point, and ranged between 170 and 185 cd/m² for the LED lights. The ability to maintain fixation properly was tested in a number of pretrials in which eye movements were monitored by an infrared photoelectric device and were displayed on an oscilloscope. The stimuli were presented for 100 msec following an acoustic warning of 150 msec that preceded the stimulus onset by 500 to 800 msec. Response keys were two microswitches (Schadow-digitast SE; with electronic rebound suppression) of a microswitch box, which were connected to an electronic clock that was started with stimulus onset and stopped by the microswitch contact. The microswitch box was freely movable and was attached to either the left or the right side of the experimental desk (for the prone conditions) or underneath a shelf placed on the desk, which allowed the subject's hands to press the key from below (for the supine condition).

Procedure

The subjects attended four sessions on different days. Each session was subdivided into four blocks separated by short rest periods. Each block consisted of 6 practice trials and 44 test trials, with 11 stimulus presentations for each of the 4 combinations of color and visual field (red/left field, red/right field, green/left field, green/right field). Stimuli were presented in a particular quasi-random order within each block, allowing a maximum of only three consecutive stimuli of the same color or in the same field.

The subject had to press one of the two microswitches with either her index or middle finger as fast as possible while maintaining her gaze on the fixation point. In two blocks of each session, the subjects made right-finger responses to red lights and left-finger responses to green lights, and, in the other two blocks, left-finger responses to red lights and right-finger responses to green lights. The order of blocks within each session was balanced across subjects. For each block, the subject was told to use the appropriate finger (index or middle finger), so that her attention would not be drawn to spatial relationships. In one of the four sessions, the subject answered with her hands in a prone position, with the responding hand altered from one block to the next (Condition 1). In another session, the subject responded with her hands in a supine position, and the responding hand was again changed between blocks (Condition 2). In the third and fourth sessions, the subject responded in the prone position with only the right hand or only the left hand, respectively; that is, within these two sessions hands were *not* alternated from block to block (Condition 3). Two subjects started with Condition 1, 2 started with Condition 2, 2 with the right-hand session of Condition 3, and 2 with the left-hand session of Condition 3. Errors were few, and error trials were repeated at the end of each block.

RESULTS

Median reaction times were computed for right- and left-hand responses to right- and left-field stimulation for compatible and incompatible light-finger relations. For each subject, eight values were obtained in Condition 1 (prone hand position, alternating hands), eight in Condition 2 (supine hand position, alternating hands), and eight in Condition 3 (prone hand position, fixed hands). These median reaction times were subjected, for every condition separately, to a three-way within-subjects analysis of variance with the following factors: field of stimulus presentation (right or left), reacting hand (right or left), and reacting finger (right or left). The corresponding cell means and standard deviations for Conditions 1, 2, and 3 are given in Table 1.

For Condition 1 (prone hand), the only significant result was the interaction between field of stimulation and responding finger [$F(1,7) = 26.24$, $p = .001$], which expresses a spatial S-R compatibility effect for fingers. Compatible reactions (i.e., reactions with right fingers to right

Table 1
Means of the Median Reaction Times (in Milliseconds) and Standard Deviations

	Left Hand				Right Hand			
	Left Finger		Right Finger		Left Finger		Right Finger	
	RT	*SD*	RT	*SD*	RT	*SD*	RT	*SD*
Left Light								
Condition 1 Prone Hand	322 MF	51	376 IF	32	320 IF	36	373 MF	23
Condition 2 Supine Hand	316 IF	54	392 MF	49	329 MF	51	369 IF	37
Condition 3 Prone Hand (Fixed)	329 MF	41	402 IF	28	319 IF	32	382 MF	40
Right Light								
Condition 1 Prone Hand	374 MF	47	322 IF	30	369 IF	37	333 MF	42
Condition 2 Supine Hand	394 IF	55	324 MF	49	412 MF	56	302 IF	46
Condition 3 Prone Hand (Fixed)	396 MF	33	359 IF	34	365 IF	23	337 MF	34

Note—IF = index finger; MF = middle finger.

