Research Article

SYMBOLIC CONTROL OF VISUAL ATTENTION

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Abstract—*The present study reports four pairs of experiments that examined the role of nonpredictive (i.e., task-irrelevant) symbolic stimuli on attentional orienting. The experiments involved a simple detection task, an inhibition of return (IOR) task, and choice decision tasks both with and without attentional bias. Each pair of experiments included one experiment in which nonpredictive arrows were presented at the central fixation location and another experiment in which nonpredictive direction words (e.g., "up," "down," "left," "right") were presented. The nonpredictive symbolic stimuli affected responses in all experiments, with the words producing greater effects in the detection task and the arrows producing greater effects in the IOR and choice decision tasks. Overall, the present findings indicate that there is a strong connection between the overlearned representations of the meaning of communicative symbols and the reflexive orienting of visual attention.*

Human communication is goal-directed. That is, humans communicate by exchanging symbols, such as signs or words, in order to produce an intended modification of addressees' cognitive state and behavior (Grice, 1969). As the successful coordination of communicative interchange requires the identification and maintenance of common themes and topics, one of the most important cognitive states to modify during and through communication is attention or, more precisely, the attentional focus of one's communicative partner. From this perspective, most signs and symbols can be seen as "nothing more than a social convention by means of which persons who know the convention direct one another's attention to particular aspects of their shared world" (Tomasello & Call, 1997, p. 408).

In the present research, we investigated a particularly interesting implication of this perspective on symbolic communication: If a main function of symbols is to orient the attentional focus of human beings, encountering a symbol should automatically redirect one's attentional orientation. Indeed, facing the picture of a realistic (Driver et al., 1999; Langton & Bruce, 1999) or schematic (Friesen & Kingstone, 1998) human face or a pointing gesture (Langton & Bruce, 2000) facilitates the processing of stimuli appearing at the location toward which the face's gaze or the gesture is directed. Even 10-week-old infants (Hood, Willen, & Driver, 1998) and chimpanzees (Povinelli & Eddy, 1996) spontaneously attend locations human faces look at, suggesting that social signals do have a function in reorienting visual attention. However, previous investigations were restricted to faces and gestures, rather direct and nonconventional communicative signals whose processing has been attributed to an innate gaze-detection mechanism (Baron-Cohen, 1995). In contrast, we were interested in whether conventional, overlearned communicative signals are also effective means to control other people's attention. If so, facing a pointing arrow or directional word should involuntarily induce, to some degree, a tendency in an observer to shift his or her attention to the indicated direction.

We investigated this implication in four pairs of experiments, each employing a different task, in which subjects responded to spatially unpredictable targets. Shortly before these targets appeared, we presented task-irrelevant arrows and directional words indicating either the correct location of the target (*compatible* cues) or an alternative location (*incompatible* cues). Although arrow and word cues were nonpredictive and could be ignored—this was explicitly pointed out to the subjects in all the experiments—we expected these symbols' meaning to catch the perceiver's attention and direct it to the indicated location. Accordingly, we expected subjects would perform better when the meaning of an arrow or word cue matched the location of the target stimulus than when it did not.

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EXPERIMENT 1

In Experiment 1, subjects searched for a target letter in four possible locations (left, right, top, or bottom). Each stimulus display was preceded by a noninformative cue: an arrow pointing to the left, right, top, or bottom (Experiment 1a) or the word "left," "right," "top," or "bottom" (Experiment 1b). Although there was no correlation between a cue and the target location, we expected that the meaning of the arrows and words would induce involuntary attentional shifts in the indicated direction—thereby improving performance for targets appearing in the corresponding location.

Method

Nineteen students participated in Experiment 1a and 12 participated in Experiment 1b. They were paid for their participation. As was the case for all subjects in this study, they reported having normal or corrected-to-normal vision and were not familiar with the purpose of the experiment. Stimuli appeared on a computer monitor, and responses were made by pressing an external key. Viewing distance was 60 cm.

