Psychonomic Bulletin & Review
2003, 10 (4), 877-883

BRIEF REPORTS

Orienting in space and time: Joint contributions to exogenous spatial cuing effects

BRUCE MILLIKEN
McMaster University, Hamilton, Ontario, Canada

JUAN LUPIÁÑEZ
Universidad de Granada, Granada, Spain

and

MARTHA ROBERTS and BILJANA STEVANOVSKI
University of Waterloo, Waterloo, Ontario, Canada

We examined whether the time course of exogenous spatial-cuing effects is sensitive to the allocation of attention in time. Expectation for a target within a particular time window following the cue was manipulated by varying the proportion of trials that appeared at each of three stimulus onset asynchronies in both a detection task and a two-alternative forced-choice discrimination task. The time course of spatial-cuing effects was sensitive to the temporal expectation manipulation only in the discrimination task. The results are discussed with reference to the role of attentional set in exogenous spatial-cuing paradigms.

The spatial-cuing method has been used by many researchers to study the orienting of attention in space (e.g., Posner & Cohen, 1984). Recently, a similar method has been used to study the orienting of attention in time (Coull, Frith, Buchel, & Nobre, 2000; Miniussi, Wilding, Coull, & Nobre, 1999). Although space and time might reasonably be thought of as orthogonal dimensions in which attention can be oriented, to our knowledge little research has been directed to this issue.[1] The interaction between spatial and temporal orienting was the focus of the experiment described below.

Exogenous Spatial and Endogenous Temporal Orienting

The spatial-orienting procedure that we used involved the presentation of an exogenous spatial cue (a brightening) at one of two marked locations. The cues were not predictive of the location of the subsequent target. In a seminal study in which this procedure was used, Posner and Cohen (1984) demonstrated that less time was required to detect a target at cued locations than at uncued locations when the cue–target stimulus onset asynchrony (SOA) was less than about 300 msec. However, for longer cue–target SOAs, the opposite pattern of results was observed; that is, response times (RTs) were longer for cued than for uncued targets. The latter effect is now commonly known as inhibition of return (IOR: see Klein, 2000, for a recent review).

A common theoretical account of these cuing effects assumes that an abrupt onset cue captures attention automatically. Consequently, targets are responded to more quickly at the cued than at the uncued location when they appear shortly after the cue. However, for longer intervals between the cue and the target, attention is disengaged from the cued location prior to target onset. The resulting slower responses for cued than for uncued targets are thought to reflect an inhibition process that prevents attention from returning to where it has already been.

Although the capture of attention by a peripheral cue is often described as automatic, not all researchers agree on this point. In particular, Folk, Remington, and Johnston (1992) have proposed that the capture of attention depends on the attentional set adopted by the observer (see Ruz & Lupiáñez, 2002, for a review). Furthermore, a growing lit-

The research reported in this article was funded by an NSERC research grant awarded to B.M. and by Spanish Ministry of Education and Culture Research Grant BSO2000-1503 awarded to J.L. We thank Bob Rafal for informing us of a similar set of experiments conducted by Andrea Berger (see note 1) and Mari Reiss Jones for comments on earlier versions of the manuscript. Correspondence concerning this article should be addressed to B. Milliken, Department of Psychology, McMaster University, Hamilton, ON, L8S 4K1 Canada (e-mail: millike@mcmaster. ca).

Note—This article was accepted by the previous editorial team, while John T. Wixted was editor.

erature suggests that spatial-cuing effects measured following attentional capture are subject to modulation by endogenous attentional processes. For example, several recent studies have demonstrated that the time course of exogenous spatial-cuing effects is sensitive to factors that alter strategic aspects of processing (Danziger & Kingstone, 1999; Lupiáñez & Milliken, 1999; Lupiáñez, Milliken, Solano, Weaver, & Tipper, 2001). Given these prior studies, it seemed reasonable to ask whether a manipulation of endogenous attention in time would modulate the exogenous allocation of attention in space.