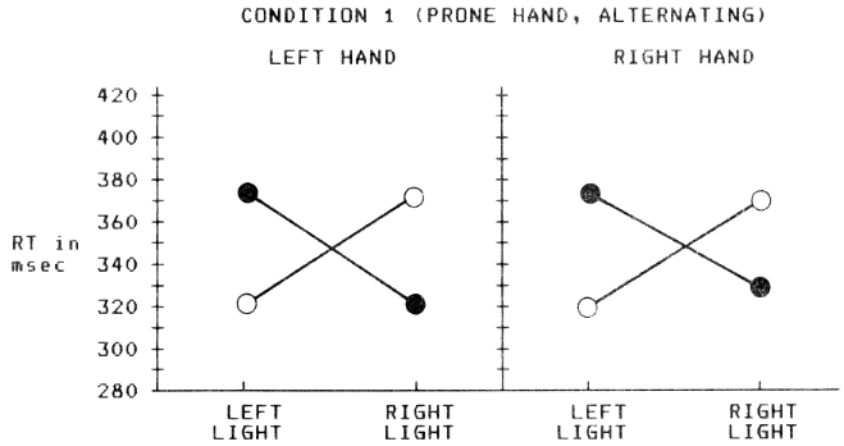

Figure 1. Means of the median reaction times for responses with the right finger (filled circles) or left finger (unfilled circles) of the right or left hand to lights in the right or left visual field under Condition 1 (hands held in pronation, alternating from block to block).

lights and left fingers to left lights) were 49 msec faster than incompatible reactions (i.e., reactions with right fingers to left lights and left fingers to right lights) (324 vs. 373 msec, see Figure 1). The interaction between field of stimulation and responding hand, which would express a compatibility effect for hands, was far from being significant [$F(1,7) = .62$].

Similarly, the analysis for Condition 2 (supine hand) showed a significant interaction between field of stimulation and responding finger [$F(1,7) = 81.74, p < .0001$]. This means that there was a strong S-R compatibility effect for fingers, compatible reactions being 73 msec faster than incompatible reactions (318 vs. 391 msec; see Figure 2). As could be confirmed through a common analysis of variance for the data of both Conditions 1 and 2, the rise of the S-R compatibility effect from prone to supine hand position is significant (interaction between experimental condition, field, and finger [$F(1,7) = 25.77$, $p = .001$]). As in Condition 1, the interaction between field of stimulation and responding hand did not approach significance [$F(1,7) = .15$]. Overall, responses under Condition 2 were 6 msec slower than those under Condition 1 (355 vs. 349 msec), but this difference was not significant in the common analysis of variance for Conditions 1 and 2.

In addition, for Condition 2, a significant main effect for responding finger [$F(1,7) = 11.04, p = .01$] and a significant interaction between hand and finger [$F(1,7) = 11.36, p = .01$] were obtained. Both of them result from a strong difference between index and middle finger of the right hand, the index finger being 37 msec faster than the middle finger (336 vs. 373 msec), whereas, for the left hand, the index finger was only 6 msec faster than the middle finger (351 vs. 357 msec: means based on medians of data with right and left fields combined). This was confirmed through a separate two-way analysis of

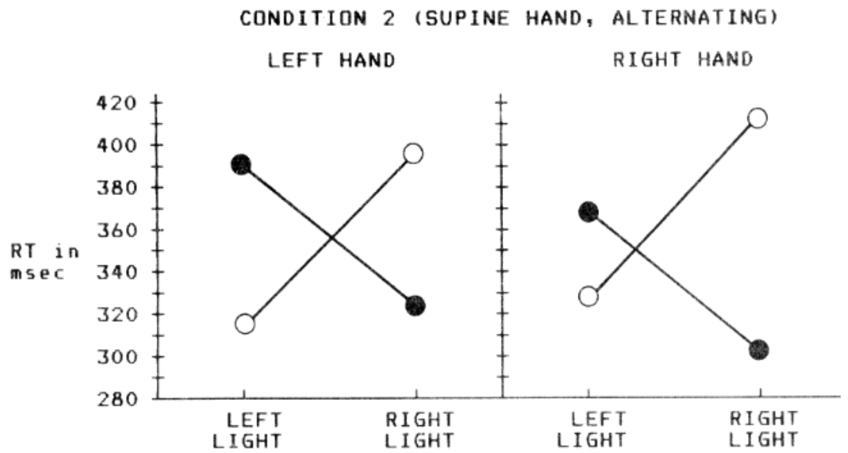

Figure 2. Means of the median reaction times for responses with the right finger (filled circles) or left finger (unfilled circles) of the right or left hand to lights in the right or left visual field under Condition 2 (hands held in supination, alternating from block to block).

