Global–local orientation congruency effects in visual search

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In a visual search task, subjects had to decide which of 2 possible target letters was presented among 12 distractor letters. The 13 characters were arranged to form a global Navon-type letter. The global letter and the local letters (target and distractors) were independently presented in four different viewer-related orientations. When the global letter and the target were frequently congruently oriented, the response times increased with growing orientation disparity between them. This global–target congruency effect was independent from target identity (Experiment 1), and it diminished when global and target orientations were not correlated (Experiment 2). The results indicate that the orientation of the global letter can be deliberately used in order to facilitate the processing of congruently oriented local targets. The alignment of a spatial frame of reference is discussed as the most probable process underlying this facilitation.

There is ample evidence that indicates that the viewer-related orientation of a visual pattern affects the speed and accuracy of its perception. In general, the time and error rate in perceiving a pattern increases the more it differs from its usual orientation. This finding is usually accounted for by assuming that an analogue representation of the misoriented stimulus has to be rotated into upright before a comparison with corresponding stimulus representations in memory can take place (e.g. Jolicoeur, Snow, & Murray, 1987; Shepard & Metzler, 1971; Tarr, 1995; Tarr & Pinker, 1989).

Alternatively it has been suggested that subjects do not rotate a specific stimulus representation into viewer-centred upright, but rather rotate an upright frame of reference into alignment with the actual stimulus orientation (Jolicoeur, 1990, 1992; Robertson, Palmer, & Gomez, 1987). Such a "frame of reference rotation" would be beneficial in many natural situations. Imagine for example, you are searching for an object with your head being slightly tilted (which often occurs as the head is rarely held in an upright or even constant orientation). Identifying each single object by rotating it to retinal or head-related upright would produce much more effort than a single alignment of a global frame

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We thank George Mather, Jeremy Wolfe, and an anonymous reviewer for their helpful comments on an earlier version of this paper. We also thank Philipp Zellmann for collecting the data of Experiment 2.

http://www.tandf.co.uk/journals/pp/02724987.html

of reference with the orientation of the congruently oriented objects in the scene (cf. Jolicoeur, 1990). What holds for a scene is also true for the perception of the local parts of an object. Aligning a reference frame into the main axis of a misoriented object would facilitate the immediate identification of its details, whereas the rotation of an object representation inevitably requires the rotation of all of its parts, which causes more effort the more complex the object is (Bethell-Fox & Shepard, 1988; Folk & Luce, 1987).

Evidence for the ability to rotate an abstract frame of reference has been provided by experiments in which misoriented objects were presented either in a rapid temporal order or in close spatial proximity. Robertson et al. (1987) presented to subjects four copies of a misoriented letter in the cells of a 2×2 matrix. The subjects had to decide whether the letters were normally faced or mirror reversed. Shortly after response a second letter was presented, which again had to be judged for reflection. The response times for the second letter increased the further it was rotated from upright. More important, response times also increased with increasing relative misorientation between the first and the second stimulus, irrespective of the identity of the first stimulus. The authors concluded that the results were most parsimoniously interpreted as the rotation of a frame of reference from the orientation of the initial stimulus matrix into the orientation of the second stimulus letter, which led to increasing response times the more disparate the orientation of the two stimuli were.

A comparable proposal has been made by Jolicoeur (1990). He presented subjects brief (about 30 msec) displays of three misoriented letters followed by a mask. The subjects were instructed to name the letters in a left-to-right order. Identification was more accurate when the letters had the same orientation (for example 60° clockwise) than when they had different orientations within a display (for example one letter 60° clockwise, the remaining two 60° counterclockwise). Thus, with the average deviation from upright being constant in all displays, the recognition of the stimuli was affected by their *relative* misorientation to each other. Jolicoeur accounted for this orientation congruency effect by assuming that a global frame of reference is aligned with the presented letters. After aligning the frame, each letter in the same orientation can be identified. In congruent displays a single adjustment is sufficient to identify all presented letters, whereas in incongruent displays at least one readjustment of the frame is necessary, leading to an inferior recognition performance.