Each trial began with the exposure of a white central fixation cross (on a black background) and four gray boxes 3.4 cm to its left, right, top, and bottom. The boxes measured 1.2 × 2.3 cm. After 100 ms, the fixation cross was replaced by a white arrow (a triangle measuring 0.5 × 1.3 cm) pointing to the left, right, top, or bottom (Experiment 1a) or by the white word "LINKS," "RECHTS," "OBEN," or "UNTEN" (German for "left," "right," "top," and "bottom"; Experiment 1b). After 500 ms, the arrow or word was replaced by the fixation cross, which was presented for another 500 ms. Next, the stimulus display appeared until a response was given or 2,000 ms had passed. The display consisted of four red letters, one in each box. In 80% of the trials (i.e., the go trials), the target letter *X* appeared in one of the boxes, and the other three boxes were filled with randomly drawn nontarget letters (*A*, *E*, *L*, and *M*). In the remaining 20% of the trials (no-go trials), the letter *X* was not presented. Subjects were to press the response key in go trials but to refrain from responding in no-go trials. The intertrial interval was 1,500 ms. After 10 warm-up trials, 480 experimental

trials were presented, with equal probabilities for each cue and target position (i.e., the cues did not predict target location).

Results and Discussion

Errors were rare and not analyzed further; there were 3.0% and 0.2% response omissions in Experiments 1a and 1b, respectively, and 0.9% and 0.8% false alarms. Mean reaction times (RTs) were calculated as a function of cue compatibility, hence, of whether the meaning of the cue did or did not correspond to stimulus position. Cue compatibility produced faster responses in both Experiment 1a, $F(1, 18) = 64.85$, $p < .001$, and Experiment 1b, $F(1, 11) = 27.96$, $p < .001$ (see Fig. 1).

The results indicated that both arrow and word cues must have attracted our subjects' attention to the locations they indicated, although they were completely irrelevant to the task and their content had no predictive potential whatsoever. Obviously, then, the meaning of those cues was automatically analyzed, and the outcome directly affected the spatial control of visual attention. Hence, symbols took over attentional control.

EXPERIMENT 2

In Experiment 2, subjects detected stimuli to the left or right of a central fixation object after having seen a prior nonpredictive stimulus (a peripheral cue) at the same or the other location. Under these conditions, RTs are known to be slower if the stimulus location is repeated (validly cued) than if it is alternated (invalidly cued), an effect called inhibition of return (IOR; Posner & Cohen, 1984). However, in this experiment, the target stimulus was preceded not only by a peripheral cue but also by either a centrally presented left- or right-pointing nonpredictive arrow (Experiment 2a) or the nonpredictive word "left" or "right" (Experiment 2b). We expected the symbolic central cues to work against the aftereffects of the peripheral cues (i.e., IOR) when indicating the location of the target. That is, we expected IOR would be diminished when the meaning of the central cue and the target location were compatible.

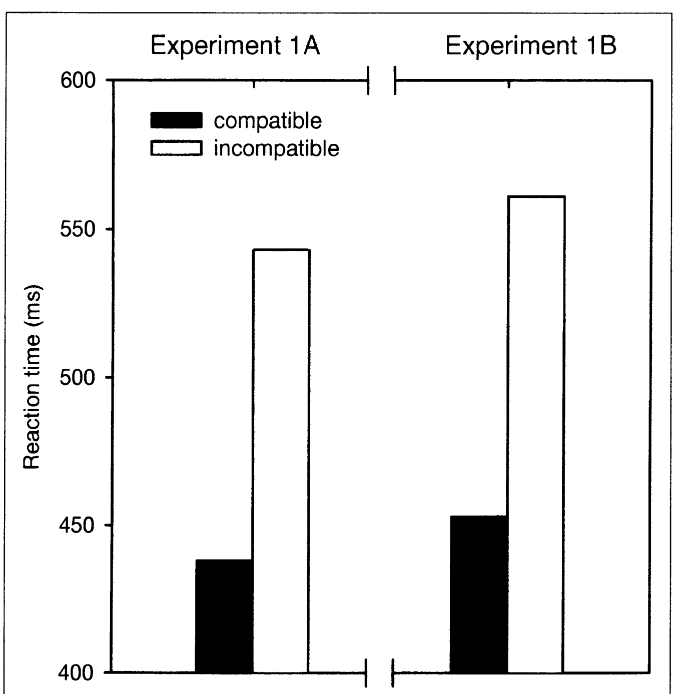

Fig. 1. Reaction times in Experiment 1, as a function of compatibility between stimulus position and the position indicated by the arrow cue (Experiment 1a) or word cue (Experiment 1b).

