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Threefold effect of peripheral precues: Alertness, orienting, and response tendencies

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Abstract

Three experiments were run revealing that peripheral cues exert an alerting and orienting effect. Novel is the finding that peripheral cues induce a (hidden) tendency to respond to the cued side, which interacts with the response tendency elicited by the subsequent following target. Compatible S-R mappings revealed either a reversed or no response tendency in cue conditions as compared to uncued conditions. Incompatible mappings mostly showed a decrease in response tendencies under influence of the peripheral cue. An increase of the interval between the cue and the target up to 500 ms resulted in a return to the baseline condition (without cue). The findings for the compatible mappings may be interpreted in terms of an extra recoding operation that was induced by peripheral cues. Inconsistencies found for incompatible S-R mappings might be attributed to the dual presence of recoding operations on account of the cue and the target.

PsycINFO classification: 2346

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1. Introduction

A finding often reported in visual attention research is that subjects react faster to target stimuli when they are preceded by cues at the same position (peripheral cues). For instance, if subjects have to press a button dependent on the identity of a presented character, and one single character is presented at one of two possible positions,

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reactions are faster if the position of that character was preceded by a peripheral dot – the precue – than if it was not so preceded. A common interpretation of such a finding is that peripheral cues induce two effects. The first is that peripheral cues enhance alertness which results in faster reactions. The second is that peripheral cues automatically attract attention, which facilitates detection or recognition of targets presented at the cued position (Posner, 1978; Jonides, 1981; Posner and Cohen, 1984), resulting in faster reactions to targets presented at cued locations. However, a third effect of using peripheral cues, is that they may also induce a tendency to react to the cued side. For instance, a cue presented at a left position in the visual field may induce a tendency to react to the left, which can have an effect on the response to a succeeding target.

An indication that the position of a target stimulus has an effect on reactions is the Simon effect (Simon et al., 1976). Simon et al. reported that reactions to stimuli presented on a specific side are faster when the required response side corresponds with the stimulus side compared to when both sides do not correspond. Simon et al. (1976) and Simon (1990) argued that presentation of a target stimulus on the left or right side of the subject's meridian induces a tendency to react on the same side – e.g. by pressing a left or right button – in conditions in which the side of the presented stimulus was irrelevant for the required response. If we generalize this suggestion, then it may be proposed that the presentation of a peripheral cue on the left or right side induces a tendency to react on that side.

However, it must be remarked that in some specific conditions reverse Simon effects are found (e.g. Hedge and Marsh, 1975). In that case reactions are faster to target stimuli if the side of presentation of the target does not correspond with the required response side compared to correspondence between side of presentation and the required response. We will return to this issue later on. To simplify terminology we will denote the normal Simon effect as a *positive correspondence* effect, and the reverse Simon effect as a *negative correspondence* effect.

A way to examine whether peripheral cues preceding the target induce response tendencies is to investigate correspondence effects in cue and no-cue conditions with identical targets. One possible outcome is that tendencies elicited by the cue and the target add up. This leads to the prediction that positive correspondence effects for targets accumulate in the cue condition. Another possible outcome is that the initial tendency elicited by the cue is inhibited, resulting in a diminished positive correspondence effect or even a negative correspondence effect for subsequent presented targets. The ideas of Tipper et al. (1991) are related to this inhibition concept. They suggested that reactions to targets in a trial slow down if responses to these targets had to be inhibited (because they were used as distractors) in a previous trial. So, the idea may be that the cue induces, analogous to a distractor, a tendency to respond that has to be inhibited. As a consequence, a response to a subsequent presented target will slow down if that target requires the inhibited response side.

Some researchers argued that the correspondence effect depends on the position of the focus of attention. Because peripheral cues attract attention, the correspondence effect to subsequent presented targets may change. Nicoletti and Umiltà (1989) performed a series of studies in which they examined the influence of focus of attention on correspondence effects. They assumed that a spatial left or right code of a target is formed relative to the position of the focus of attention. Correspondence between the spatial code of the target and a spatial response code (e.g. a left or right button) may facilitate reactions compared to noncorrespondence between the spatial code of the target and the response code. Six empty boxes were presented in a horizontal row on a screen and subjects were required to respond to a target appearing within one box by pressing a left or right positioned button. The identity of the target defined the appropriate response side. A positive correspondence effect was found that did depend on the position of a preceding cue. This suggests that the correspondence effect depends on the position of the attentional focus. An experiment with symbolic cues showed similar results. Nicoletti and Umiltà concluded that orienting leads to a left–right partioning of the visual space with the boundary at the locus of the oriented position. Therefore, the use of cues may alter the spatial codes of specific positions, and consequently modify correspondence effects to subsequent presented targets.

However, running an experiment with targets in no-cue and cue conditions resulting in a decreased correspondence effect in the cue condition, leaves us with two alternative interpretations. First, the initial tendency induced by the cue was inhibited, resulting in a decreasing correspondence effect for targets, and second, the spatial code of the target became neutral due to orienting on the account of the peripheral cue. As a consequence no Simon effect becomes manifest. Hence, such an experiment cannot distinguish between these two explanations.

This blind alley can be avoided by the use of specific stimulus-response (S-R) mappings that show either a positive, or a negative correspondence effect. If the spatial code of a target becomes neutral in the cue condition, then, for both S-R mappings, no correspondence effect should be observed. However, if inhibition operates on the basis of the initial tendency resulting from the cue, then quite different effects for these S-R mappings should be observed.

Hedge and Marsh (1975) reported an experiment that showed positive and negative correspondence effects. Subjects had to push a red or green button in response to the color of a target, also either red or green, presented in a left or right location. Either a compatible (green target – green button) or an incompatible (red target – green button) S-R mapping was used. The compatible mapping showed a positive correspondence effect, but the incompatible mapping showed a negative correspondence effect. In some other experiments, reported by Simon et al. (1981) and Stoffels et al. (1985), a spatial manipulation of S-R compatibility was used. The results of these experiments showed no correspondence effect for the incompatible S-R mapping.