Jolicoeur (1992) intended to confirm this orientation congruency effect in a visual search paradigm using reaction times as the dependent measure. Subjects had to decide whether the target letter E was presented among the distractor letters F and L. The target as well as the distractors were presented in six different orientations varying from 0° to 300°. Two different types of display were used: In congruent displays all letters had the same orientation. In incongruent displays the items were equally distributed over all possible orientations with an average deviation from upright of 90°. Two important results were observed. First, the detection time for the target was strongly affected by its viewer-related orientation. When plotted over orientation, the detection times had a pronounced M-shape—that is, a strong increase from 0° to 60°, a plateau (or sometimes slight decrease) at 120°, and a striking dip at 180°. Second, in agreement with the aforementioned study that used briefly presented letters, the search was faster in congruent than in incongruent displays. This holds true also for congruent displays in which the deviation from upright was *larger* (for example 120°) than that in incongruent displays (where the averaged deviation constantly amounted to 90°). Again this result is consistent with the assumption that item identification is facilitated by aligning a single frame of reference with the homogeneous stimulus orientation in congruent displays.

However, Jolicoeur (1992) pointed out that other reasons may at least partly account for the orientation congruency effect. First, the results are also compatible with the view that each single item is rotated to upright, but the normalization in congruent displays becomes more efficient (is primed) by repetition. Second, the orientation congruency effect could also be explained by the influence of the target–distractor and distractor–distractor similarity on search rate. It is known that search times increase with increasing target–distractor similarity and decreasing distractor–distractor similarity (Duncan & Humphreys, 1989, 1992). The homogeneous orientation in congruent displays may have led to a high similarity of the distractors, resulting in *decreased* search times. On the other hand, the congruent orientation could have made the target appear more similar to the distractors, which would *increase* search times. In fact the argument of increased target–distractor similarity in congruent displays was used to account post hoc for a rather unappealing lack of converging evidence in the data, namely a failure to show a main effect of congruency in target-present displays. Whichever conjecture is correct, it is clear from this brief consideration that in Jolicoeur's (1992) study congruency was confounded with target–distractor and intra-distractor similarity in a manner that prevented accurate estimation of the influence that congruency has on target detection.

The following two experiments investigated whether orientation congruency effects in visual search in favour of the adjustment of a frame of reference can be found, when conditions are established that rule out the aforementioned alternative explanations. For this purpose Jolicoeur's search task was modified in three major ways.

First, in our experiments the items were arranged to form a compound or global letter, with a dominant main axis (the global letter F, Figure 1). Orientation congruency was varied not between the local items but between the global letter and the local target. Thus, congruency varied between two distinct levels of a hierarchical configuration. The main advantage of this design is that orientation congruency between distinct levels of a hier-

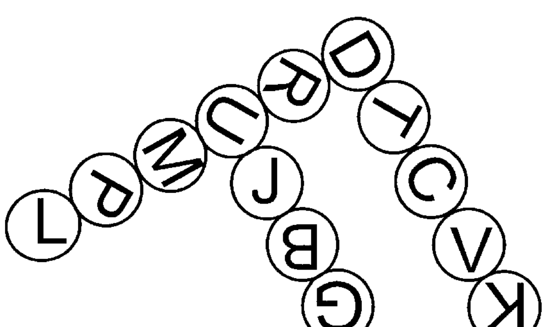

FIG. 1. Sample stimulus. Orientation of the global letter: 60°. Orientation of the local target (R): 120°. Resulting disparity: 60°.

archical pattern can be altered, while target–distractor similarity and the intra-distractor similarity can be held constant. Moreover, as the distribution of viewer-related orientations of the distractors was the same in each trial, an effect of global-to-local orientation congruency can certainly not be attributed to the priming of a normalization process for local items.

Second, the frequency of congruently aligned targets was varied. Adjusting a global reference axis will improve target detection, the more often this axis meets the actual orientation of the presented target. Consider that targets were always embedded in a congruently oriented global letter – that is, that global orientation and target orientation were perfectly correlated. After a single frame alignment with the orientation of the global letter, the target could be identified with certainty. Therefore, aligning a frame of reference with the global letter should be of great benefit for target detection. If in contrast the orientation of the target and the global letter are not correlated, the target only seldomly appears congruently oriented. In this case aligning a frame of reference with the global letter would rarely be beneficial, as the target could be presented congruently or disparately oriented in an unpredictable manner. Thus, increasing the probability of congruently oriented targets increases the gain of aligning a global reference axis with the orientation of the global letter. This variation should allow us to estimate the extent to which the alignment of a frame of reference with a global pattern is strategic versus automatic. If it is completely automatic, it should not depend on the benefit being associated with it.