The temporal-orienting procedure that we used varied the proportion of trials presented at each of three cue–target SOAs: 100, 500, and 900 msec. In principle, manipulating the proportions of trials that occur at each SOA ought to affect how subjects allocate attention in time. Indeed, several recent studies have shown that attention can be endogenously oriented to a specific moment in time (Coull et al., 2000; Miniussi et al., 1999). In these studies, a cue was presented at fixation, indicating that a subsequent target (also to be displayed at fixation) would most likely appear after either a short (600 msec) or a long (1,400 msec) temporal interval. These cues were effective in inducing shifts of attention in time, since detection responses were faster for targets appearing at expected intervals than for targets appearing at unexpected intervals.

The Interaction Between Spatial and Temporal Orienting

How might spatial and temporal orienting interact? A starting place for thinking about this issue is to assume that the orienting of attention in time is related to the preparatory state, or attentional set, of subjects in advance of the onset of a target stimulus. Characterizing temporal orienting in this manner establishes a bridge to conceptual issues in the attention capture literature. In particular, Folk et al. (1992) proposed that attention capture by a cue depends on the task subjects are required to perform on a following target. In their study, when a target task required selection of an abrupt onset singleton, an abrupt onset singleton cue produced an attention capture effect, whereas a color singleton cue failed to do so. Similarly, when a target task required selection of a color singleton, a color singleton cue produced an attention capture effect, whereas an abrupt onset singleton cue failed to do so.

To extend this framework to the study of temporal orienting, we assume that the nature of a task (e.g., color singleton vs. onset singleton), as well as other factors related to preparatory state, can alter an attentional set and, consequently, modulate the influence of an exogenous spatial cue. In particular, we propose that the effect of an exogenous spatial cue may depend on whether that cue appears during a period of time in which a subject is optimally prepared for the onset of a target. For example, consider an exogenous spatial cue that appears just 100 msec prior to the point in time at which a subject expects a target to appear. In this case, the preparatory set engaged by the subject in anticipation of a target is likely to be in place when the cue appears. In contrast, if an exogenous spatial cue appears a full 900 msec before the subject expects a target to appear, the preparatory set engaged by the subject in anticipation of a target is less likely to be in place when the cue appears. The difference in the preparatory states upon onset of the cue in these two situations could, in turn, modulate the influence of the spatial cue on performance.

Given this general framework, predictions concerning the interaction between spatial and temporal orienting can be made. For example, it seems plausible that attention capture would be strongest when the cue occurs while the subject is in an optimal state of preparation for the target. In the context of this study, this interaction between temporal and spatial orienting would reveal itself in larger spatial-cuing effects in the 100-msec SOA condition when subjects expect the target to appear 100 msec after the cue than when they expect the target to appear 900 msec after the cue.

Although predictions regarding cuing effects at longer SOAs are assumption dependent, it is worth specifying at least one possibility. As a guide to this prediction, we refer to Klein's (2000) proposal that exogenous spatial-cuing effects reflect two influences that produce opposite effects on performance. This proposal is depicted in Figure 1. The positive influence is depicted by the dashed line and represents the influence of the capture of attention at the cued location. This influence speeds performance for cued relative to uncued trials, is large at short cue–target SOAs, but decreases rapidly with increasing SOA. The negative influence is depicted by the dotted line and represents the influence responsible for the IOR effect. Note that this influence slows responses to cued, relative to uncued, trials and is equivalent across the range of SOAs. The measured cuing effect is depicted by the solid line and is simply the sum of the two influences described above.

For the sake of simplicity, we assume that temporal expectancy will affect only the positive influence on cuing effects (i.e., the attention capture component), which we depict by shifting the dashed line upward. As was noted above, changing this positive influence should affect the magnitude of positive cuing effects at short SOAs (note the different lengths of the double-headed arrows in the upper and lower panels). However, note that magnifying the positive influence can produce two further effects: a shift in the point at which cuing effects change from facilitation to IOR (note the different positions of the circled area in the upper and lower panels) and smaller IOR effects at longer SOAs. These predictions were used as a starting point for interpreting the interaction between spatial and temporal orienting in the experiment described below.

METHOD

Subjects

One hundred forty-four undergraduate students from McMaster University received course credit or were paid for their participation. All had normal or corrected-to-normal vision.

