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ORIGINAL ARTICLE

Wilfried Kunde · Peter Wühr

Actions blind to conceptually overlapping stimuli

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Abstract Participants are worse at identifying spatial symbols (arrowheads) while performing spatially compatible manual key presses. The present experiments investigated the generality of this "blindness effect" to response-compatible stimuli. In Experiment 1 a left key press deteriorated the identification of left-pointing arrows, and a right key press deteriorated the perception of right-pointing arrows, independent of the hands used to press the key. Thus the blindness effect is based on codes of the distal response location rather than on the body-intrinsic anatomical connection of the hands. Experiment 2 extended the blindness effect to verbal responses and written position words (left, right, up, down). Vocalizing a position word blinded to directly compatible position words (e.g., left-left), but not to orthogonally compatible position words (e.g., left-down). This result suggests that the use of identical stimulus-response codes, and not the use of saliency-matching but distinct codes, suffices to produce blindness effects. Finally, Experiment 3 extended the blindness phenomenon beyond the spatial domain by demonstrating blindness between saying color words and perceiving color patches. Altogether, the experiments revealed action-induced blindness to be a phenomenon of broad empirical validity occurring whenever action and perception afford simultaneous access to the same conceptual codes.

Introduction

Action affects perception. The blindness to response-compatible stimuli, or "blindness effect," nicely demonstrates this fact (cf. Müsseler and Hommel, 1997a, 1997b). In a typical blindness experiment participants face a dual-task situation. Task 1 affords the execution of a left or right key press. Task 2 requires the identification of a masked left- or right-pointing arrow presented in close temporal proximity to the spatial key press. The arrows are thus either spatially compatible or incompatible with the lateral key press, and they have to be encoded during the planning or execution of the manual action. As a result the identification of compatible stimuli (e.g., left key press-left arrow) is worse than the identification of incompatible stimuli (e.g. left key press-right arrow).

Wühr and Müsseler (2001, cf. also Müsseler and Wühr, 2002) explain the blindness effect as follows. Firstly, perception and action planning are assumed to use shared codes, which represent the features of perceived stimuli or actions to be produced (common coding approach, cf. Hommel, Müsseler, Aschersleben, & Prinz, 2001). Secondly, it is assumed that a feature needed for action planning is temporarily less accessible for the concurrent coding of a feature-overlapping stimulus. Thus, when an actor is about to perform a left key press, she will integrate a left code into the representation of the planned action, making this feature less available for the concurrent coding of a left stimulus.

There is little doubt that the original blindness effect is a robust empirical phenomenon, replicable under a variety of conditions. For example, it is independent of the way the key press is cued (i.e., whether a word, a color, or a tone is used to signal the key press; Müsseler and Hommel, 1997a; Müsseler, Wühr, & Prinz, 2000). Also, it is not determined by post-perceptual judgment biases: Only measures of perceptual sensitivity (e.g., d') but not measures of response tendencies (e.g., c) are affected by response-target compatibility, and when no stimulus is presented (in catch trials) there is no bias towards (or contrary to) response-compatible judgments (Müsseler & Hommel, 1997a; Müsseler, Steininger, & Wühr, 2001) Finally, blindness concerns the identification as well as the detection of compatible stimuli (Müsseler and Hommel, 1997b).

W. Kunde (✉)
Martin-Luther Universität Halle-Wittenberg, Germany
E-mail: w.kunde@psych.uni-halle.de

P. Wühr
Friedrich-Alexander Universität Erlangen, Germany

Remarkably, however, all published reports on the blindness effect relied on just one particular stimulus-response (S-R) ensemble, namely, left or right arrowheads and left or right key presses. Given the ubiquitous use of the features left and right in spatial perception and action this was certainly a reasonable starting point. However, the reliance on just one set of stimuli and responses creates an uncomfortable gap between the proposed far-reaching theoretical implications of the effect and its rather narrow empirical reality. After all, in the absence of empirical evidence we cannot rule out that the blindness effect is tied to something inherent in this particular S-R set.

Therefore, the present study explored the generality of the blindness effect for several instances that have not yet been tested. Experiment 1, beyond replicating the standard blindness effect with key presses and arrowheads, explored the distality of the response features left and right. Do these features represent anatomical connections of the hands or response locations in extrapersonal space? To clarify this question, participants performed an otherwise standard blindness experiment with arms crossed. Experiment 2 aimed at extending the blindness effect in three ways. Firstly, it used the spatial features up and down in addition to the spatial features left and right. Secondly, it used verbal responses and word stimuli instead of manual responses and arrowheads. Thirdly, it tested if response-induced blindness concerns directly compatible stimuli only (e.g., left-left) or extends to orthogonally response-compatible stimuli as well (e.g., left-down, Weeks and Proctor, 1990). Finally, Experiment 3 extended the blindness effect beyond the spatial domain by using color as the overlapping perception-action feature. Here participants were to vocalize a color word, while perceiving a masked color patch.