Third, not one but two different targets were used (Table 1). One of the two targets (the probably congruent target) appeared congruently oriented with high probability (i.e. in 75% of its presentations) whereas the other (rarely congruent) target barely appeared co-oriented with the global level (25% of its presentations). This allows us to clarify whether or not a global-to-local orientation congruency effect (provided it can be observed) depends on the identity of the target. In other words, is the expected processing facilitation for congruently oriented targets common to all stimuli with this orientation (identity–non-specific) or is it restricted to a particular stimulus occurring with high probability in a congruent orientation (identity specific)? If only the probably congruent target would profit from its congruent orientation this would not be sufficient evidence to assume a frame of reference adjustment. As has been pointed out by Robertson et al. (1987) target-specific orientation effects are better accounted for by assuming an alignment of a target template with which each individual item is compared (the so-called "template hypothesis"). If, on the other hand, a frame of reference is adjusted, both targets should profit from being aligned with it by a comparable amount.

EXPERIMENT 1

Experiment 1 had two purposes. First it examined whether a frame of reference could be aligned with the orientation of a global letter in order for this frame to be used for local target detection. In Experiment 1, conditions were selected in which target detection would profit from such a process. The targets appeared in the same orientation as that of the global figure 50% of the time, with the other 50% of trials divided equally between the remaining target orientations. Thus, the orientation indicated by the global letter met the actual target orientation three times more often than any other possible target orientation.

TABLE 1
Frequencies of the two targets in the different target orientations and congruency conditions in Experiment 1

	Target Orientation								
	Rarely Congruent Target				*Probably Congruent Target*				
	0°	*60°*	*120°*	*180°*	*0°*	*60°*	*120°*	*180°*	*Sum*
Congruent	27	27	27	27	81	81	81	81	432
Incongruent	81	81	81	81	27	27	27	27	432
Sum	108	108	108	108	108	108	108	108	864

The second question was whether the expected advantage for congruent targets is identity specific—that is, is restricted only to a specific target letter that often appears co-oriented with the global letter—or is identity-non-specific, that is, generalizes to any congruent stimulus. To clarify this question, two targets were used. One target was probably congruent, the other target was rarely congruent. A correctly oriented frame of reference should facilitate the processing of any stimulus being aligned with it. Therefore, we expected an advantage of global-to-local orientation congruency to be identity–non-specific.

Method

Subjects

A total of 12 undergraduates (5 men, 7 women) between the ages of 20 and 24 years at the University of Würzburg, and with normal or corrected-to-normal vision, served as subjects in fulfilment of a course requirement.

Apparatus and Stimuli

The presentation of the stimuli and the recording of responses and reaction times (RTs) were provided by a 486 IBM-compatible PC with a 15-inch VGA Graphics Display. The viewing distance was approximately 80 cm. Responses were made on an external key pad connected to the parallel port of the computer. The pad had two lateral response keys and one start key in between. The midpoints of the keys were separated by 20 mm.

The local stimulus letters were 10 mm high and 7 mm wide. The letters E and R served as targets and the letters B, C, D, G, J, K, L, P, M, T, U, V were used as distractors. In each trial one of the targets was presented in a randomly selected location within the 12 distractors. The 13 letters were arranged to form the global letter F (see Figure 1). The centre-to-centre distance of the local letters was 15 mm.

The target as well as the distractors appeared in one of four orientations (0°, 60°, 120°, 180°). In each trial, three of the distractors were randomly assigned to one of the four orientations, so that orientation congruency on the local level and the averaged distractor orientation were the same in each trial. Presenting the items in this way made the outline of the global letter somewhat blurred. Thus, in order to improve the phenomenal impression of a compact global letter, each local letter was surrounded by a circle of constant radius (7 mm).