Recently, De Jong et al. (1994) put forward 'A dual-process model of effects of spatial stimulus-response correspondence' to account for the positive and negative correspondence effect for compatible and incompatible mappings in the Hedge and Marsh paradigm. A distinction was made between an unconditional component and a conditional component. The unconditional component (UC) was assumed to be a reflection of the original positive correspondence effect. Furthermore, it was assumed that this component shows an initial facilitatory and a later inhibitory effect for responses of which the side corresponds with the side of the presented target. In addition, the conditional component (CC) was assumed to reflect a generalization of the transformation rule applied on the compatible and the incompatible mapping for the irrelevant spatial code of the target. This conditional component was assumed to be a constant. Both components are assumed to add up to the total effect of correspondence. Hence, the compatible mapping results in a benefit for a corresponding spatial code because both components are positive. However, the incompatible mapping can result in a cost for a corresponding spatial code when the contribution of the conditional component is larger than the unconditional component.

Three different views can be distinguished that differ in their predictions concerning correspondence effects for compatible and incompatible S-R mappings with peripheral cues. First, if the correspondence effect depends on the spatial code of a target, and this code is determined relative to the position of the attentional focus, as was suggested by Nicoletti and Umiltà (1989), then it seems logical to assume that the spatial code of the target becomes neutral when it was preceded by a peripheral cue. This will lead to an extinction of correspondence effects for both compatible and incompatible S-R mappings (Hypothesis 1).

Second, if the tendencies induced by the peripheral cue and the target add up then the positive correspondence effect increases for the compatible S-R mapping compared to the compatible baseline condition. For the incompatible mapping, addition of the effect induced by the cue and the effect induced by the target will result in a decreased negative correspondence effect in the peripheral cue condition compared to the incompatible baseline condition. Hence, according to the adding up hypothesis, presentation of a peripheral cue will lead to a strong positive correspondence effect for a compatible mapping, and a decrease of the negative correspondence effect for the incompatible mapping (Hypothesis 2).

Third, if the tendency to react to the peripheral cue has to be inhibited (i.e. producing a negative correspondence effect) then the net outcome depends on the strength of the negative correspondence effect elicited by the peripheral cue and the correspondence effect elicited by the target. If one assumes that the inhibitory effect is very strong, then a negative correspondence effect may be found for the compatible S-R mapping, and an increased reverse Simon effect may be predicted for the incompatible S-R mapping (Hypothesis 3).

2. Experiment 1

Compatible and incompatible S-R mappings were investigated with targets pointing to either the left or the right. In the compatible mapping subjects had to press a button that corresponded with the pointing side of the target, and in the incompatible mapping subjects had to press the other button. Three conditions were investigated. In the baseline condition, without precues, we expected a positive correspondence effect for the compatible mapping and a negative or zero correspondence effect for the incompatible mapping. In the warning cue condition, we explored the possibility whether the correspondence effect changes as a result of a preceding cue that conveys only temporal information. For instance, alertness might suppress correspondence effects. In the peripheral precue condition the target was preceded by a peripheral cue indicating the precise target position. The interval between the onset of the cue and the target (stimulus onset asynchrony: SOA) amounted to 200 ms to optimize orienting. Targets were presented at four possible positions to improve the use of the peripheral precues.

2.1. Method

2.1.1. Subjects

Twenty subjects participated in this experiment and received 30 Dutch guilders (about US$20) for their participation. All subjects (5 male, 15 female, mean age 21.8 years, 2 left-handed) had normal or corrected-to-normal vision.

2.1.2. Task and stimuli

In each trial subjects focused on a black fixation square ($0.53° \times 0.38°$) presented in the center of a screen on a white background at a distance of 75 cm that was continuously present. As targets black Xs ($0.76° \times 0.92°$) were used with one of the upper lines missing, resulting in two alternative targets: a normal and a mirrored λ (Fig. 1).

Targets appeared for 1500 ms at 0.8° or 2.5° to the left or right side of the fixation square. In the compatible session subjects were instructed to press a left button for a left pointing target, and a right button for a right pointing target. In the incompatible session this instruction was reversed. In addition, subjects were instructed to react as fast and accurate as possible, to avoid premature responses, and to avoid eye movements before making a response. Trials were separated by 3000 ms. In two conditions the target was preceded by a cue: a peripheral precue ($0.69° \times 0.23°$), presented 0.5° underneath the position of the target, or a warning precue, presented 0.5° underneath all possible target

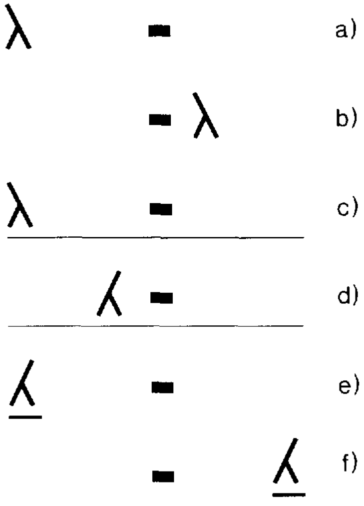


Fig. 1. λs presented in a neutral block (a+b), a warning precue block (c+d), and a peripheral precue block (e+f). In blocks c–f the precue was presented prior to the λ. In the compatible S-R mapping condition a, c, and f are considered as correspondence between the stimulus position and the required response and b, d, and e are considered as non-correspondence. This relation is reversed for the incompatible S-R mapping.

positions (6.92° × 0.07°). Precues were presented for a duration of 100 ms with an SOA of 200 ms.

2.1.3. Apparatus

Stimulus presentation and data collection (vertical electro-oculogram [VEOG], horizontal electro-oculogram [HEOG], reaction times [RTs], and proportion errors [PEs]) were controlled by the InstEP system (Campbell and Bell, 1992) running on a 386SX (for stimulus presentation) and a 486DX2 (for data collection) computer. Subjects were lying on a bed in a sound-attenuated, dimly lit (15 lux) cubicle. On each side of the bed a response button was positioned at an optimal location for each subject.