Observing blindness effects under this variety of conditions would not only serve the mere methodological need to verify the robustness of the basic phenomenon, but it would also help to specify the nature of the common perception-action codes it is assumed to be based on. Finding actions consistently blind to feature-overlapping stimuli, despite the large variability of stimulus and response types we employed, would strongly suggest that these features abstract from peripheral input-output modes. In other words, this would suggest that response-induced blindness is based on the meaning extracted from stimuli and responses rather than on something physically inherent in these events per se. The nature of these codes and its implication for the future investigation of the blindness effect will be considered in more detail in the General discussion section.

Experiment 1

Experiment 1 explored whether the original blindness effect with manual key presses is based on intrinsic (anatomical) or extrinsic (extra-personal) response features. A study by Stevanovski, Oriet, and Jolicoeur (2002) has recently addressed a similar question on the stimulus side. These authors instructed participants in an otherwise standard blindness experiment to interpret the arrows as "headlights", and to decide whether the headlight pointed left or right. Thus, the stimulus, e.g., "<", required a right judgment under headlight instructions rather than a left judgment under standard arrow instructions. With this modification the blindness effect reversed, so that performance was worse when response side was compatible with headlight direction. Accordingly, Stevanovski et al. (2002) concluded that the interpretation of the visual stimulus, rather than some features inherent in arrowheads, determines the blindness effect.

We investigated the distality of feature codes on the response side by instructing participants to operate left and right response keys with their arms crossed. With normal arm posture the body-intrinsic anatomical status of the hands (left hand vs. right hand) is confounded with the extrapersonal position of the response. Thus, it is not possible to decide whether the former or the latter factor causes the blindness effect. With crossed arms, however, anatomical status and extrapersonal position are set in opposition. This manipulation has been used in classic research on spatial stimulus-response compatibility, where participants perform better with compatible S-R mappings than with incompatible S-R mappings independent of whether arms are held in the normal position or crossed (e.g., Nicoletti, Umiltà, & Ladavas, 1984). Therefore, it has been concluded that the (relative) position of the response in the external world, and not the anatomical status of the effectors, is the major determinant of traditional S-R compatibility effects.

Transferring this rationale to the blindness effect for response-compatible stimuli leads to the following predictions. If the blindness effect is due to anatomical hand status, the effect should be reversed with crossed arms. If, however, the blindness effect is due to extrapersonal response position, the effect should be independent of arm posture. If both factors contribute to the blindness effect, it should be significantly smaller with crossed arms than with parallel arms.

Method

Participants

Thirty-two undergraduates from the Martin-Luther University of Halle-Wittenberg, of whom 21 were female, and who had a mean age of 21 years, participated in fulfillment of a course requirement. All participants in this and in the following experiments were uninformed about the purpose of the experiment, and all reported to have normal or corrected-to-normal vision. Half of the participants performed the experiment with hands in the parallel position, whereas the other half performed the experiment with hands crossed.

Apparatus and stimuli

An IBM-compatible PC controlled stimulus presentation and response sampling. Stimuli were shown on a 17” VGA display with a refresh rate of 70 Hz. The experiments were run in 640 × 350 pixel graphics mode. Viewing distance was approximately 60 cm. Manual responses were made by pressing micro-switches connected to the parallel port. The switches were located in front of the participants in comfortable separation (approximately 50 cm). All visual stimuli were presented in white on a dark gray background. Response cues were the words LINKS (left) and RECHTS (right), presented in uppercase letters. Response cues were followed by a rectangular frame (100 × 35 mm). The go-signal was a simultaneous increase in thickness (from 1 to 3 pixels) and a change in color (from white to green) of the frame. Target stimuli were left-pointing or right-pointing arrowheads (3 mm wide and 5 mm high). The mask was a random dot pattern (20 pixels wide, 15 pixels high), in which each pixel was randomly set as black or white.

Procedure

The participants received written instructions. It was emphasized, firstly, that every response-arrowhead combination was equally probable and, secondly, that the manual response should be prepared as efficiently as possible, and performed as quickly as possible after the go signal. An experimental trial started with the 1,000 ms presentation of a response cue, which indicated the key to be pressed (cf. Fig. 1). Then a warning frame appeared. One and a half seconds after warning frame onset the frame was replaced by a go signal (750 ms duration), which afforded the execution of the prepared key press. Simultaneously with the go signal, the target stimulus appeared at the screen center for an individually adjusted presentation time (see below). Next, the mask replaced the target. One second after the manual key press, a display containing two arrowheads appeared, asking participants to verbally report the target. This judgment was given at leisure and then recorded by the experimenter. If the program detected an incorrect manual response, or if a correct manual response occurred more than 750 ms after the go signal, a brief visual error feedback was provided. Erroneous trials were not analyzed. The next trial started 2 s after the experimenter had entered the judgment.