For each subject, one of the two target letters was selected as the probably congruent target that appeared with high probability (75% of its presentations) in congruence with the global letter and seldom in a disparate orientation (see Table 1). The other target was rarely congruently presented (25% of its presentations). Incongruent presentations were achieved by misaligning the global F with respect to the local target. The global letter could also appear in an orientation of 0°, 60°, 120°, or 180°, relative to upright. Hence, there were three possible levels of incongruency on each level of target orientation, which were used with equal probability. For half of the subjects the E and for the other half the R served as the probably congruent target. Half of the subjects responded to the target E with the left key and to R with the right key. For the other half this mapping was reversed.

Procedure

The subjects were instructed to determine as fast as possible, without making errors, which one of the two possible target letters was presented. The subjects started a trial by pressing the middle start key, 1000 msec later the stimuli were presented. Responses were made by pressing either the left or the right key of the pad with the index finger of the right hand. An error was indicated by a 1000-Hz warning tone. After 24 practice trials, the experiment was run in three blocks of 288 trials within a single session of approximately 1 hr.

Results

Response times that were more than 3 standard deviations above or below a subject's mean were discarded as outliers (1.4% of the correct responses). RTs for correct responses were entered into a three-way analysis of variance (ANOVA) for repeated measures with the variables target orientation (0°, 60°, 120°, 180°), global–target congruency (incongruent vs. congruent), and target type (rarely vs. probably congruent).

There was a significant effect of target orientation, $F(3, 33) = 12.39, p < .001$. Response times increased up to 120° and had a typical dip at 180° (see Figure 2). Additionally, there was a highly reliable influence of congruency, $F(1, 11) = 23.44$, $p < .001$. Congruent

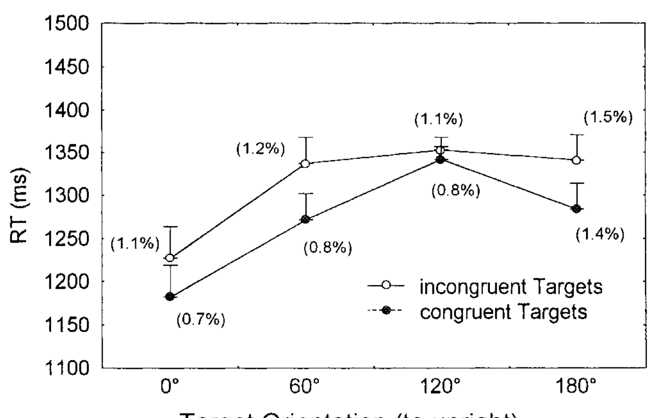

FIG. 2. Experiment 1. Mean reaction times (plus 95% confidence intervals) as a function of target orientation and global–target congruency. Mean error rates in parentheses.

targets could be detected faster than incongruent targets. No other effects approached significance (all *p*s > .25). The interaction of congruency and type of target, indicating a different influence of congruency for the two targets was far from being significant, $F(1, 11) = 0.32$. The averaged congruency effect was 38 msec for the probably congruent target and 51 msec for the rarely congruent target. From this analysis it seems safe to conclude that the influence of congruency is at least as strong for the rarely congruent target than for the probably congruent target. The averaged error rate was low (1.1%). There were no reliable effects in the error data.

In order to get a more detailed view of the influence of congruency we computed an additional analysis. As the global letter as well as the target appeared in four different orientations there were also four different levels of global–target disparity (0°, 60°, 120°, 180°). However, due to the fact that stimuli captured only the range between 0° and 180° and not the whole range between 0° and 360°, these levels of disparity result from different levels of global and target orientation. For example, a 180° disparity between global and target orientation occurred only when the target was upright and the global letter was upside-down, or vice versa. Thus, only two of the four possible target orientations (0° and 180°) and two of the four possible global orientations (0° and 180°) contributed to a disparity of 180°. This is different for a disparity of 120° that results from the following combinations of global (g) and target (t) orientations: (g: 0°, t: 120°), (g: 60°, t: 180°). (g: 120°, t: 0°), (g: 180°, t: 60°). Thus, each level of target orientation and of global orientation contributes 25% of the data in the 120° disparity condition. Fortunately, this criterion is also fulfilled for 0° disparity (g: 0°, t: 0°), (g: 60°, t: 60°), (g: 120°, t: 120°), (g: 180°, t: 180°), and for four of the six 60° disparities (g: 0°, t: 60°), (g: 60°, t: 0°), (g: 120°, t: 180°), (g: 180°, t: 120°). As a consequence, three levels of disparity (0°, 60°, 120°) can be compared without any confounded influence of target or global orientation. The respective mean RTs and error rates in the three levels of disparity were 1273 msec (0.86%), 1295 msec, (1.00%), and 1330 msec (1.59%). Thus, RTs as well as the error rates increase with increasing disparity. A one-way ANOVA indicates that the mean RTs differ significantly, $F(2, 22) = 6.02$, $p < .01$.