2.1.4. Design and procedure

A within-subjects design with repeated measures was used that included three independent variables: compatibility of the S-R mapping (a λ or mirrored λ pointing to the same or the opposite side of the required response), correspondence (correspondence or noncorrespondence between the stimulus side and the response side), and cue block (baseline, a warning precue, and a peripheral precue). For each subject the experiment was divided in a compatible and an incompatible session, each consisting of three cue blocks. Correspondence was varied randomly within each block of 200 trials. A Latin square design was used for the order of the cue blocks within a session. The order of compatible and incompatible sessions was counterbalanced. Each subject performed the complete experiment in about three hours. First EOG electrodes were attached; resistance was kept below 5 kΩ. After calibration, the subject was instructed to focus on a fixation square during each trial until a response was made. The first experimental block was preceded by 100 practice trials. The other five blocks were preceded by 50 practice trials. A block started with an instruction about the S-R mapping and the type or absence of precue. Each out of eight configurations was presented 25 times in a random sequence for each block. Dependent variables were reaction times (RTs) and proportion errors (PEs). RT was measured from the onset of the target. Trials with RTs below 200 ms or above 1400 ms and trials with detectable eye movements before making a response, were excluded from analysis. Incorrect responses with no detectable eye movements were marked as errors. RTs were averaged over 0.8° and 2.5°, and over both hands.

2.2. Results

MANOVAs (the Pillai–Bartlett trace) and *t*-tests for repeated measures were performed on reaction times (RTs) and percentage errors (PEs). In all analyses results with $p < 0.05$ were considered significant. The results are dealt with in two main sections. The first section contains the overall analyses and the second section contains results per cue block. Fig. 2 shows mean RTs and PEs for the three cue blocks.

2.2.1. Overall analyses

A main effect of cue block was found, $F(2,18) = 14.91$, $p < 0.001$. Contrast analyses revealed slower RTs in the baseline blocks than in the warning cue blocks (499 versus

469 ms), $t(19) = 3.66$, $p < 0.002$, and slower RTs in the warning cue blocks than in the peripheral precue blocks (469 versus 450 ms), $t(19) = 2.82$, $p < 0.011$. A trend towards significance was found for compatibility (465 versus 480 ms), $F(1,19) = 3.60$, $p < 0.075$.

A highly significant second-order interaction was found between compatibility, correspondence, and cue block, $F(2,18) = 6.64$, $p < 0.007$. Contrast analyses revealed a difference between the warning cue blocks and the peripheral precue blocks $t(19) = -2.69$, $p < 0.015$, and a difference between the baseline blocks and the peripheral precue blocks, $t(19) = -3.74$, $p < 0.001$). That is, the underadditive interaction between correspondence and compatibility for the baseline blocks turned into an overadditive interaction when the target stimulus was preceded by a peripheral precue. MANOVAs performed on PEs showed no significant effects.

2.2.2. *Separate cue blocks*

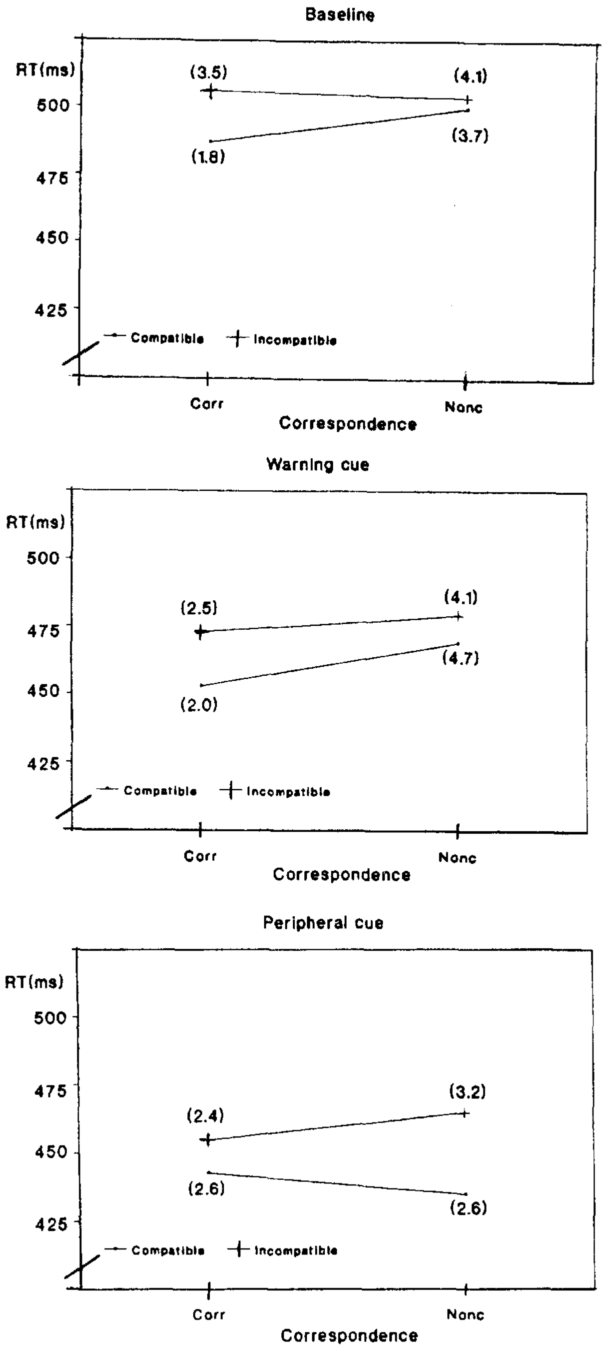
In the baseline block a significant underadditive interaction was found between the effect of compatibility and correspondence, $F(1,19) = 5.10$, $p < 0.04$; RTs for the compatible mapping showed a positive correspondence effect (487 versus 500 ms), $t(19) = 5.90$, $p < 0.025$, whereas no effect was observed for the incompatible mapping, (506 versus 504 ms), $t(19) = 0.16$.

In the warning cue blocks a positive correspondence effect was found, $F(1,19) = 5.31$, $p < 0.04$, i.e. reactions were faster to stimuli presented at corresponding compared to noncorresponding positions. Separate analyses for the compatible and incompatible mapping only showed a correspondence effect for the compatible mapping, (453 versus 469 ms), $t(19) = 5.83$, $p < 0.03$, and no effect for the incompatible mapping (473 versus 479 ms). A trend towards significance was found for compatibility, (461 versus 476 ms), $F(1,19) = 3.27$, $p < 0.09$.

In the peripheral precue blocks a significant overadditive interaction was found between the effect of compatibility and correspondence, $F(1,19) = 6.18$, $p < 0.023$. A tendency towards a positive correspondence effect was found for the incompatible mapping (455 versus 465 ms), $t(19) = 3.61$, $p < 0.075$, whereas a slight reversal of the correspondence effect was found in the compatible mapping (443 versus 435 ms), $t(19) = 2.82$, $p = 0.11$. A trend to significance was found for compatibility (439 versus 460 ms), $F\ (1,19) = 4.10$, $p < 0.06$.