The experiment consisted of 16 blocks of 16 trials each (2 responses × 2 targets × 4 repetitions). Thus in each individual trial one of the targets was presented with a chance level of 50%. The initial presentation duration of the arrows was set to 70 ms. If accuracy of target discrimination in a block of 16 trials was above 80%, the presentation duration was decreased (if possible) by 14 ms for the next block. If accuracy of target discrimination in a block was below 60%, the presentation duration was increased by 14 ms for the next block. No feedback regarding accuracy of target discrimination was provided. The first two blocks served as practice for the participants. Participants had a short break after every second block. The whole experiment took approximately half an hour.

Results

Trials with incorrect manual responses (1.9% of the data) and trials with manual response latencies below 50 ms and above 750 ms (1.2% of the data) were excluded. Then the percentages of correct target identifications were computed and submitted to a 2 × 2 analysis of variance (ANOVA), with target-response compatibility (arrow direction and response key position corresponding or noncorresponding) as a within-participants factor, and arm posture (crossed or uncrossed) as a between-participants factor. These mean percentages of correct target identifications are depicted in Fig. 2.

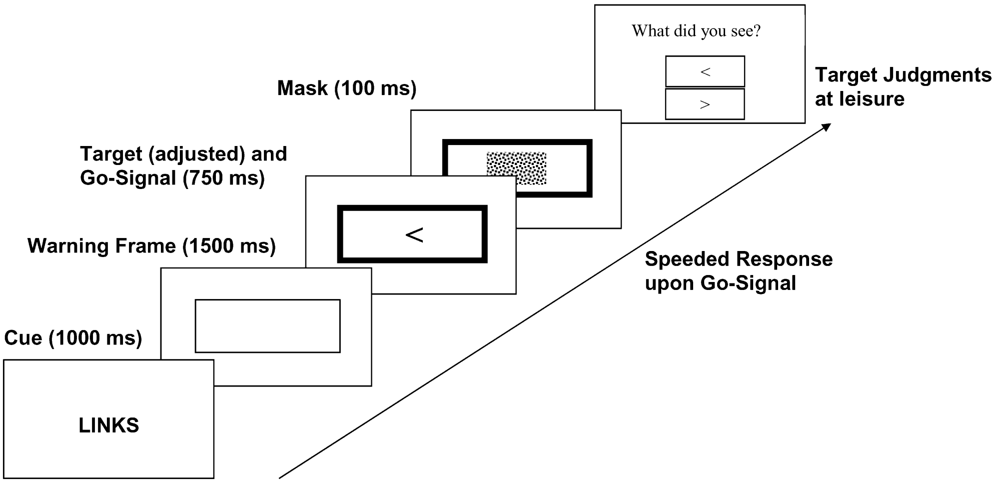

Fig. 1 Example sequence of events in an experimental trial of the present study

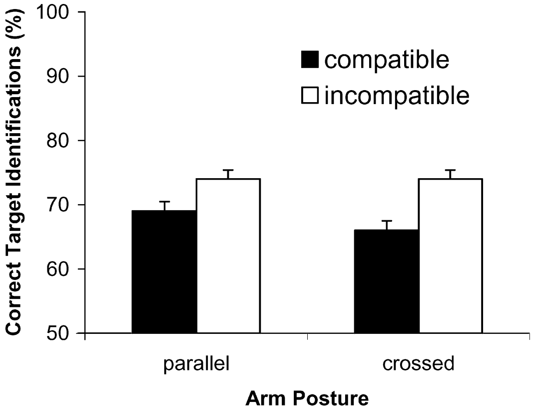

Fig. 2 Experiment 1: Percentages of correct target judgments as a function of response-target compatibility and arm posture. *Error bars* represent standard errors of the means. Chance level in Experiment 1 was 50%

Identification accuracy was lower with compatible (M = 67%) than with incompatible (M = 74%) target-response combinations, $F(1, 30) = 12.44$, $p < .001$, whereas the main effect for arm posture, $F(1, 30) = 2.10$, $p > .15$, and the two-way interaction, $F(1, 30) = 1.45$, $p > .23$, were not significant. The same ANOVA on manual RTs revealed no reliable effects (all *p*s > .20). With parallel arms, RT was 266 ms with target-response compatibility and 264 ms with target-response incompatibility. With crossed arms RT was 260 ms with target-response compatibility and 262 ms with target-response incompatibility.