variance with the factors hand and anatomical finger (main effect for anatomical finger [$F(1,7) = 6.80$, $p < .05$], again based on the combined data for right and left fields).

As for Conditions 1 and 2, a significant interaction between field of stimulation and responding finger was obtained for Condition 3 (prone hand, responses given with hand fixed throughout experimental session) [$F(1,7) = 97.63$, $p < .0001$], showing that the S-R compatibility effect for fingers also occurs when hands are not changed during an experimental session. Compatible reactions were 50 msec faster than incompatible reactions (336 vs. 386 msec; see Figure 3).

Whereas for Conditions 1 and 2, there was no difference in speed of reaction between right and left hands, for the fixed-hand condition (Condition 3), left-handed responses were significantly slower than right-handed ones [371 vs. 351 msec, $F(1,7) = 17.94$, $p < .01$]. This was confirmed through a common analysis of variance for the palm-down conditions (Conditions 1 and 3), showing a significant interaction between experimental condition and responding hand [$F(1,7) = 8.75$, $p < .05$]. Finally, a significant main effect for finger was obtained for Condition 3 [$F(1,7) = 18.78$, $p < .01$]; this was caused by the fact that, as opposed to Conditions 1 and 2, the index finger of the left hand reacted 15 msec more slowly than the middle finger (383 vs. 368 msec), whereas, for the right hand, the index finger was 18 msec faster than the middle finger (345 vs. 363 msec: means based on medians of data with right and left fields combined).

Of greater interest was the question of whether, in the fixed-hand condition, contrary to the conditions with alternating hands (especially the related [palm-down] Condition 1), an S-R compatibility effect for hands would occur. The corresponding interaction between field of stimulation and responding hand nearly reached significance [$F(1,7) = 5.09$, $p = .059$]. This is mainly due to a left-field advantage of 12 msec for left-hand responses (377 vs. 365 msec), whereas right-hand responses were equally fast for both fields (351 msec). The difference of 12 msec failed to be significant in a separate analysis of variance for left-hand responses [$F(1,7) = 4.66$, $p = .068$]. Since our sample of 8 subjects may not have been large enough to prove such a small difference to be significant, 4 additional subjects were tested under Condition 3. They fulfilled the same specifications as the other subjects (female, right-handed, etc.), except that they did not serve under Conditions 1 or 2. Two of them started with the left-hand session and 2 with the right-hand session of Condition 3. The results based on this enlarged sample of 12 subjects confirmed those reported for the smaller sample, the left-field advantage for left-hand responses now being significant [$F(1,11) = 4.88$, $p < .05$].

DISCUSSION

The main purpose of this study was to investigate (1) whether the spatial S-R compatibility effect for two-finger choice reactions, as obtained in a previous study for relevant stimulus location (Heister et al., 1986), also pertains to irrelevant stimulus location; (2) whether a hand compatibility effect, which was absent in the first study, would occur under the condition of irrelevant stimulus location; and (3) whether holding the hands fixed throughout an experimental session makes a difference as to hand compatibility.