Method

Ten students participated in Experiment 2a and 10 participated in Experiment 2b in exchange for credit toward a course requirement. Stimuli appeared on a computer monitor. The viewing distance of 44 cm was held constant by using a chin-head rest. Each trial began with the presentation of a white fixation point (on a black background).

In Experiment 2a, the fixation point was surrounded by the white outlines of two overlapping acute triangles (1.0 × 0.66 cm) forming an elongated Star of David. After 1,200 ms, a peripheral cue (the white outline of a 1-cm circle) was presented for 200 ms 6.5 cm to the left or right of fixation. Following a 200-ms delay, portions of the overlapping triangles were removed so that a left- or right-pointing triangle, or a random set of lines, appeared. In noncatch trials, the target (a white filled-in circle) appeared 400 ms later, 6.5 cm to the left or right of fixation.

In Experiment 2b, only the fixation point was presented for 1,200 ms, followed by a 200-ms peripheral cue. Following a 200-ms delay after cue offset, a word ("left," "right," "center") appeared at fixation for 400 ms and then, on noncatch trials, the target was presented.

In both Experiments 2a and 2b, participants were explicitly instructed to ignore the central cues (i.e., the triangles and words, which remained present until the response) and the peripheral cues because they were nonpredictive. The instructions were to respond only to the onset of the target as quickly and accurately as possible by pressing the space bar on the keyboard. The intertrial interval was 1,500 ms.

Participants completed 288 trials in which a target appeared and 72 catch trials in which no target appeared and no response was to be made. Cues and targets were equally likely to occur to the left and right of fixation.

Results and Discussion

As before, errors were rare (0.4% and 0.6% false alarms in Experiments 2a and 2b, respectively, and 0.8% and 1.0% response omissions). Mean RT was calculated for each combination of peripheral cue (valid vs. invalid) and central cue (compatible vs. incompatible vs. neutral). Experiment 2a produced main effects of peripheral cue, $F(1, 9) = 23.7$, $p < .0015$, and central cue, $F(2, 18) = 19.1$, $p < .0001$, indicating that IOR did occur in response to the peripheral cue (longer RTs on valid trials than on invalid trials) and that the central arrows affected RTs (faster RTs when arrows validly cued the target than when they were incompatible with target location). (See Fig. 2.) Planned comparisons confirmed that IOR occurred in each condition ($p < .03$ for compatible central cues, $ps < .001$ for incompatible and neutral central cues). The interaction was also significant, $F(2, 18) = 15.6$, $p < .0005$, as the smallest IOR effect was found when the arrow pointed toward the target location and the largest IOR effect was found when the arrow pointed away from the target location.