Discussion

Experiment 1 explored whether the blindness effect is tied to an intrinsic response feature (the anatomical status of the hands), or to an extrinsic response feature (the position of the response in the external world). When participants operated two response keys with crossed arms, we found a blindness effect with respect to the extrapersonal response position, which was similar in size to the effect with parallel arms. Therefore, we conclude that the extrapersonal response position gives rise to the blindness effect, and not the intrinsic anatomical hand status. This finding is consistent with the notion that the blindness effect is not tied to features inherent in stimulus and response events per se, but is based on the interpretation of these events (Stevanovski et al., 2002).

Experiment 2

Experiment 2 aimed at extending the blindness effect in three ways. Firstly, we wanted to explore whether it goes beyond manual responses and arrow stimuli. To this end, we modified stimulus and response modes. Participants performed vocal instead of manual actions and were presented with words instead of arrows. The common coding approach, which prompted the investigation of the phenomenon, is meant as a general framework for perception-action coupling. Thus, there is no reason to expect a restriction to just one particular S-R combination. Indeed, a study by Hommel and Müsseler (2000, 2003) already found blindness effects beyond manual responses and arrowheads. The basic paradigm was identical to the one used here. Participants were to vocalize either the position word “left” or “right” on presentation of a visual go signal. In close temporal proximity to the go signal (and thus execution of the vocal response) one of the position words LEFT or RIGHT was visually presented, which was to be identified. Words that were compatible to the vocal response (e.g., “left”-LEFT) were less accurately identified than words that were incompatible to the vocal response (e.g., “left”-RIGHT). Replicating this finding would confirm that the blindness effect generalizes to the verbal domain.

Yet, even in the study by Hommel and Müsseler (2000, 2003) the effect has still been investigated with stimuli that refer to positions (or directions) on the horizontal dimension. Therefore our second goal was to test whether the effect extends to spatial features other than “left” and “right”. Participants had to say one of the four words “left,” “right,” “up,” or “down” (in German). While doing this, one of the masked words LEFT, RIGHT, UP, or DOWN (in German) was presented, which was to be identified. The question was whether the response-stimulus combinations “left”-LEFT and “right”-RIGHT produce similar verbal blindness effects to the response-stimulus combinations “up”-UP and “down”-DOWN. This may appear a moderate extension. However, horizontal left-right locations may have a special status in perception-action coupling, as is indicated by the more robust and functionally distinct effects of irrelevant spatial S-R compatibility (Umiltà and Nicoletti, 1990; Vu, Proctor, & Pick, 2000). After all, in the absence of any empirical evidence we cannot know if this special status holds for the blindness effect as well.

The third goal was to test whether or not different types of S-R compatibility produce blindness effects. Half of the S-R combinations in Experiment 2 contained two members from the same spatial dimension. Therefore, these combinations are either directly compatible (e.g., left-left, up-up) or directly incompatible (e.g., left-right, up-down). These conditions are known to produce S-R compatibility effects (e.g., Morin & Grant, 1955) in choice reaction time (CRT) tasks, and to produce blindness effects in dual task situations (e.g., Müsseler and Hommel, 1997a). The source of direct S-R compatibility effects is seen in an overlap of stimulus and response codes (e.g. Kornblum, Hasbroucq, & Osman, 1990; Hommel, 1997). The other half of the S-R combinations consisted of one member from the horizontal dimension and one member from the vertical dimension. Interestingly such combinations do also produce S-R compatibility effects in CRT tasks. The combinations left-down (or down-left) and right-up (or up-right) reveal better performance than the combinations left-up (or up-left) and right-down (or down-right). These effects are called orthogonal S-R compatibility effects (cf. Weeks and Proctor, 1990). Orthogonal S-R compatibility effects are attributed to differences in saliency of the poles of horizontal and vertical dimension respectively. Right is the more salient pole of the horizontal dimension and up is the more salient pole of the vertical dimension. S-R codes from orthogonal dimensions combine more easily when they match regarding saliency (Cho & Proctor, 2003). Thus, whereas direct compatibility effects are attributed to the use of identical stimulus-response codes, orthogonal effects are attributed to the use of distinct but saliency-matching codes. Experiment 2 examined whether action-induced blindness is confined to overlapping spatial codes, or extends to distinct, but saliency-corresponding codes as well.

Method

Participants

Seventeen undergraduates from the University of Würzburg, of whom 14 were female, and who had a mean age of 22 years, participated in fulfillment of course requirements.