Our results show a strong compatibility effect under both the palm-down and palm-up conditions with alternating hands (which correspond to the two conditions of the previous study), and also under the palm-down condition with nonalternating hands. Thus, we may conclude that, with respect to finger compatibility, there is no difference in principle between relevant and irrelevant stimulus location. Recent psychophysiological findings on intrahemispheric S-R compatibility (Ragot & Lesevre, 1986) agree with our finger compatibility results for the prone hand conditions. The fact that in our study the finger com-

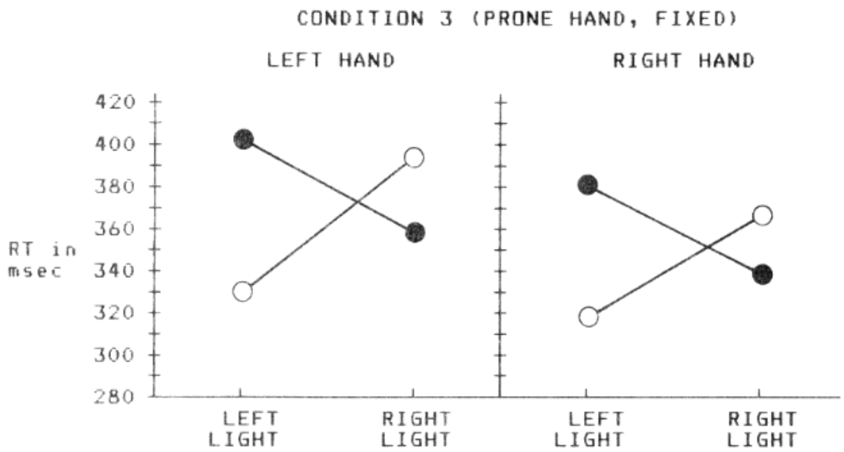

Figure 3. Means of the median reaction times for responses with the right finger (filled circles) or left finger (unfilled circles) of the right or left hand to lights in the right or left visual field under Condition 3 (hands held in pronation, fixed throughout experimental session).

patibility effect obtains both for prone and supine hand positions, with the responding hand held, not in midline, but in normal right or left position, shows that the effect obtained depends on the spatial positions of the responding fingers with respect to each other. This means that, as in the relevant case, the best available hypothesis to explain this effect is the coding hypothesis according to which the relative locations of stimuli and responses are translated into a spatial code, so that compatible S-R pairings need shorter processing time than incompatible ones.

As in the previous study, the finger compatibility effect is stronger for the palm-up than for the palm-down condition, this difference now being even statistically significant. This might be related to an increase of attention to spatial differences under the unusual palm-up hand position, when the spatial relationships are no longer directly associated with anatomical relationships. However, whereas in the study with relevant location a retardation in the palm-up condition, as compared to the palm-down condition, could be observed, there is now only a (nonsignificant) trend in this direction. That reaction times are now overall slower than before (305 vs. 352 msec) represents a well-known difference between relevant and irrelevant stimulus location.

No hand compatibility effect was obtained under Conditions 1 and 2, not even a (nonsignificant) trend. Therefore, there is no difference between relevant and irrelevant stimulus location with respect to hand compatibility. This conforms well with the hypothesis of spatial coding that does not predict a hand compatibility effect. It would predict such an effect only if there were a choice reaction between hands (and not only between fingers), since it refers to the relative positions of stimuli and of *choice* effectors.

However, a small hand compatibility effect, at least for left-hand responses, was found under Condition 3, in which hands did not alternate within experimental sessions. This cannot be explained by the coding hypothesis. As in Conditions 1 and 2, there was no choice reaction between hands in Condition 3, the responding hand being even more fixed than in Conditions 1 and 2 (viz., for the whole session, not for only one block of trials).

Although a hand compatibility effect was demonstrated explicitly only for left-hand responses, our findings may nevertheless be viewed as indicating a general hand compatibility effect for fixed hands, if one takes into account the fact that the corresponding effect for right-hand responses (right-field advantage) may be concealed by lateralization of color discrimination to the right hemisphere. This lateralization would favor the left field and could therefore "extinguish" a small right-field advantage due to hand compatibility for right-hand reactions. A lateralization of color discrimination to the right hemisphere could also account for the fact that the overall right-field advantage of Heister et al. (1986) disappeared in the present study. (For a discussion of lateralization of color discrimination, see Davidoff, 1976; Hannay, 1979; Pennal, 1977; see also Simon, Paullin, Overmyer, & Berbaum, 1985).