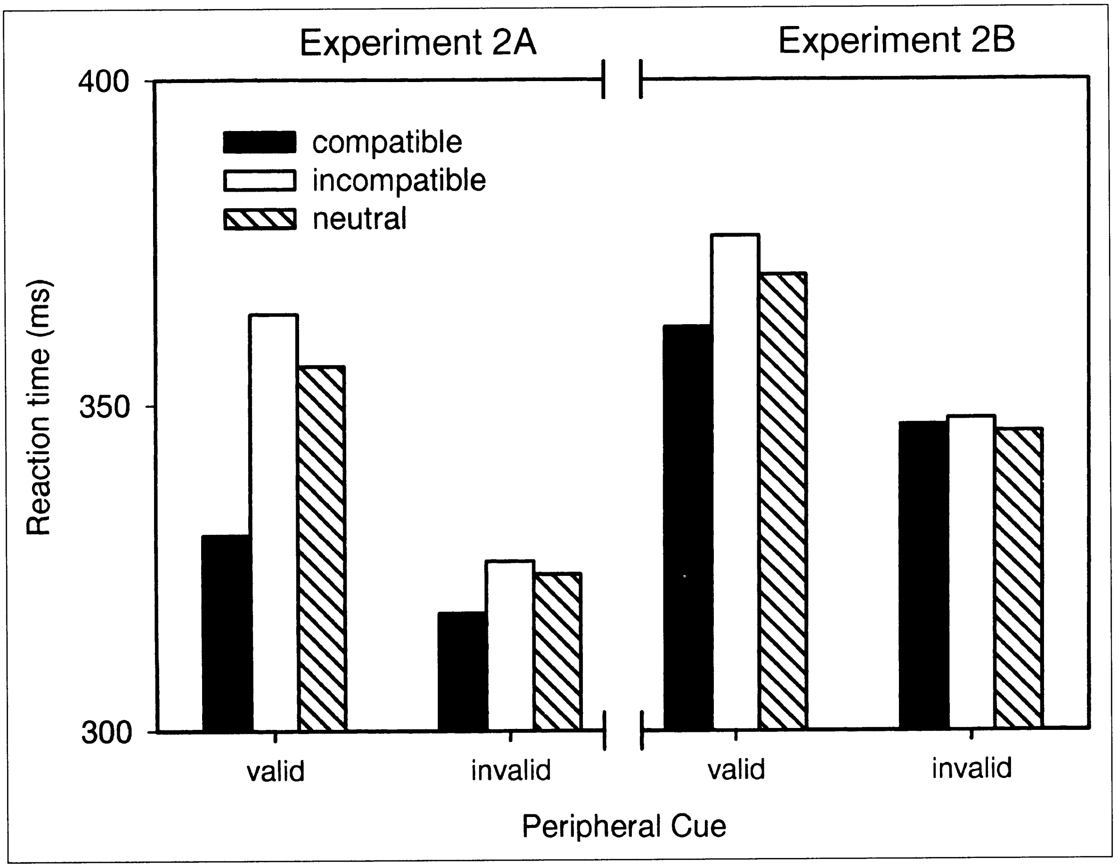

Fig. 2. Reaction times in Experiment 2, as a function of validity of the peripheral cue, and of compatibility between stimulus position and the position indicated by the central arrow cue (Experiment 2a) or word cue (Experiment 2b).

Experiment 2b yielded similar results, as main effects of peripheral cue, $F(1, 9) = 14.3$, $p < .005$, and central cue, $F(2, 18) = 9.4$, $p < .002$, were found (see Fig. 2). As before, the peripheral cue produced IOR, and the RTs were fastest when the central cue validly cued the target location. Planned comparisons again confirmed that IOR occurred in each condition ($p < .03$ for compatible central cues, $p < .005$ for incompatible central cues, and $p < .001$ for neutral central cues). The interaction was also significant, $F(2, 18) = 6.2$, $p < .01$, with less IOR occurring when the word cue was valid than when it was invalid.

IOR is commonly attributed to attention being inhibited to return to previously attended locations (e.g., Maylor & Hockey, 1985; Posner & Cohen, 1984; but see Taylor & Klein, 1998). Recently, Pratt and his colleagues (Pratt, Adam, & McAuliffe, 1998; Pratt, Spalek, & Bradshaw, 1999) have suggested that the direction that attention travels produces the inhibitory effect. If attention is reoriented from a peripherally cued location to the fixation cue, a target at the invalidly cued location is along the current path of attention, whereas a target at the validly cued location requires a 180° change of direction. Thus, RTs in IOR tasks may reflect the angle of change attention must go through to be oriented to a target. Our results are consistent with this notion as the direction of the central cue (triangle or word) interacted with the peripheral cue to affect RTs. Moreover, the central cues affected RTs although participants were explicitly told to ignore them because they conveyed no information about target location. Overall, the results from Experiment 2 support not only the notion that the attentional system is susceptible to control by extraneous symbolic cues, but also the suggestion that the direction of attention plays a role in IOR.