Apparatus, stimuli, and procedure

The materials and the experimental setup were similar to Experiment 1. We only note the procedural differences here. The response cues were the English words LEFT, RIGHT, UP, and DOWN, presented in uppercase letters. Participants' task was to translate these terms into German. The manual responses in Experiment 1 were replaced by vocal responses. Participants had to say aloud the German position words upon the presentation of a go signal. A microphone connected to the parallel port of the PC registered the vocal response onset. The experimenter, who remained in the laboratory throughout the experiment, registered the correctness of vocal responses. The target stimulus was one of the German words LINKS (left), RECHTS (right), RAUF (up), and RUNTER (down), presented in lowercase letters (individual characters were 6 mm wide and 10 mm high, on average). Presenting the response cues and the target stimuli in different cases, and in different languages aimed at reducing the perceptual overlap between these stimuli (cf. Altarriba and Soltano, 1996). The mask consisted of eight uppercase letters, each of which was randomly drawn from a set of six letters (K, N, M, V, W, and X) with replacement. Participants entered their judgments of target identity at leisure by clicking with the computer mouse on one of the four possible target words, each framed by a box, on the screen. The experiment consisted of 16 blocks of 16 trials each (4 responses × 4 targets). The initial target presentation duration was set to 42 ms. The presentation duration was increased by 14 ms if identification accuracy in a given block was below 30% and decreased (if possible) when accuracy was above 80%. Note that the chance level in this experiment is 25%.

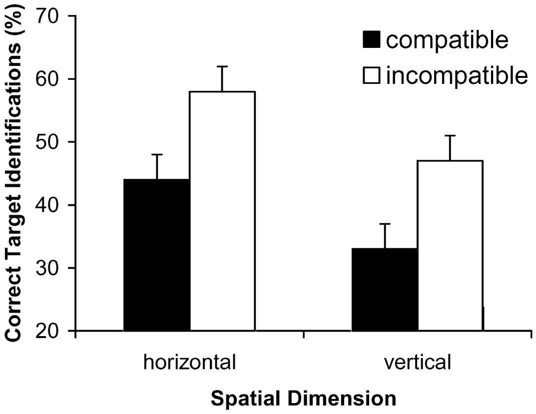

Fig. 3 Experiment 2: Percentages of correct target judgments as a function of response-target compatibility and spatial dimension. *Error bars* represent standard errors of the means. Chance level in Experiment 2 was 25%

Results

The first two blocks were considered practice. We excluded trials in which RT was shorter than 50 ms or longer than 750 ms from the analysis. Moreover, we also excluded trials with erroneous or ambiguous responses. As a result, 12% of the trials were not analyzed. Compatible conditions (418 ms) produced somewhat faster RTs than incompatible conditions (438 ms), but the difference was not significant, $F(1,15) = 2.45$, $p = .14$.

In a first analysis, we checked whether words denoting horizontal positions and words denoting vertical positions produced blindness effects or not. Therefore, only the half of the trials in which both the response and the target referred to the same spatial dimension was considered. The percentages of correct judgments were entered into a 2 × 2 ANOVA, with spatial dimension (horizontal or vertical), and compatibility level (compatible or incompatible), as within-participants factors. The corresponding means are depicted in Fig. 3. Response-target combinations referring to the horizontal dimension produced better performance than those for the vertical dimension, $F(1,16) = 6.70$, $p < .05$. Compatible combinations (M = 39%) produced inferior performance to incompatible combinations (M = 53%), $F(1,16) = 15.5$, $p < .01$. Finally, the interaction was far from significance ($F < 1$).

In a second analysis, we checked whether direct compatibility relationships (e.g., left-left compared with left-right), and orthogonal compatibility relationships (e.g., left-up compared with left-down) produced similar blindness effects or not. In this analysis, all trials were considered. Percentages of correct judgments were entered into a 2 × 2 ANOVA, with compatibility type (direct or orthogonal) and compatibility level (compatible or incompatible) as within-participants factors. The mean percentage of correct target judgments for directly compatible vs. incompatible targets amounted to 39% vs. 52%. The mean percentage for orthogonally compatible vs. incompatible targets amounted to 54% vs. 53% (rounded). The ANOVA revealed that compatible combinations (M = 46%) produced inferior performance to incompatible combinations (M = 53%), $F(1,16) = 13.7$, $p < .01$. Moreover, direct compatibility (M = 47%) revealed somewhat inferior performance to orthogonal compatibility (M = 53%), $F(1,16) = 4.3$, $p = .056$. Both main effects were qualified by a significant two-way interaction, however, $F(1,16) = 11.9$, $p < .01$. The interaction indicates a strong blindness effect with directly compatible relationships (D = 13.7%), and the absence of a blindness effect with orthogonally compatible relationships (D = .8%).