Obviously, further experimentation is needed to fully establish a general hand compatibility effect under the fixed hand condition. In particular, this condition should be run for relevant stimulus location in order to estimate how far the results of the present study interfere with specific features of color discrimination tasks. If our hypothesis is correct that the hand compatibility effect for right-hand responses is concealed by a lateralization of color discrimination, a hand compatibility effect should explicitly be present for both hands in an experiment with fixed hands and relevant stimulus location. Since we are concerned here with irrelevant stimulus location, we leave this for subsequent experimental work.

As a theoretical explanation for a general hand compatibility effect for responses with nonalternating hands, we propose a modified attentional hypothesis. In the context of S-R compatibility, "attentional hypothesis" usually means that the occurrence of a stimulus on the right or left of the fixation point evokes an attentional preference for this side which leads to shorter reactions when the response is given on the same (i.e., compatible) side. The attentional hypothesis in this form has been ruled out as an explanation of S-R compatibility for designs with bimanual reactions by investigations with stimuli and/or responses on the same side of the body midline (Nicoletti et al., 1982; Umiltà & Nicoletti, 1985). Similarly, it cannot explain our finger compatibility effect, since in all our experimental conditions hands are held on the right or left of the body, so that the responding fingers are both on one side of the body midline. It can explain our hand compatibility effect, however, if it is modified in such a way that the subject's attention is influenced only by *constant* spatial cues, which may be either on the stimulus or on the response side. This modified attentional hypothesis differs from the standard version in the constancy requirement and also in admitting directional cues as being produced by the response arrangement. According to this hypothesis, subjects focus their attention on features of the stimulus or of the response that remain most constant. In the present case, it can explain that with alternating hands, when the constancy requirement is not fulfilled, no compatibility effect takes place, but that with hands held constant throughout an experimental session, attention is oriented toward the side of the responding hand, and thus compatible stimuli are reacted to more quickly than are incompatible ones. The modified attentional hypothesis also accounts for the results of Heister and Schroeder-Heister (1987), who investigated unimanual reactions with hands held constant (as in Condition 3 of the present study), and of Umiltà and Nicoletti (1985, Experiment 3), who used red or green stimuli presented at a fixed location, the attention being drawn to a constant *stimulus* position.

Attention, in this context, might also be understood in terms of hemispheric activation (see Nicoletti et al., 1982, p. 670). There is experimental evidence for the possibility of intrahemispheric cognitive/motor interference (see Heister, 1984a, 1984b, who demonstrated a change in the reaction time asymmetry pattern of a lexical decision task, depending on whether subjects had to press the response button once, twice, or three times; the reaction time was always measured on the first press). This means that the motor reaction of one hand may provoke an "arousal" or "overload" in the contralateral hemisphere, expressed in faster or slower processing of stimuli reaching primarily the hemisphere that controls the responding hand. Therefore, it seems possible that in the present study permanent use of only one hand produced an arousal of the hemisphere controlling this hand. If this occurred, it would suggest that the hand compatibility effect was not due to the constancy of a spatial cue (as described above) but rather to the constant use of the *anatomically* right or left hand, which would influence the processing speed of the controlling hemisphere. Similarly, Umiltà and Nicoletti's (1985, Experiment 3) findings (with fixed stimulus location in either the right or the left field) could be explained by an arousal through constant stimulation of the same hemisphere.

An unexpected result of our study was the relative slowness of the left hand under Condition 3, which might be related to a stronger tiring of the untrained left hand for right-handed subjects under this more monotonous condition. A final explanation for this side effect, which is unrelated to S-R compatibility, lies outside the range of the present investigation. The same holds true for the anatomical finger effects, resembling those found in the previous study (Heister et al., 1986). They are not relevant for the question of spatial S-R compatibility, since the analysis of compatibility effects relies on reaction times from both index and middle fingers.

To sum up, our results confirm the hypothesis of spatial coding also for spatial S-R compatibility effects found with irrelevant stimulus location. Yet, for specific conditions, a modified attentional hypothesis may be considered as supplementing the coding hypothesis.

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(Manuscript received October 31, 1986;
revision accepted for publication March 16, 1987.)