Discussion

Experiment 1 replicated the finding of Jolicoeur (1992) that the detection time for target letters in visual search is affected by their viewer-related orientation. The search times from 0° to 180° had the shape of the left half of the upper-case letter M. The possible reasons for this familiar RT pattern are not considered here (see Jolicoeur, 1988, for a discussion). More important, the detection time for the local target letters was additionally affected by their orientation with respect to the global letter of which they were part. Targets were detected faster when they had the same orientation as the letter on the global level: a *global–local orientation congruency* effect. The congruency effect did not depend on target identity: A target letter that seldom appeared in congruence with the global letter gained from its co-orientation in the same way as did a target that commonly appeared congruently oriented. A detailed analysis of the influence of congruency showed that targets were slower detected the more disparately they were presented.

This pattern of results can be accounted for by assuming that, at least in a sufficient number of trials, a global frame of reference is aligned with the global letter. Consequently, the identification of all stimuli with the same or similar orientation is facilitated. If the target is incongruently oriented the frame of reference presumably has to be readjusted, which leads to increased RTs for targets in disparate orientations.

In Experiment 1 the adjustment of a global frame of reference was beneficial, as targets in general were often congruently oriented. This leaves unresolved the issue of whether the frame alignment with a global pattern was deliberately applied by the subjects as a useful strategy or whether it occurred more or less automatically whenever a global pattern was presented.

That the frame alignment might be automatic is suggested by evidence showing that the global properties of a pattern have an obligatory influence on the processing of its local parts (e.g. Navon, 1977). Moreover, an obligatory influence of a global frame of reference for the coding of spatial position of local details has been shown by Hommel and Lippa (1995, Experiment 2). They instructed subjects to respond to the colour of a black or white probe stimulus, which was located in the left or right eye of a face, presented on a computer screen. It is well known that responses are faster when the position of stimulus and response correspond (e.g. both on the left side) than when they do not correspond (e.g. stimulus left, response right). This is also the case when subjects respond to the non-spatial attribute of the stimulus colour, suggesting that stimulus location is automatically coded (Simon effect; Simon, Hinrichs, & Craft, 1970). This Simon effect was also observed with the face stimuli: Subjects responded to a left-eye stimulus (relative to the observer) faster with the left key than with the right key, and vice versa for right-eye stimuli. Interestingly, this effect also occurred when the faces were tilted by 90° so that the left and right stimulus position corresponded to an egocentrically top and bottom position. This suggests that stimulus location was coded in a global (face-based) frame of reference. As the stimulus location was task-irrelevant the authors concluded that the coding of stimulus location in a global frame of reference is obligatory.

Given these findings, aligning a frame of reference with a global pattern might be considered as being a "default procedure" that is more or less automatically used. If it is automatic, it should also occur when it will not improve search performance. This question was addressed in Experiment 2.

EXPERIMENT 2

Experiment 2 investigated whether a global–local orientation congruency effect can also be observed when the orientation of the global pattern is not predictive for target orientation. For this purpose the statistical covariation between global and target orientation of Experiment 1 was removed. In Experiment 2 both targets appeared equally often in each of the four viewer-related orientations under each of the four possible global orientations. Consequently, aligning a frame of reference with the orientation of the global letter would facilitate target detection in as many cases as would aligning it with any other of the remaining three possible target orientations. Therefore, no improvement of search performance would result from adopting such a strategy. Thus, if aligning a global frame of reference is under strategic control, it should not occur in this experiment, and no advantage for congruently oriented targets should be observed. If, on the other hand, a frame of reference is automatically aligned with the global letter, the advantage for congruently oriented targets should appear in the same way as in Experiment 1.