2.3. *Discussion*

The results showed a 30 ms decrease in reaction time when the target was preceded by a general warning precue (the alerting effect) compared to the baseline condition, and an additional 19 ms decrease when the location of the target was indicated by a peripheral precue (the orienting effect). In the baseline condition a positive correspondence effect was found for the compatible mapping whereas no correspondence effect was found for the incompatible mapping. The manipulation with a general warning precue showed a similar pattern for correspondence effects for the compatible and incompatible S-R mappings compared to the base line condition. Hence, the correspondence effect was not distorted as a result of an alerting precue.


Baseline
RT(ms)
500
475
450
425
(3.5)
(4.1)
(1.8)
(3.7)
Compatible
Incompatible
Corr
Nonc
Correspondence
Warning cue
RT(ms)
500
475
450
425
(2.5)
(4.1)
(4.7)
(2.0)
Compatible
Incompatible
Corr
Nonc
Correspondence
Peripheral cue
RT(ms)
500
475
450
425
(3.2)
(2.4)
(2.6)
(2.6)
Compatible
Incompatible
Corr
Nonc
Correspondence

Earlier in this paper we described three views concerning the effect of a peripheral precue on response tendencies elicited by a target. The view that is based on the ideas of Nicoletti and Umiltà (1989) predicted no response tendencies elicited by the side of the target if attention is focused on the target position for both the compatible and the incompatible mapping (Hypothesis 1). The second view assumed that summation of activation of the tendencies resulting from the precue and the target takes place (Hypothesis 2). The third view, which is related to the ideas of Tipper et al. (1991), suggested that the precue triggers inhibition of its initial response tendencies which could, if strong enough, lead to a reversal of response tendencies to targets in the baseline condition (Hypothesis 3).

Overall analyses suggested that a reversal of the effects in the peripheral precue condition took place compared to the baseline condition, which confirms Hypothesis 3. For the compatible condition, we found a reversal of the correspondence effect (from +13 to −8 ms). However, no reversal was found for the incompatible mapping.

In our second experiment we tested whether time between the cue and the target (SOA) is a critical variable for correspondence effects for compatible and incompatible S-R mappings. In addition, we decided to use arrows instead of lambdas because these stimuli probably have stronger compatibility effects, and may show a negative correspondence effect for the incompatible mapping.

3. Experiment 2

A compatible and an incompatible mapping were investigated in four conditions: a baseline condition without precues, and three peripheral precue conditions with an SOA of respectively 100, 200 and 500 ms.

3.1. Method

3.1.1. Subjects

Sixteen subjects participated in this experiment and received 25 Dutch guilders (about US$17) for their participation. All subjects (4 male, 12 female, mean age 21.3, all right-handed) had normal or corrected-to-normal vision.

3.1.2. Task and stimuli

In a trial subjects focused on a continuously present black fixation square ($0.53° \times 0.38°$) being in the center of a screen on a white background. As targets black arrows ($0.84° \times 0.61°$) were used pointing to the left or the right. Targets appeared at respectively 4.3° to the left or right side of the fixation square. In the compatible mapping

Fig. 2. Reaction times (RTs) and proportion errors (PEs) (in parentheses) for the compatible and incompatible S-R mapping as a function of correspondence between stimulus position and response side (Corr = correspondence, Nonc = noncorrespondence) for the baseline condition (upper panel), the warning cue condition (middle panel), and the peripheral cue condition (lower panel) in Experiment 1.

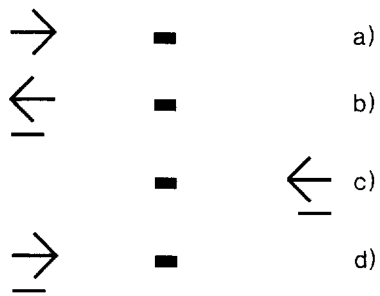


Fig. 3. Arrows were presented to the left and right pointing to the left or the right, without a preceding precue (a), and with a preceding peripheral cue (b–d) with SOAs of 100, 200 and 500 ms.

conditions, subjects were instructed to respond with a left button press to a left-pointing arrow, and with a right button press to a right-pointing arrow. This instruction was reversed in the incompatible mapping conditions. Equal emphasis was laid on speed and accuracy. Each target was presented for 1000 ms and trials were separated by an interval that varied between 2000 and 2500 ms. In three of the four conditions a peripheral precue ($0.69° \times 0.23°$) was presented for 100 ms, 0.5° underneath the position of the target. The onset of the precue was either 100, 200 or 500 ms before the onset of the target. Targets and precues are shown in Fig. 3.

3.1.3. Apparatus

The apparatus was the same as in Experiment 1.

3.1.4. Design and procedure

The within-subjects design with repeated measures had three independent variables: compatibility (an arrow pointing to the same or to the opposite side of the required response), SOA (no precue, or a peripheral precue with an SOA of respectively 100, 200 and 500 ms), and correspondence. The experiment was divided in a compatible and an incompatible session, each consisting of three SOA blocks plus one baseline block. Each block contained 100 trials. Correspondence was varied randomly within blocks. A Latin square design was used for the order of the blocks within a session. The order of compatible and incompatible sessions was counterbalanced. Each subject performed the experiment in about two and a half hours. Calibration of VEOG and HEOG was similar to Experiment 1. The first block was preceded by 300 practice trials. Each block was preceded by instructions regarding the mapping and the kind of precue. The dependent variables, RT and PEs, were handled as in Experiment 1.

3.2. Results

MANOVAs and *t*-tests were performed on RTs and PEs (proportion errors). Fig. 4 shows mean RTs and PEs for each SOA block.