EXPERIMENT 3

Having shown automatic effects of symbolic cues in two target-detection tasks with rather low response-related demands, we went on to determine if symbolic cuing can also be found in more common binary-choice tasks. In Experiments 3 and 4, the subjects' task was to indicate the color of a stimulus appearing on the left or right of fixation by pressing the designated key.

In Experiment 3a, the stimulus was preceded by nonpredictive arrows pointing randomly to the left, right, top, or bottom, as in Experiment 1a. Again, we expected better performance if the arrow pointed to the location where the stimulus would appear. In Experiment 3b, we again used nonpredictive direction words to direct our subjects' attention to the left and right. To double our chances of finding an effect, we used two different cue-stimulus intervals. However, we discovered that the cue-compatibility effects were independent of the interval between cue and stimulus.

Method

Twenty-four students participated in Experiment 3a and 16 participated in Experiment 3b. They were paid for their participation. The

apparatus was the same as in Experiment 1, except that binary-choice reactions were made by pressing the left or right shift key of the computer keyboard. Stimuli appeared on a black background on which two white boxes were continuously displayed, centered 2.5 cm to the left and right of the center of the screen. The boxes measured 1.7 × 2.2 cm.

In Experiment 3a, each trial began with the 100-ms exposure of a white arrow (a triangle measuring 1.0 × 0.5 cm) randomly pointing to the left, right, top, or bottom. After a blank interval of 100 ms, the target stimulus, a red or blue square measuring 0.8 × 0.8 cm, appeared for 120 ms only in the left or right box. The mapping of red and blue stimuli onto left and right response keys was balanced across subjects. The program waited until a response was given or 1,000 ms had passed. The intertrial interval was 2,500 ms. Subjects performed two warm-up and 20 experimental blocks, each comprising the 16 possible combinations of cue content, stimulus location, and response. Again, cue content did not predict target location.

Experiment 3b used the same method with only two exceptions. First, there were only two cues: the words "Links" and "Rechts" (German for "left" and "right"), which appeared for 300 ms. Second, we used two different intervals between cue onset and stimulus onset, 350 and 750 ms, so that the blank after cue offset lasted 50 or 450 ms. Otherwise, the design was the same as that of Experiment 3a.

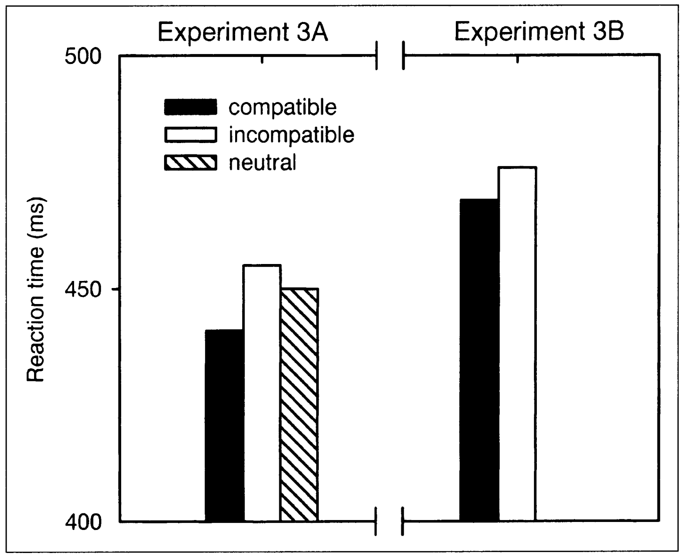

Fig. 3. Reaction times in Experiment 3, as a function of compatibility between stimulus position and the position indicated by the arrow cue (Experiment 3a) or word cue (Experiment 3b). Note that no neutral cues were used in Experiment 3b.

Results and Discussion

Again, errors were rare and were not further analyzed; there were 3.7% and 2.9% incorrect responses in Experiments 3a and 3b, respectively, and 0.3% and 0.6% response omissions. Mean RT was calculated for each combination of cue meaning and target location (compatible vs. incompatible vs., as with the top and bottom cues in Experiment 3a, neutral) and cue-stimulus interval (in Experiment 3b only).