Method

Subjects

A total of 12 undergraduates (5 women, 7 men), aged between 20 and 24 years, served as subjects in fulfilment of a course requirement. None of them took part in Experiment 1.

Stimuli

Experiment 2 was a replication of Experiment 1 with the exception that both targets were rarely congruently presented (see left half of Table 1). Hence the orientation of the global letter did not covary with the orientation of the target letter.

Results

1.4% of the reaction times were discarded as outliers. RTs of correct responses were entered into a two-way ANOVA for repeated measures with the variables target orientation (0°, 60°, 120°, 180°) and congruency (incongruent vs. congruent).

Viewer-related target orientation again had a significant influence on RTs $F(3, 33) = 10.95$, $p < .001$, although the dip at 180° was less pronounced than in Experiment 1 (see Figure 3). The effect of congruency was weak, $F(1, 11) = 4.40$, $p > .05$, and restricted to targets in upright orientation, leading to a marginally significant interaction of target orientation and congruency, $F(3, 33) = 2.42$, $p < .10$. The mean error rate again was low (3.74%). No effects were significant in the analysis of error data.

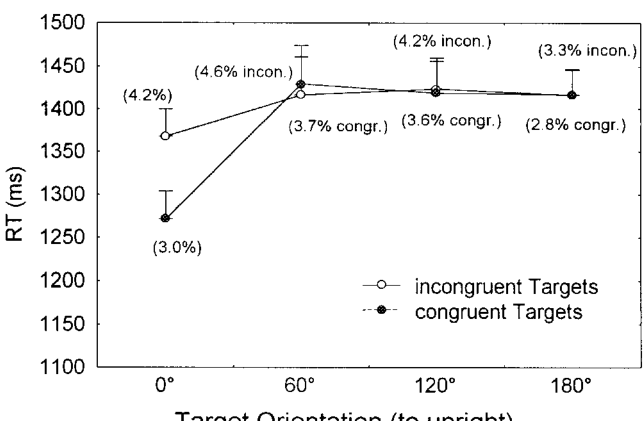

FIG. 3. Experiment 2. Mean reaction times (plus 95% confidence intervals) as a function of target orientation and global–target congruency. Mean error rates in parentheses.

As in Experiment 1, the influence of disparity was further explored. The mean RTs and error rates for targets that were 0°, 60°, or 120° disparately presented were 1384 msec (3.26%), 1412 msec (3.86%), and 1406 msec (3.94%). In this analysis disparity did not have a significant influence on RTs, $F(2, 22) = 1.44$, $p > .25$ or on error rates, $F(2, 22) = 0.73$.

In order to test the reliability of the apparently different influence of disparity in the two experiments a mixed ANOVA with experiment as a between-subjects variable and disparity as a within-subject variable was computed. The analysis revealed no main effect of experiment, $F(1, 22) = 1.34$, $p > .20$, but a significant influence of disparity on RTs, $F(2, 44) = 5.48$, $p < .01$. The interaction of experiment and disparity missed significance, $F(2, 44) = 1.78$, $p > .10$. A closer inspection of the data showed that this unexpected absence of a significant interaction is caused mainly by the fact that the influence of disparity is relatively low in the first block of Experiment 1 but grows with increasing practice. This is to be expected if the frame alignment is under strategic control, as a sufficient number of trials is necessary in order to establish the contingency between global and target orientation. If the data of the initial block of the experiment are excluded from the analysis, the differential influence of disparity in the two experiments becomes even more pronounced: RTs and error rates of 1222 msec (0.93%), 1240 msec (0.97%), and 1287 msec (1.74%) for the 0°, 60, and 120° disparity, respectively, in Experiment 1, and 1313 msec (2.96%), 1352 msec (3.56%), and 1320 msec (3.72%) in Experiment 2. An ANOVA for these data reveals the interaction of disparity and experiment as reliable, $F(2, 44) = 4.67$, $p < .02$. No effects are present in the error data.

Discussion

The purpose of Experiment 2 was to investigate whether the global target congruency effect persists although the global orientation was not predictive for target orientation. In comparison to Experiment 1 the influence of congruency was remarkably reduced and less systematic. This suggests that the alignment of a frame of reference is under strategic control. Yet as small congruency effects were still present in the data it would be premature to conclude that congruency had no effect at all. Further research is certainly warranted to clarify to what extent the alignment of a frame of reference is automatic versus strategic. So far we can conclude that (at least after a sufficient amount of practice) a process of frame alignment can be encouraged when it is beneficial for task performance, which of course suggests an influence of strategic factors.