3.2.1. Overall analyses

A main effect of SOA was found, $F(3,13) = 87.5$, $p < 0.001$. Contrast analyses showed an almost significant increase in RT between the baseline and the precue blocks with an SOA of 100 ms (from 489 to 504 ms), $t(15) = -2.10$, $p = 0.053$ (this might be due to timing problems with the computer that controls presentation of the stimuli). RT decreased when SOA increased from 100 to 200 ms (from 504 to 446 ms), $t(15) = 16.4$, $p = 0.001$. A further increase in SOA, from 200 to 500 ms, showed a significant increase in RT (from 446 to 461 ms), $t(15) = -2.2$, $p = 0.043$. Reactions for compatible mappings were faster than for incompatible mappings (461 versus 488 ms), $F(1,15) = 14.4$, $p = 0.002$. A trend towards a significant interaction was found between SOA and S-R compatibility, $F(3,13) = 3.14$, $p = 0.062$. The compatibility effects for the baseline condition, and the precue blocks with an SOA of 100, 200, and 500 ms, were respectively 29, 13.5, 30.5, and 33.5 ms. No main correspondence effect was found, $F(1,15) = 0.76$, but a significant interaction was found between correspondence and SOA, $F(3,13) = 3.56$, $p = 0.045$. Furthermore, a significant interaction was found

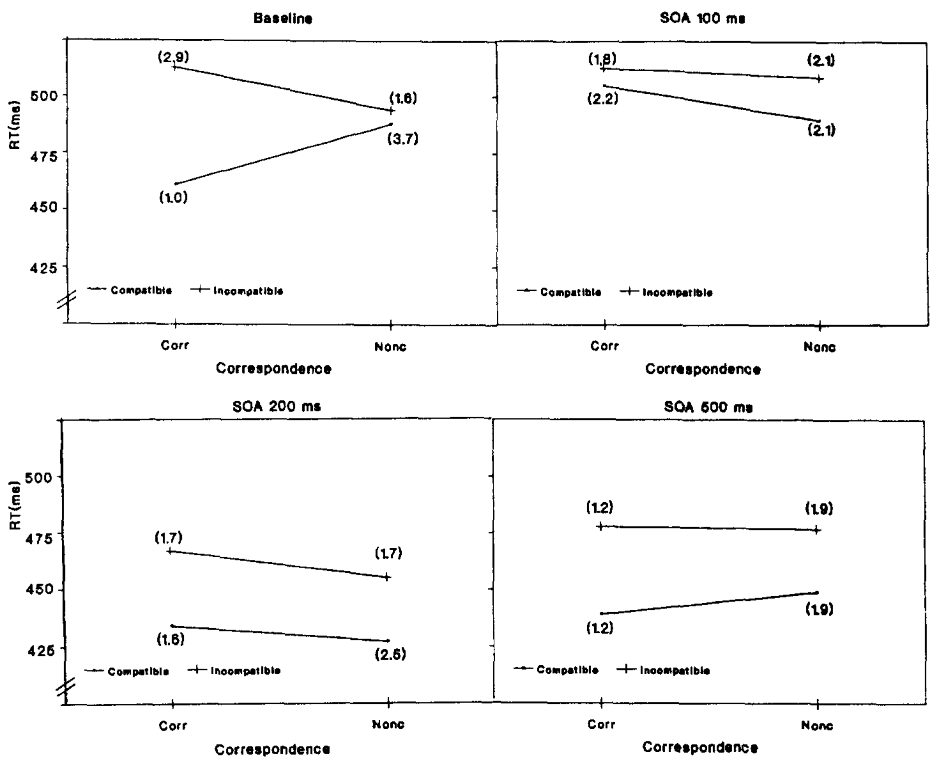


Fig. 4. Reaction times (RTs) and proportion errors (PEs) (in parentheses) for compatible and incompatible S-R mapping as a function of correspondence between stimulus position and response side (Corr = correspondence, Nonc = noncorrespondence) for the baseline condition (upper left panel), and the peripheral cue conditions with SOAs of 100 ms (upper right panel), 200 ms (lower left panel), and 500 ms (lower right panel) in Experiment 2.

between correspondence and S-R compatibility, $F(1,15) = 6.88$, $p = 0.019$. The second-order interaction between SOA, S-R compatibility, and correspondence was highly significant, $F(3,13) = 6.13$, $p = 0.008$. Contrast analyses revealed a significant difference between the baseline blocks and the precue blocks; the no-precue condition compared as follows to the respective precue blocks: SOA of 100 ms, $t(15) = -4.44$, $p < 0.001$; SOA of 200 ms; $t(15) = -3.43$, $p = 0.004$; and SOA of 500 ms, $t(15) = -2.66$, $p = 0.018$. A small difference was found between the precue block with an SOA of 100 and the precue block with an SOA of 500 ms, $t(15) = 2.06$, $p = 0.057$. Inspection of Fig. 4 suggests that the underadditive interaction in the baseline blocks turned into an overadditive interaction in the precue blocks with an SOA of 100 ms. Furthermore, the overadditive interaction of the precue condition with an SOA of 100 ms turned into an additive relation in the precue condition with an SOA of 200 ms. MANOVAs performed on PEs showed no significant effects.

3.2.2. Separate cue blocks

In the baseline condition reactions were faster for compatible than for incompatible S-R mappings (475 versus 504 ms), $F(1,15) = 8.49$, $p < 0.011$. An interaction was found between correspondence and S-R compatibility, $F(1,15) = 14.33$, $p = 0.002$. In the compatible mapping, a positive correspondence effect was found (+17 ms), $t(15) = -3.63$, $p = 0.002$, whereas in the incompatible mapping a negative correspondence effect was found (−19 ms), $t(15) = 2.06$, $p = 0.057$.

In the precue blocks with an SOA of 100 ms reactions for compatible S-R mappings were faster than for incompatible S-R mappings (498 versus 511 ms), $F(1,15) = 6.18$, $p = 0.025$. A negative correspondence effect was found (−9 ms), $F(1,15) = 14.9$, $p = 0.002$. Separate analyses only showed a significant difference for the compatible S-R mapping (−15 ms), $t(15) = 3.32$, $p = 0.005$.

In the precue blocks with an SOA of 200 ms reactions were faster for compatible than for incompatible S-R mappings (431 versus 461 ms), $F(1,15) = 9.31$, $p = 0.008$. In addition, a trend towards a negative correspondence effect was found (451 versus 441 ms), $F(1,15) = 3.42$, $p = 0.084$. However, neither the compatible nor the incompatible mapping showed a significant correspondence effect, $t = 1.21$, and $t = 1.74$.

A further increase of SOA to 500 ms showed a main effect of S-R compatibility (444 versus 478 ms), $F(1,15) = 19.99$, $p < 0.001$. The compatible mapping showed a trend towards a correspondence effect (+10 ms), $t(15) = -1.86$, $p = 0.083$.