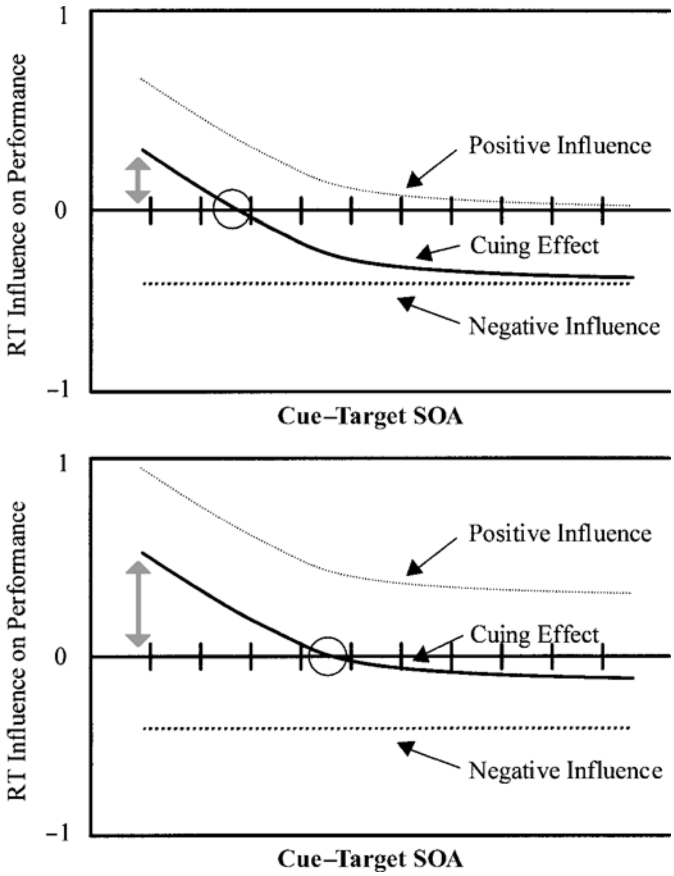

Figure 1. Hypothetical cuing effects as a function of stimulus onset asynchrony (SOA) broken down into two components, as proposed by Klein (2000). In the top panel, the component that produces faster responses for cued than for uncued trials (the positive influence) is depicted as a dashed line, whereas the component that produces slower responses for cued than for uncued trials (the negative influence) is depicted as a dotted line. The resulting cuing effect is the sum of these two components and is depicted as a solid line. The lower panel differs from the upper panel only in that the positive influence, which is presumed to reflect the capture of attention at the cued location, is larger in the lower panel. Note that this change in the positive influence can (1) magnify cuing effects measured at short SOAs (see the different lengths of the gray double-headed arrows in the two panels), (2) delay the transition of cuing effects from positive to negative (see the shift in position of this transition point, marked by a circle, from the upper to the lower panel), and (3) produce smaller inhibition of return effects at long SOAs.

Design

The experiment consisted of a 2 (task: detection/discrimination) × 3 (bias: unbiased/short/long) × 3 (SOA: 100/500/900 msec) × 2 (cuing: cued/uncued) mixed factorial design, in which task and bias were between-subjects variables and SOA and cuing were within-subjects (within-blocks) variables. Each task[2] was completed by 72 subjects, randomly assigned to one of the three levels of bias. In the unbiased condition, there were equal proportions of trials at each SOA. In the short- (long-) bias condition, 66% of the trials were presented at the 100-msec (900-msec) SOA, 17% at the 500-msec SOA, and 17% at the 900-msec (100-msec) SOA.

Materials

Stimuli were presented on a Sony SVGA monitor connected to an IBM personal computer, running MEL software (Schneider, 1988). Stimuli consisted of two black boxes (1.4º in width and 1.7º in height) that were displayed 8.5º to the right and left of a central fixation cross (a plus sign, +) on a pale gray background. The target was either a black X or a black O displayed in the center of one of the two boxes. Target letters were 0.4º in width and 0.8º in height and were viewed at a distance of approximately 57 cm.

Procedure

Prior to beginning the experimental session, the subjects read a set of instructions displayed on the computer monitor. In the discrimination task, the subjects were asked to decide whether the letter was an X or an O as quickly and accurately as possible and to respond by pressing the X or the M key on a standard keyboard (response key mappings were counterbalanced across subjects). In the detection task, the subjects were asked to make a response by pressing the B key upon onset of any target and to withhold responses on the 20% of the trials in which a target was not presented (i.e., catch trials). Auditory feedback for incorrect responses allowed the subjects to monitor their accuracy.