Experiment 3a produced a highly significant effect of cue compatibility, $F(2, 46) = 27.13$, $p < .001$. Separate comparisons confirmed that all three conditions differed from each other ($ps < .005$); that is, compatible cues sped up responses more than neutral cues, which yielded faster reactions than incompatible cues (see Fig. 3).

Experiment 3b also produced a significant effect of cue compatibility, $F(1, 15) = 7.29$, $p < .05$, indicating faster responses with compatible cues than with incompatible cues (see Fig. 3). RTs were shorter with the longer cue-stimulus interval (462 vs. 483 ms), $F(1, 15) = 30.96$, $p < .001$, but this effect did not interact with the cuing effect ($p > .6$).

The results are clear in showing reliable cuing effects for nonpredictive arrows and direction words in choice reaction time tasks. Thus, although the effects are again rather small, automatic symbolic cuing is not restricted to simple reactions or detection tasks but generalizes to standard binary-choice tasks.

EXPERIMENT 4

We interpret the findings we obtained as indicating an automatic influence of symbols on visual attention. Indeed, given that our symbolic cues were always nonpredictive, subjects had reason to ignore them. However, it is still possible that they intentionally used the cues to direct their attention, perhaps in a futile attempt to improve their performance. To exclude this possibility, in Experiment 4 we replicated Experiment 3 but explicitly directed the participants' attention. To do so, we presented the target stimuli in 80% of the trials of a given block in the left or right location and informed the subjects about the most likely location in advance. We assumed that they would direct their attention to the expected location, which would lead to a benefit for stimuli appearing there. We also presented irrelevant, nonpredictive, and randomly varying arrow and word cues. If these cues indeed had an automatic impact, their effects would be independent of the induced spatial bias; that is, cue-compatibility effects would be obtained irrespective of the subjects' expectations.

Method

Sixteen students participated in Experiment 4a and 31 participated in Experiment 4b. They were paid for their participation. The method was the same as in Experiment 3, with the following exceptions. After a 2,000-ms intertrial interval, each trial began with the 100-ms exposure of a left- or right-pointing arrow (Experiment 4a) or the 300-ms presentation of the word "Links" or "Rechts" (Experiment 4b). Following a further blank interval of 200 ms (Experiment 4a) or 350 ms (Experiment 4b), the target stimulus appeared for 120 ms in the left or right box. Each of the 20 blocks comprised 4 randomly determined practice trials and 20 experimental trials. In each block, the same number of "left" and "right" cues were presented, and "left" and "right" responses were correct an equal number of times. However, in each block, one stimulus location was four times as frequent as the other, with the more frequent location alternating between blocks. The start location was balanced across participants, who were informed about the most likely stimulus location before each block.

Results and Discussion

The few errors made consisted of 2.7% and 3.5% incorrect responses and 0.3% and 0.7% response omissions in Experiments 4a and 4b, respectively. Experiment 4a produced significant main effects of bias (i.e., whether the target appeared at the more likely or the less likely location), $F(1, 15) = 45.44$, $p < .001$, and of cue compatibility,

$F(1, 15) = 7.30, p < .05$, but no interaction ($p > .7$). As shown in Figure 4, RTs were faster when subjects were responding to the more likely stimulus location, and when the arrow cue pointed toward the stimulus location.

Experiment 4b yielded a significant main effect of bias, $F(1, 30) = 37.01, p < .001$, but the effect of cue compatibility missed the significance criterion, $p < .13$. More detailed analyses revealed a three-way interaction of bias, cue, and stimulus location, $F(1, 30) = 8.65, p < .01$. With right-side bias (i.e., the stimulus was more likely to appear on the right), the cuing effects were very similar to those in Experiment 4a (424 vs. 431 ms for compatible and incompatible cues, respectively), but with left-side bias (i.e., the stimulus was more likely to appear on the left), cues were ineffective (430 vs. 429 ms). A speculative explanation might be that attending (but not moving one's eyes) to the left visual field engages the right cortical hemisphere to a degree that effectively blocks the processing of words—which is known to be mediated by the left hemisphere.