3.3. Discussion

The precue-target interval (SOA) of 200 ms showed faster reactions compared to the baseline, and the precue blocks with an SOA of 100 and 500 ms. Hence, the combined alerting and orienting effect was maximal with an SOA of 200 ms.

In the no-cue, or baseline, condition a clear compatibility effect was found, a positive correspondence effect (+17 ms) was found for the compatible mapping and a trend towards a negative correspondence effect (−19 ms) was found for the incompatible mapping. In the precue condition with an SOA of 100 ms a negative correspondence effect (−15 ms) was found for the compatible S-R mapping and no significant correspondence effect (−4) was found for the incompatible mapping. In the precue condition with an SOA of 200 ms, the negative correspondence effect for the compatible mapping decreased from −15 to −7 ms, whereas the null effect of −2 ms for the incompatible mapping changed into −12 ms. In the precue condition with an SOA of 500 ms, an almost significant positive correspondence effect (+10 ms) was found for the compatible mapping and no correspondence effect was found for the incompatible mapping. These findings suggest that presentation of a cue changes the original correspondence effect for compatible and incompatible mappings with small SOAs. This effect disappears if SOA increases, showing a return to the data pattern that was found in the baseline condition.

Until now, we investigated only spatial variants of S-R compatibility. It may be argued that our effects appear only in the case of spatial compatibility. Therefore, we performed a final experiment according to the Hedge and Marsh paradigm that concerns compatibility between the color of presented targets and response buttons. Labelling of responses were varied randomly on a trial by trial basis to avoid interpretations in terms of confounding of color of response button and the position of the button.

4. Experiment 3

In this experiment red and blue squares were used as targets appearing to either the left or right side of a fixation square. Red and blue square response labels indicated the appropriate response button. Color labeling of a left and right response button varied randomly per trial. For a compatible and an incompatible mapping, a baseline condition and three peripheral precue conditions, with an SOA of 100, 200 and 500 ms respectively were run.

4.1. Method

4.1.1. Subjects

Sixteen subjects participated in this experiment and received 50 Dutch guilders (about US$34) for their participation. All subjects (5 male and 11 female subjects, mean age 25.9, 1 left-handed) had normal or corrected to normal vision.

4.1.2. Task and stimuli

In a trial subjects focused on a continuously present black fixation square ($0.53° \times 0.31°$) that was presented 3.1° above the center of a white screen. Red and blue response labels ($0.92° \times 0.92°$) were presented until the offset of the target with their center 6.4° below the fixation square and 1.3° to the left or right side of the vertical midline. Labeling of response keys varied randomly per trial. In the no-precue conditions, the target was presented 1400 ms after presenting the response labels. The center of the target, either a red or blue square ($0.92° \times 0.92°$), appeared 1.3° to the left or right side of the fixation square for a duration of 2000 ms. In the precue conditions, a black peripheral precue ($0.92° \times 0.15°$) was presented (1400 ms after presenting the response labels) 0.61° below the center of a subsequent presented target for a duration of 100 ms.

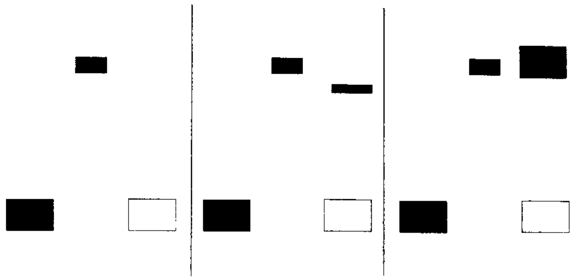


Fig. 5. A trial started with presenting two response labels indicating the response side for a red (here filled: left) or blue (here unfilled: right) target (see left panel). A target (red or blue square) was presented to the left or right side of a fixation square (right panel), requiring either a button press to the side labeled with the same color (compatible; i.e. here the left key) or a press to the side labeled with the other color (incompatible; i.e. here the right key). In three conditions, the precise position of the target was indicated by a peripheral precue (middle panel) that preceded the target with either 100, 200, and 500 ms.

After an SOA of 100, 200, or 500 ms, the target was presented for 2000 ms. The interval between the offset of the target and response labels, and the onset of the new response labels amounted to 2000 ms. In the compatible mapping, a target required a key press with the key labeled with the color of the target, whereas in the incompatible mapping a target required a key press with the other key. Subjects were instructed to react as fast and accurate as possible and to avoid premature reactions. In addition, they were requested to prevent eye movements before eliciting a response. The targets, response labels, and precues are shown in Fig. 5.

4.1.3. Apparatus

The apparatus was the same as in Experiment 1, but recording was performed in the continuous mode instead of the single trial mode to overcome possible timing problems. In addition, EEG was registered that is not dealt with in our results section.

4.1.4. Design and procedure

The within-subjects design was identical to the second experiment. The experiment, consisting of eight experimental blocks with each 160 trials, was performed in about four hours. The first block of the compatible and incompatible session was preceded by 100 practice trials.

4.2. Results

MANOVAs and *t*-tests were performed on RTs. The results are discussed in two main sections. Fig. 6 shows mean RTs and PEs for each SOA block.

4.2.1. Overall analyses

A main effect of SOA was found, $F(3,13) = 20.8$, $p < 0.001$. Contrast analyses showed a decrease in RT between the baseline and the blocks with an SOA of 100 ms (from 499 to 441 ms), $t(15) = 7.55$, $p < 0.001$. RT decreased when SOA increased from