A trial began with the display of the central fixation cross and the two boxes for 1,000 msec. One of the boxes then changed to white for 50 msec, which created the illusion of a flicker. At varying intervals following the offset of this cue, the target was then presented for 100 msec, producing a cue–target SOA of 100, 500, or 900 msec. The boxes and the fixation cross remained visible for 2,000 msec after the offset of the target or until the subject made a response. The entire display then disappeared, leaving only a blank screen. The boxes and the fixation point reappeared 500 msec later, marking the start of a new trial.

Half of the trials were cued (the target appeared at the cued location), and the other half were uncued, so that the cue provided no predictive information about the location of the target. Short-SOA trials were most probable in the short-bias group, long-SOA trials were most probable in the long-bias group, and the three SOAs were equally probable in the unbiased group. Given that the duration of the fixation point was constant across trials, the subjects in the two biased groups could use the fixation point to anchor an expectation for when the target would appear: 1,100 msec after fixation onset (and 100 msec after cue onset) in the short-bias group or 1,900 msec after fixation onset (and 900 msec after cue onset) in the long-bias group.

After the instructions had been read and understood, the subjects pressed the space bar to begin a set of 48 practice trials, followed by four blocks of test trials. Each block of test trials proceeded until 96 correct responses were recorded in the discrimination task or until 120 correct responses were recorded (96 correct responses to targets and 24 correct response omissions to catch trials) in the detection task. In each bias condition, the proportion of trials in each condition within a block mirrored that for the experimental session as a whole. After every 16 trials in both the practice and the test sessions, a message appeared on the screen, reminding the subjects to keep their eyes on the fixation cross and to be fast and accurate. The experimental session lasted approximately 30 min.

RESULTS AND DISCUSSION

RTs for correct responses in the discrimination task and for hits in the detection task were first submitted to an outlier elimination procedure (Van Selst & Jolicœur, 1994) that excluded 2.3% of the RTs from further analyses.[3] Mean RTs were computed using the remaining observations and then were submitted to a 2 × 3 × 2 × 3 (task × bias × cuing × SOA) mixed factorial analysis of variance (ANOVA) with task and bias as between-subjects variables. Mean RTs and error rates for each condition are displayed in Table 1.

Spatial Orienting

The usual effects of exogenous spatial cues on performance were reflected in a significant interaction between cuing and SOA [$F(2,276) = 59.18$, $MS_e = 379.63$, $p < .001$]. Simple main effects tests revealed significantly faster responses for cued than for uncued trials for the 100-msec SOA (458 vs. 467 msec) and significantly slower responses for cued than for uncued trials for both the 500-msec (466 vs. 444 msec) and the 900-msec (465 vs. 441 msec) SOAs. These results correspond to those in many prior studies of exogenous spatial cuing.[4]

Temporal Orienting

As is illustrated in Figure 2, which presents RT collapsed over cue status, there were robust temporal-orienting effects in this experiment. The effect of temporal orienting was revealed by a significant interaction between bias and SOA [$F(4,276) = 76.97$, $MS_e = 475.13$, $p < .001$]. Although this interaction was modulated by task [$F(4,276) = 2.79$, $MS_e = 475.13$, $p < .03$], separate analyses of the two tasks revealed significant bias × SOA interactions that were qualitatively similar [see Figure 2; $F(4,138) = 47.09$, $MS_e = 493.62$, $p < .001$, and [$F(4,138) = 32.08$, $MS_e = 456.64$, $p < .001$, for the detection and the discrimination tasks, respectively]. In the short-bias condition of both the detection and the discrimination tasks, RTs were lowest for the 100-msec SOA and increased monotonically with increases in SOA. This pattern of data produced significant linear trends across SOA for both tasks [$F(1,23) = 127.00$, $MS_e = 268.62$, $p < .001$, and $F(1,23) = 12.45$, $MS_e = 590.59$, $p < .005$, respectively]. In neither case was the residual quadratic trend significant. In the long-bias

Table 1
Mean Response Times (RTs, in Milliseconds) and Percentages of Errors (ERs) for Each Task, Stimulus Onset Asynchrony (SOA) Bias, and Level of Cuing