Apart from the results for the particular combination of left-side bias and word cues, our findings show that nonpredictive arrows and words can produce reliable cuing effects on top of, and largely independent of, the perceivers' expectations. The sizes of these effects were very much the same as in Experiment 3, in which expectations were not controlled, suggesting that expectations were not responsible for the outcome of that experiment either.

GENERAL DISCUSSION

Our findings consistently show that a nonpredictive arrow or directional word facilitates the processing of an upcoming stimulus if its location matches the meaning of the arrow or word. Apparently, seeing a conventional, overlearned symbol with a spatial meaning automatically directs one's visual attention to the location this symbol designates—much as more "natural" communicative signals such as gaze and pointing do. The fact that evidence of attentional direction was found with two types of symbols and across three different types of task strongly suggests that this is a rather general effect that does not depend on contextual particularities and task details. Indeed, this is what one would expect of communicative symbols that are used to direct the attention of fellow beings to particular aspects of a shared environment (Tomasello & Call, 1997). The observation that symbolic information can automatically affect behavior is not new, as irrelevant, nonpredictive word primes are well-known to facilitate responding to semantically related target stimuli (e.g., Neely, 1977; Posner & Snyder, 1975). However, whereas these previous findings are sufficiently explained by assuming automatic retrieval of semantic information, the present observations demonstrate an impact of such information on attentional control.

We did not control the eye movements of our subjects, and are therefore unable to attribute the processing benefits to overt or covert