Discussion

Experiment 2 revealed three major results. Firstly, we replicated Hommel and Müsseler's (2000, 2003) finding of a blindness effect in the verbal domain. When participants were engaged in saying the words "left" or "right," they had more difficulties in encoding a compatible word than in encoding an incompatible word. Secondly, the results of Experiment 2 extended those of the Hommel and Müsseler study by demonstrating a blindness effect for verbal responses and stimuli that referred to the vertical dimension. When participants were engaged in saying the words "up" or "down", they also had more difficulties in encoding a compatible word than in encoding an incompatible word. Moreover, words denoting horizontal directions (or positions) and words denoting vertical directions (or positions) produced blindness effects of the same size.

The third result of Experiment 2 was that only direct S-R relationships (e.g., left-left) produced a blindness effect, whereas orthogonal S-R relationships (e.g., left-up) did not. This result accords with the notion that direct compatibility effects and orthogonal compatibility effects arise from different mechanisms. The former effects are attributed to the overlap or non-overlap of identical S-R codes (e.g., Kornblum, et al., 1990; Hommel, 1997), whereas the latter effects are attributed to a saliency match or saliency mismatch of distinct S-R codes (Weeks & Proctor, 1990). Accordingly, the results of Experiment 2 suggest that the use of the same S-R code produces blindness effects whereas the use of saliency-associated but otherwise distinct codes does not.

Experiment 3

Experiment 1 showed that there is nothing per se in a left- or right-hand movement that blinds to spatially compatible stimuli but the interpreted response location. Moreover, Experiment 2 showed that there is nothing particular in key presses or arrows that may cause the blindness effect but that blindness occurs with other stimuli and responses as well. Taken together these observations suggest that blindness could be based on relatively distal feature codes that abstract to a considerable degree from the specific perception-action events that convey these features.

However, these codes may not be abstract enough to extend to any S-R combination. This is suggested by Hommel and Müsseler's (2000, 2003) observation that left-right manual actions did blind to left-right arrows, and "left"-"right" vocal actions did blind to the words LEFT and RIGHT, whereas manual key presses did not blind to position words and vocal actions did not blind to arrows. This led these authors to conclude that the blindness effect "is modality-specific and not mediated e.g., by abstract-conceptual codes" (Hommel and Müsseler, 2000, p.28, translation by W.K.).

To us this conclusion appeared not entirely compelling. Given the plethora of possibilities how a certain set of actions could be combined with a certain set of stimuli the failure to observe blindness effects under these conditions may be an exception rather than the rule. Although it is certainly necessary to clarify why a blindness effect did not occur under these conditions (cf. General discussion section), we made an additional attempt to establish a blindness effect for actions and stimuli that are not perceptually similar at all. To this end, we tested whether saying color words would affect the participants' ability to perceive colors. We find it very difficult to imagine a perceptual relationship between the utterance "red" and a red color patch. At least, these events should not share more perceptual features than the utterance "left" and a left-pointing arrow (Hommel and Müsseler, 2000, 2003). Finding action-induced interference under these conditions would thus suggest that the blindness effect may well occur on a sensory-independent level of representation.

Method

Participants

Fourteen undergraduates from the Martin-Luther University Halle-Wittenberg, of whom 11 were female, and who had a mean age of 23 years, participated in fulfillment of course requirements. None of them had participated in Experiment 1 or 2.

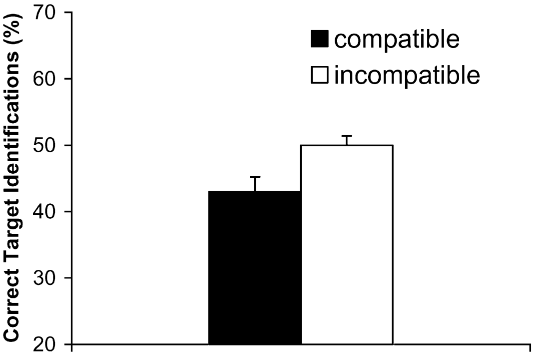

Fig. 4 Experiment 3: Percentages of correct target judgments as a function of response-target compatibility. *Error bars* represent standard errors of the means. Chance level in Experiment 3 was 25%

Apparatus, stimuli, and procedure

The apparatus and procedure were identical to those of Experiment 2, with the following exceptions. The response cue was one of the German color words BLAU (blue), GRÜN (green), ROT (red) or GELB (yellow), presented in uppercase letters. Participants had to say these words aloud as quickly as possible on the occurrence of a go signal. The target stimulus was a row of three asterisks (***, 20 mm wide, 8 mm high all together) that were all colored blue, or green, or red, or yellow (from the standard VGA color palette). The target stimulus was followed by a random dot mask presented for 100 ms. The mask covered an array of 50 × 20 pixels, in which each individual pixel was randomly presented in one of the 16 standard VGA colors of the BGI driver. To avoid confusions between the go signal and the colored mask (cf. Fig. 1), the warning frame was now changed from white to magenta, which was not used as a target color. The initial presentation duration of target stimuli was 56 ms and was adjusted according to a similar procedure in Experiment 2. Again, the chance level was 25%.