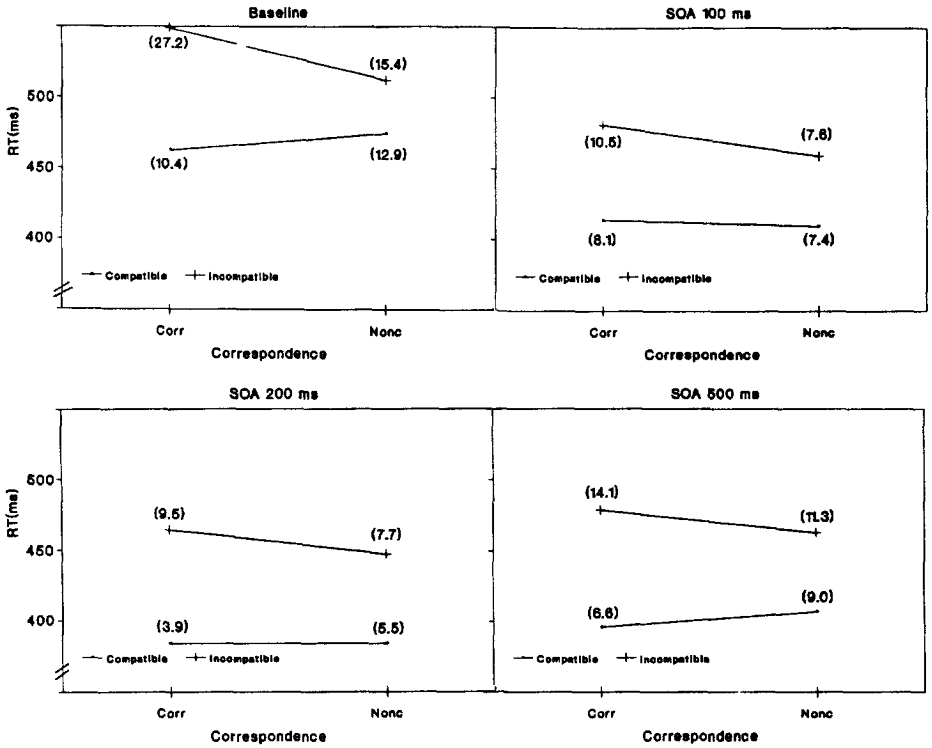


Fig. 6. Reaction times (RTs) and proportion errors (PEs) (in parentheses) for compatible and incompatible S-R mappings as a function of correspondence between stimulus position and response side (Corr = correspondence, Nonc = noncorrespondence) for the baseline condition (upper left panel), and the peripheral cue conditions with SOAs of 100 ms (upper right panel), 200 ms (lower left panel), and 500 ms (lower right panel) in Experiment 3.

100 to 200 ms (from 441 to 420 ms), $t(15) = 3.4$, $p < 0.005$. A further increase in SOA, from 200 to 500 ms, showed a significant increase in RT (from 420 to 436 ms), $t(15) = -2.6$, $p = 0.019$. Reactions for compatible mappings were faster than for incompatible mappings (416 versus 482 ms), $F(1,15) = 25.3$, $p < 0.001$.

A significant interaction was found between correspondence and S-R compatibility, $F(1,15) = 9.89$, $p < 0.007$. A MANOVA performed on proportion errors (PEs) showed a significant effect of SOA, $F(3,13) = 4.1$, $p < 0.03$. Contrast analyses showed a significant decrease in PEs between the baseline (16.4%) and the SOA 100 condition (8.4%), $t(15) = 3.6$, $p = 0.003$. A further increase of SOA to 200 ms (6.7%) showed no differences. PES increased in the SOA 500 condition (10.3%) compared to the SOA 200 condition, $t(15) = -2.21$, $p = 0.043$. PEs were higher for the incompatible S-R mapping (12.9%) than for the compatible condition (8.0%), $F(1,15) = 7.9$, $p = 0.013$, and PEs were higher for correspondence trials (11.3%) than for noncorrespondence trials (9.6%). A significant interaction was found between SOA and compatibility, $F(3,13) = 9.39$, $p = 0.001$. Contrast analyses showed that the compatibility effect was much larger in the baseline condition than in the other SOA conditions; SOA 100, $t(15) = -5.5$, $p < 0.001$; SOA 200, $t(15) = -2.48$, $p = 0.026$; SOA 500, $t(15) = -2.0$, $p = 0.063$. In addition, the interaction between correspondence and compatibility was highly significant, $F(1,15) = 10.0$, $p = 0.006$. Most important, the second-order interaction between correspondence, compatibility, and SOA was significant, $F(3,13) = 5.6$, $p = 0.011$. Contrast analyses showed significant differences between the baseline block and: the SOA 100 block, $t(15) = -4.3$, $p < 0.001$; the SOA 200 block, $t(15) = -3.2$, $p < 0.006$; and the SOA 500 block, $t(15) = -2.4$, $p = 0.027$.

4.2.2. Separate precue blocks

In the baseline condition RTs were faster for compatible than for incompatible S-R mappings (468 versus 531 ms), $F(1,15) = 16.0$, $p < 0.001$. A significant interaction was found between correspondence and S-R compatibility, $F(1,15) = 11.5$, $p = 0.004$. Results showed no significant correspondence effect (+12 ms) for the compatible mapping, $t(15) = -1.3$. A negative correspondence effect (−37 ms) was found for the incompatible mapping, $t(15) = 3.0$, $p = 0.008$. Analyses of PEs also showed a significant interaction between compatibility and correspondence, $F(1,15) = 14.2$, $p = 0.002$. PEs for the incompatible mapping was higher for correspondence trials than for noncorrespondence trials, $t(15) = 3.55$, $p = 0.003$.

In the cue condition with an SOA of 100 ms we observed a significant effect of compatibility, $F(1,15) = 19.1$, $p = 0.001$. The incompatible mapping showed a trend to a negative correspondence effect (−22 ms), $t(15) = 1.84$, $p = 0.085$. No effects were found on PEs.

In the cue condition with an SOA of 200 ms, we found a significant effect of compatibility, $F(1,15) = 32.1$, $p < 0.001$, and a trend to an interaction between correspondence and compatibility, $F(1,15) = 3.26$, $p = 0.091$. Separate analyses for the compatible and incompatible mappings showed a trend to a negative correspondence effect (−17 ms) for the incompatible mapping, $t(15) = 1.95$, $p = 0.071$. Analyses of PEs showed a significant effect of compatibility, $F(1,15) = 6.23$, $p = 0.025$.

In the cue condition with an SOA of 500 ms, we found a significant effect of compatibility, $F(1,15) = 19.65$, $p < 0.001$, and a significant interaction between compatibility and correspondence, $F(1,15) = 5.84$, $p = 0.029$. Contrast analyses revealed a nonsignificant correspondence effect for the compatible mapping (+11 ms), $t(15) = -1.39$, and a trend to a negative correspondence effect for the incompatible mapping (−16 ms), $t(15) = 1.84$, $p = 0.086$. Analyses on PEs showed a significant effect of compatibility, $F(1,15) = 5.03$, $p = 0.041$, and a significant interaction between correspondence and compatibility, $F(1,15) = 6.24$, $p = 0.025$. Contrast analyses for the compatible mapping showed a positive correspondence effect, i.e. more errors for noncorrespondence than for correspondence trials, $t(15) = -2.56$, $p = 0.022$.