GENERAL DISCUSSION

The present experiments intended to replicate and extend the effect of orientation congruency in visual search reported by Jolicoeur (1992). The main question addressed by the experiments was whether target detection profits from the co-alignment of the target with the orientation of an encompassing global letter. Additionally, the use of two different targets allowed us to test whether this expected benefit is restricted to a specific target, commonly appearing co-oriented with the global pattern, or whether it also generalizes to a second target letter, which rarely appears in a congruent orientation.

In Experiment 1 targets were often congruently oriented with the global letter, so that the orientation of the global letter was predictive for target orientation. The results were as follows. First, the time to detect a target increased up to a viewer-related orientation of 120° and had a dip at 180°. Second, targets that were congruently oriented with the global letter were detected faster than incongruently oriented targets. Third, detection times increased with growing disparity between global and target orientations. Fourth, the effects of viewer-related target orientation and of global–target orientation congruency were independent of target identity.

Experiment 2 tested whether the effect of global–target orientation congruency in Experiment 1 persists when the global orientation is not predictive for target orientation. The results showed that the influence of global–target disparity was weak and unsystematic. This suggests that the processes underlying the observed global–local orientation congruency effect are under strategic control.

The present global–local orientation congruency effect, unlike the congruency effects in the Jolicoeur (1992) study, can be attributed neither to an increased intra-distractor similarity nor to an accelerated normalization process in congruent displays. The data are in accordance with the assumption that subjects can use the early available orientation of a global pattern to align a spatial frame of reference, which allows the identification of all co-oriented local stimuli. This frame alignment can be encouraged when it is beneficial for task performance, which suggests that it is under voluntary control.

As one reviewer correctly remarked, the global–local orientation congruency effect can be regarded as a cueing effect: The orientation of the global letter served as a cue for the most probable target orientation, which facilitated the processing of targets in their expected alignment, irrespective of target identity. However, if one holds this view, two points must be specified.

First, previous research failed to demonstrate effects of pure orientation cues on object identification. For example, Braine (1965) found no effect of an acoustically presented orientation cue on object-naming accuracy. This result was replicated by McMullen, Hamm, and Jolicoeur (1995) using visual orientation cues (point markers and arrows). Thus, if one accounts for the present congruency effects by cueing, it is necessary to specify what in contrast to the cues in the foregoing studies makes the global letter in the present study an effective orientation cue. The fact that in the present experiments the targets were an inherent local part of the global letter might be crucial in this respect. The global aspects of the common visual input (e.g. the global orientation of a scene or the global layout of an object) mostly provide a reliable cue for the orientation of its parts. Thus, it is reasonable to assume that the visual system is specifically adapted to this ubiquitous congruency between the orientation of global patterns and their local parts. Second, if one considers congruency effects as an effect of orientation cueing, it remains to be specified by which processes the cues take effect. The assumption of a frame of reference adjustment provides a reasonable conceptualization for such a process, which accounts for the present results as well as for the congruency effects in the studies by Jolicoeur (Jolicoeur, 1990, 1992). However, further experiments are needed before the notion of the frame alignment can be said to be clearly proved.

Further experiments are also warranted to clarify to what extent the global–local orientation congruency effects are automatic or strategic. For example, if there is a strong strategic component involved, subjects should also be able to prepare for non-congruently oriented targets, as long as the targets are reliably displaced by a constant amount relative to the global letter (for example +120° clockwise). This should not be possible if the actual orientation of the presented global pattern captures the frame of reference in an automatic fashion.

Despite the open questions, the present demonstration of the orientation-congruency effect provides further evidence for the ability of the visual system to facilitate selectively the processing of visual stimuli in a certain orientation, which has seldomly been demonstrated so far. The notion that this is due to an alignment of a frame of reference certainly needs further confirmation, and it is also necessary to specify the conditions under which the phenomenon occurs.

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Original manuscript received 18 November 1997
Accepted revision received 19 January 1999