Results

Trials in which the vocal response was either incorrect or ambiguous, or with an RT below 50 ms or above 750 ms, were excluded from data analysis. This applied to 4.0% of the data. The accuracy of target identification was lower in compatible conditions than in incompatible conditions (42.7% vs. 50.1%, $t(13) = 2.32, p < .05$). As in the previous experiments, compatibility had no effect on vocal RTs (317 ms vs. 320 ms, $t = .66$; Fig. 4).

Discussion

Experiment 3 established a new blindness effect for color. While engaged in saying a color word, participants were impaired in their ability to perceive a compatibly colored stimulus. Obviously, a spoken word and a visually presented color patch do not share perceptual features. Therefore, this finding challenges the assumption that the blindness effect would only arise when stimulus and response processing operate upon perceptual codes. Instead, the finding of action-induced blindness to colors suggests that the blindness effect arises when stimuli and responses are assigned to the same meaning.

General discussion

The present study addresses an intriguing phenomenon. Motor actions hamper the concurrent perception of feature-overlapping stimuli. This finding is of considerable theoretical interest, as it suggests that action and perception operate on common cognitive codes. Yet little is known about the generality of the effect, because so far it has been reported with only one particular set of actions and stimuli: Participants identify a left or right arrow while performing a left or right key press. It is thus far from clear if action-induced blindness is a sufficiently general phenomenon to justify the far-reaching theoretical conclusion that has been drawn from it. Therefore, the present study sought to test the generality of the blindness phenomenon. Moreover, we also wanted to explore the nature of common codes that perception and action may use.

Experiment 1 revealed that the blindness effect is based on extrapersonal rather than anatomical response features. Experiment 2 showed that the effect is not confined to spatial features from the horizontal dimension, but extends to stimuli and responses from the vertical dimension. Moreover, it is not confined to manual responses and arrows but extends to vocal responses and words. It is necessary, however, that stimuli and responses refer to the same cognitive concept (e.g., left-left), whereas reference to saliency-associated but distinct concepts (e.g., left-down) is insufficient. Experiment 3 showed a blindness effect for the nonspatial feature of color, when actions and stimuli were perceptually distinct.

To summarize, we consistently observed blindness effects when stimuli and responses relied on overlapping codes independent of the peripheral stimuli or responses that access these codes. Traditionally such codes that abstract from peripheral features of stimulus-response events are denoted as conceptual (Proctor and Wang, 1997). We thus conclude that blindness to response-compatible stimuli results from a conceptual level of stimulus and response coding.

The conclusion of the conceptual basis of the blindness phenomenon has been corroborated by other recent studies. As we already noted, Stevanovski et al. (2002) observed that a left key press blinds to the symbol "<" when interpreted as an arrow but to the symbol ">" when interpreted as a headlight. This clearly shows that "the interpretation of the target is critical to the blindness effect and not the physical identity of the target" (p. 73). Additionally, Eder and Klauer (2003) reported an "affective" blindness effect: Pulling a joystick towards the actor blinds to the word "positive" whereas pushing it away from the body blinds to the word "negative" (Eder & Klauer, 2003). Again, there is nothing "perceptual" in a forward joystick move that makes it more similar to the word "negative" than to the word "positive". After all, we do not find it trivial to specify what qualifies a feature as "perceptual" (and what does not). What makes a right-pointing arrow perceptually more similar to a right key press than to the spoken word "right"? Given this ambiguity, and given the present blindness effects across a considerable variability of stimulus-response modes, we consider the conceptual basis of the blindness phenomenon to currently be the most parsimonious explanation.