4.3. Discussion

The combined orienting and alerting effect showed optimal performance in terms of speed and accuracy with an SOA of 200 ms. In addition, performance was worse in the incompatible mapping compared to the compatible mapping, which was reflected in delayed responses and an increase in proportion errors. In the no-cue, or baseline, condition we observed a negative correspondence effect for the incompatible mapping (−37 ms) and a nonsignificant positive correspondence effect (+12 ms) for the compatible mapping. A similar pattern was observed for proportion errors. In the cue condition with an SOA of 100 ms a trend to a negative correspondence effect was found for the incompatible mapping that amounted to −22 ms. In the cue condition with an SOA of 200 ms we found a trend to a negative correspondence effect for the incompatible mapping. In the condition with an SOA of 500 ms we found a significant interaction between compatibility and correspondence. Correspondence effects for the compatible and the incompatible mapping amounted to respectively +11 and −16 ms.

Again, these results suggest that correspondence effects elicited by targets change due to prior presentation of a cue. In addition, the effect seems to decay if SOA increases.

5. General discussion

Three experiments were performed to investigate whether peripheral precues not only induce an alerting and orienting effect but also influence response tendencies, and whether these influences change when time between presentation of a cue and a target increases. Compatible and incompatible mappings were examined to overcome problems with interpreting results as favoring either an inhibitory account or as favoring an extinction of response tendencies. The results suggest that response tendencies for compatible and incompatible S-R mappings change due to prior presentation of a peripheral precue. In addition, on the basis of results of the second and third experiment we suggest that these influences disappear if cue-target interval is relatively long. Three different views were examined with respect to the influence of peripheral precues on response tendencies to targets. The view of Nicoletti and Umiltà (1989) suggests that for a subject spatial codes, or coordinates of an object in visual space, are referenced to the locus of attention. That is, the spatial code of an object is dependent on its position relatively to the focus of attention. Responses will be faster when the spatial code of a target corresponds with a required response code than in the case of noncorrespondence between the spatial code of the target and the required response code. If an object is presented at the position of the focus of attention, then the spatial code of that object will be neutral. Hence, no correspondence effects will be predicted for targets presented at the position of attentional focus. This view was clearly disconfirmed in all three experiments. One way to salvage this spatial coding hypothesis is to assume that the subjects' attentional focus was not exactly at the precued position. For instance, attention could have been focused at a greater eccentricity than the intended location or nearer to the fixation square, a situation we call 'attentional overshoot' and 'attentional undershoot'. A systematic higher amount of 'attentional overshoot' might account for a reversal of correspondence effects for compatible S-R mappings. However, in our studies precues were always presented beneath the relevant position, so it seems unlikely that such an attentional tendency emerges. Furthermore, the effects we found were relatively strong, which suggests, in the case of overshoot, that attention was focused rather far from the precued position. The latter seems very implausible. Somewhat related to the conception of Umiltà and Nicoletti is the conception of Stoffer (1991). He suggested that correspondence effects arise because the spatial code that is needed for refocusing attention, at the same time unintentionally facilitates spatially corresponding responses. As a consequence, stimuli presented exactly at the focus of attention should produce a neutral spatial code, leading to no correspondence effects. However, this is not what we found.

The two other views we have mentioned assume that there is either a summation of tendencies induced by a peripheral cue and a next presented target, or, in line with Tipper et al. (1991), an inhibition of the tendency induced by the peripheral cue that counteracts the tendency induced by the target. Inhibition of the initial tendency seems reasonable since subjects should not react to the peripheral precue. However, the inhibitory view was only partially confirmed (i.e. for the compatible S-R mapping). The results of the second and third experiment suggest that the tendency induced by the peripheral cue gradually decays over time. The latter finding is in line with results presented by Hommel (1993), who suggested that a decrease in correspondence effects occurs by each experimental manipulation that markedly increases the temporal distance between presentation of a relevant stimulus and the initiation of an overt response.

However, some rather confusing results were found for the incompatible S-R mappings. De Jong et al. (1994), suggested that correspondence effects for compatible and incompatible mappings consist of a conditional component and an unconditional component. The unconditional component reflects the effect resulting from correspondence between spatial stimulus codes and response codes, whereas the conditional component reflects an additional recoding effect that is either positive for compatible S-R mappings or negative for incompatible S-R mappings. Three different views with respect to the effect of peripheral cues on response tendencies can be proposed. Peripheral cues might influence either the unconditional component, or the conditional component, or both the conditional and the unconditional component. For the compatible mapping, both the conditional and the unconditional component are positive. Hence, a reversal of correspondence effects with peripheral cues can be attributed to either a reversal of the unconditional component, the conditional component, or both. However, for the incompatible mapping, a reversal of the unconditional component would result in a larger negative correspondence effect. None of the presented experiments showed such an effect. Therefore, it seems more logical to assume that the conditional component is affected by prior presentation of a cue. Hence, if the model of De Jong is correct, then it seems reasonable to assume that peripheral cues mainly affect the conditional component. A small deviation of the model of De Jong is that response tendencies in the compatible mapping without precues are only a result of an unconditional component, whereas tendencies in the incompatible mapping are a result of both an unconditional and a conditional component. In that case, it may be argued that presentation of peripheral cues might automatically induce a reversal operation that operates on spatial stimulus codes. Because this operation is present in incompatible S-R mappings and not in compatible mappings the effect results in no changes for the incompatible mapping, and drastic changes for response tendencies for compatible mappings if target stimuli are preceded by peripheral cues.

5.1. Conclusions

Peripheral cues induce three different effects. First, subjects become alerted; second, subjects automatically orient towards the cued position; and third, peripheral cues influence response tendencies to subsequent presented target stimuli if the interval between cue and target is relatively small. Compatible S-R mappings were strongly affected, showing a reversal or nullification of positive correspondence effects when targets were preceded by peripheral cues. Incompatible S-R mappings showed almost similar results in cued and uncued conditions. The latter effect may be attributed to an insertion of a specific recoding operation that was already present in the incompatible S-R mapping but was not present in the compatible S-R mapping.

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