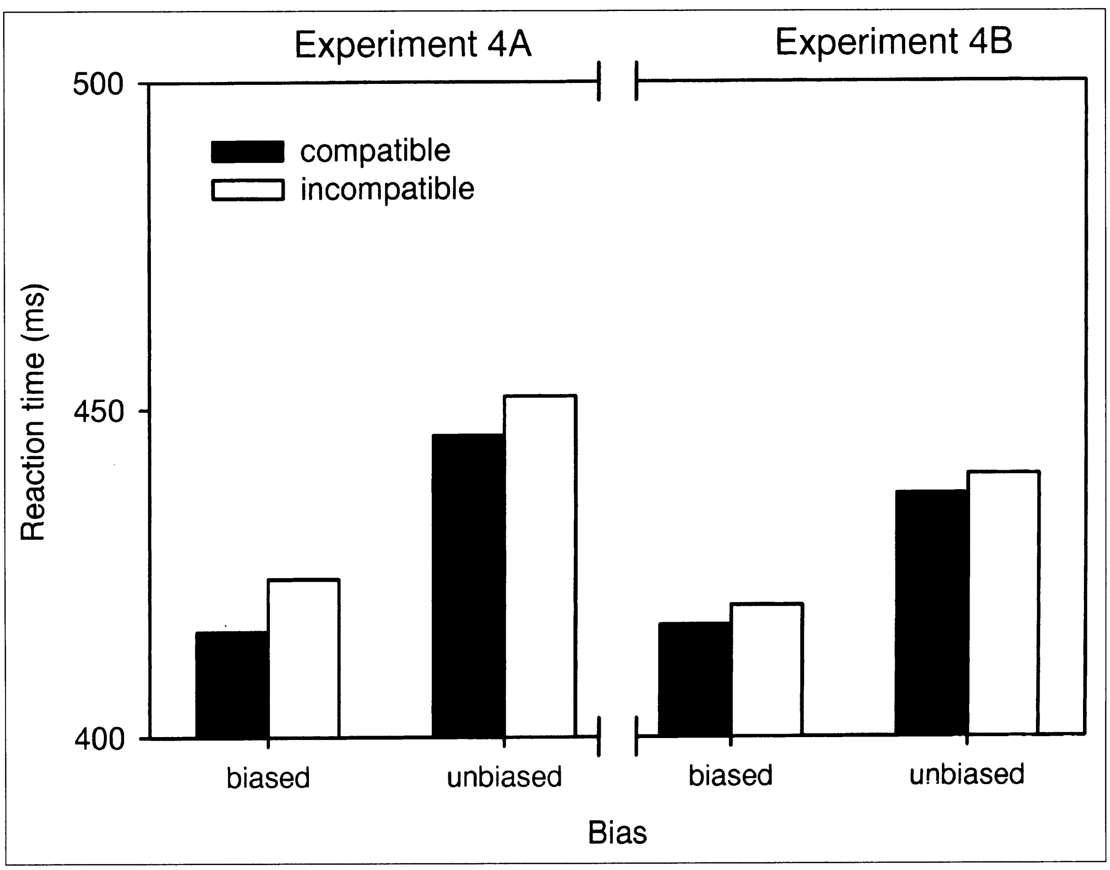

Fig. 4. Reaction times in Experiment 4, as a function of spatial bias (i.e., whether the target appeared at the more likely or less likely location), and of compatibility between stimulus position and the position indicated by the arrow cue (Experiment 4a) or word cue (Experiment 4b).

attention, or both. In everyday life, these two types of attention are strongly coupled; hence, people look where they attend and vice versa. Accordingly, it makes sense to assume that under normal circumstances arrows and words will induce both covert attentional shifts and overt eye movements—how else should people find out whether their communicative attempts were actually successful? Moreover, our conclusions in no way depend on whether covert or overt attention was responsible for the demonstrated effects. Nevertheless, it might be interesting to see in future investigations whether the two types of attention are affected differently by symbols with spatial meaning.

Although our findings make sense from a communicative perspective, they challenge the way spatial cues are commonly believed to function. In the attentional literature, two types of cues are usually distinguished. So-called exogenous cues share the location of the indicated stimulus, such as a light flash preceding or accompanying a target stimulus. If such cues appear with an abrupt onset, they automatically attract attention to their location, thereby facilitating the processing of other stimuli appearing at the same location (e.g., Posner, 1980). So-called endogenous cues are symbolic stimuli that indicate the likely location of an upcoming target. Given some degree of predictive validity, such cues also facilitate target processing (e.g., Yantis & Jonides, 1990). However, up to now only exogenous cues have been assumed to operate in an automatic fashion, whereas almost all approaches attribute effects of endogenous cues to intentional processes (e.g., Müller & Rabbitt, 1989; Posner, 1980; Theeuwes, 1993; Yantis & Jonides, 1990). In the present study, only symbolic cues without any predictive value were used—yet substantial cuing effects were obtained. Therefore, we must conclude that even "endogenous," meaning-based cues can operate automatically, at least if they are sufficiently overlearned.

However, our results do leave room for intentional and task factors. Interestingly, the sizes of the cuing effects differed for arrows and words: Whereas words showed the bigger effects in Experiment 1, arrows had stronger and more reliable effects in Experiments 2 through 4. A possible reason is that the directional meaning of arrows is, in a sense, less ambiguous. Whereas locatives such as "left" and "right" can refer to a new location of interest (implying an attentional shift) or an already attended location (implying no shift), arrows always point away, hence, refer to other than their own location. Therefore, people may simply be more used to shifting their attention in response to arrowlike stimuli than in response to words. Another (not exclusive) possibility is that these stimulus differences reflect different time courses of the processing of arrow and word information, and of the impact of this information on attentional control. Effect sizes differed not only between stimulus modes but also between experiments, ranging from 10 ms in Experiment 2 to about 100 ms in Experiment 1. Apart from possible effects of the differing cue-stimulus intervals, these differences likely reflect the higher demands on stimulus-selection processes in Experiment 1, in which the target had to be selected from a set of four stimuli. Given the feature overlap between the target and distractors, selecting the target required letter information to be integrated first—a process that is assumed to be mediated by spatial localization and attentional focusing (Treisman & Gelade, 1980). Accordingly, stimulus location was more task-relevant in Experiment 1, so that location-related cues could have a stronger impact. That is, the size of the cuing effect may reflect the importance of spatial information in the given task, a possibility that fits well with the idea that task-related control settings mediate the impact of automatic processes (e.g., Folk, Remington, & Wright, 1994).

To conclude, we have demonstrated that conventional, overlearned symbols can direct the visual attention of human observers in a relatively automatic fashion, which suggests a strong link between representations of the meaning of communicative symbols on the one hand and the control of visual attention on the other. Further exploration of this relationship is likely to enhance understanding of the basic mechanisms underlying human communication.

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