What remains to be clarified is why blindness effects are harder to establish with certain types of stimuli and responses than with others. In particular, why does blindness not occur with manual responses and words or with vocal responses and arrows (cf. Hommel and Müsseler, 2000, 2003)? If one assumes a conceptual basis of the blindness phenomenon, it is clear that blindness effects will occur only if a conceptual analysis of stimulus-response events actually occurs, and occurs consistently enough. For some reason this may not be the case with vocal responses and arrows (or with manual responses and words). Consider, for example, that most students are highly practiced at identifying characters on a computer screen in close temporal proximity to a manual key press, as this is the standard way to control for typos. By contrast, the visual identification of characters after an utterance seems a rather uncommon task (except for someone familiar with a voice recognition system). In other words, there may be certain stimulus-response combinations where the creation of meaning-based codes occurs more instantaneously and more consistently than in others.

Another consideration on the lack of blindness for manual responses and words or vocal responses and arrows in the studies by Hommel and Müsseler (2000, 2003) is a more technical one: In a dual-task situation performance in one (perceptual) task cannot be assessed independently of performance in the other (response) task. Feature overlap may not only hamper perception of a stimulus but also the execution of a response, particularly when the response was not sufficiently planned in advance. This conjecture is supported by the observation that vocal responses at least numerically hamper the perception of arrows when instructions stress response speed, which suggests that sufficient response planning may be a crucial precondition for conceptual blindness effects to occur (Hommel and Müsseler, 2000, 2003, Experiment 3b). Unfortunately response latencies were not reported in that study in sufficient detail to allow a closer examination of this conjecture. Of course, these considerations need not necessarily be correct, but they warrant a more thorough investigation of the lack of blindness effects where they should occur from the perspective of a conceptual basis of the effect.

After all, we want to note here that our conclusion of a meaning-based origin of the blindness effect complements rather than contradicts the original explanation of the effect, which holds that actions are planned in terms of the features that are to be produced (i.e., by anticipating their effects, cf. Hommel et al., 2001). It is true that many of our actions aim at goals that may be qualified as "perceptual" (e.g., reaching for a glass of water, switching on the room light). Yet many goal-oriented actions often aim at effects that go beyond that. Consider for example the goal of creating a warm interpersonal atmosphere in a social interaction. This situation is hardly portrayed by some low-level sensory features. From this perspective it seems plausible to us that action and perception may well interact on a very distal, more or less sensory-independent level (cf. Koch & Kunde, 2002). In other words, we do not deny that blindness to response-compatible stimuli results from problems that arise when perception and action concurrently utilize the same cognitive codes, but we suggest that these common codes represent concepts rather than percepts.

Although our data concur with a modified code-occupation explanation, there may be other, not mutually alternative, explanations of the present (and other) blindness experiments that afford some discussion. Recently, Stevanovski, Oriet, and Jolicoeur (2003) reported that a response cue under certain conditions suffices to impair the perception of a cue-compatible target even when no motor response is afforded. This suggests that part of the blindness effect may be due to a motor-independent cue-target repetition blindness effect (Kanwisher, 1987). Importantly, however, this cue-related component was confined to a short cue-target time interval (200 ms) and was entirely absent with a longer interval (1,000 ms), which led to the conclusion that an "activation of 'left' and 'right' may be maintained only for a short period of time in the absence of a stimulus or a response plan" (Stevanovski et al., 2003, p. 437). This crucial cue-target interval in the present study was even longer (1,500 ms, cf. Fig. 1) which renders a contribution of this type of cue-target repetition effect very unlikely.

Another alternative explanation holds that the blindness effect is based on impaired memory rehearsal of the target rather than on impaired target encoding itself. Consider that participants in the present paradigm have to keep two events in their memory: 1. The response for response execution. 2. The perceptual target for later reporting. Response rehearsal is terminated by response execution, and target rehearsal is terminated by target report. In compatible conditions, response execution may not only terminate response rehearsal but (erroneously) target rehearsal as well. This would reduce the accuracy of target reports despite preserved target encoding. This alternative account has been identified and tested by Wühr and Müsseler (2001, Experiments 4 and 5). In their experiments, the target was presented well in advance of the response cue and could thus be encoded without temporal overlap with response planning. The target still had to be reported after response execution, and thus response planning temporally overlapped with target rehearsal. With this modification the blindness effect for response-compatible stimuli was abolished. This clearly shows that response planning hampers perceptual target encoding but not target rehearsal (cf. Wühr & Müsseler, 2001, for a detailed discussion).

To conclude, the present experiments show that action-induced blindness of feature-overlapping stimuli is a phenomenon of broad empirical validity. We therefore see no principled reason why the effect should not emerge with features that are considerably more abstract than the ones we employed here. For instance, curved hand movements may hamper the perception of curved visual forms (e.g., circles) more than perception of straight-lined forms (e.g., triangles). Or continuous movements may hamper the perception of continuous visual events (e.g., a moving dot) more than the perception of discrete visual events (e.g., a briefly flashed dot). These predictions remain open to empirical testing.

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