	SOA (msec) in Detection Task												SOA (msec) in Discrimination Task											
	100				500				900				100				500				900			
	RT		ER		RT		ER		RT		ER		RT		ER		RT		ER		RT		ER	
Condition	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
Short Bias																								
Cued	334	9.0	1.5	0.6	374	10.3	2.7	1.0	388	10.8	4.8	1.6	518	19.4	5.7	0.9	551	22.7	6.6	1.2	561	26.0	5.5	1.2
Uncued	335	10.7	3.1	1.1	342	12.2	2.5	0.9	356	8.2	4.3	1.2	547	21.5	6.4	1.0	534	19.4	6.3	1.0	539	19.6	5.1	1.1
Unbiased																								
Cued	382	12.1	1.3	0.4	391	10.8	0.8	0.3	403	10.4	1.2	0.5	541	18.3	5.2	1.0	535	18.7	5.4	1.0	536	20.1	4.1	0.8
Uncued	383	11.9	1.0	0.3	347	10.7	0.8	0.3	364	10.5	0.9	0.3	556	18.7	5.7	1.1	537	18.8	6.1	1.2	531	17.4	4.3	1.1
Long Bias																								
Cued	413	12.3	1.3	0.4	394	8.2	1.6	0.4	381	8.2	1.1	0.3	562	15.6	3.8	0.8	551	15.0	4.2	0.9	517	16.4	3.9	0.8
Uncued	408	9.7	1.2	0.5	360	6.9	1.1	0.4	346	7.1	1.0	0.3	566	15.2	4.0	1.0	541	15.8	4.1	0.9	509	15.6	3.7	0.8

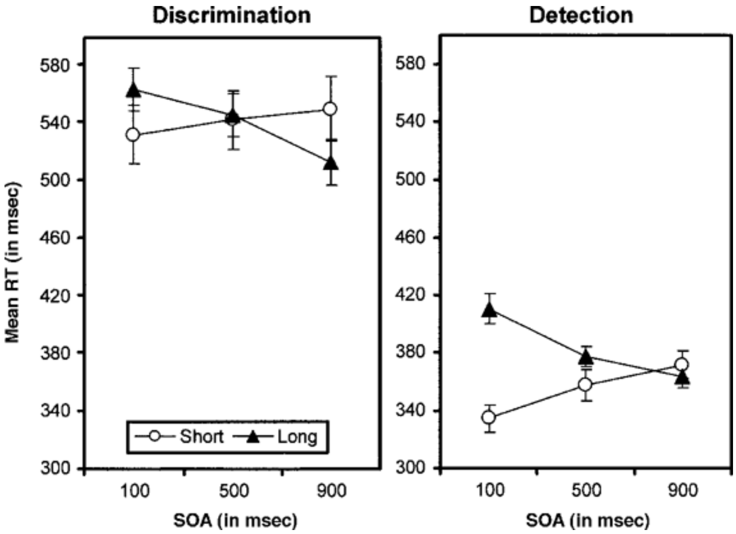

Figure 2. Mean response times (RTs, in milliseconds) for the short-bias and long-bias groups as a function of stimulus onset asynchrony (SOA; 100, 500, and 900 msec) and task (detection vs. discrimination). Note that responses were fastest for short SOAs in the short-bias group and for long SOAs in the long-bias group for both tasks.

condition, RTs were highest for the 100-msec SOA and decreased monotonically with increases in SOA, again producing significant linear trends for both tasks [$F(1,23) = 54.63$, $MS_e = 971.17$, $p < .001$, and $F(1,23) = 122.12$, $MS_e = 508.01$, $p < .001$, respectively]. The residual quadratic trends were also significant [$F(1,23) = 8.56$, $MS_e = 365.71$, $p < .01$, and $F(1,23) = 9.16$, $MS_e = 201.47$, $p < .01$] but accounted for relatively small proportions of variance (.06 and .03, respectively).

These results illustrate a robust effect of temporal expectancy in both the detection and the discrimination tasks. These effects were observed both when the most frequent SOA was short and when the most frequent SOA was long, demonstrating that they were not due simply to increases in readiness with increases in SOA (Niemi & Näätänen, 1981). Instead, the results suggest that the subjects generated an expectancy for a stimulus within a particular time window (see also Coull et al., 2000; Miniussi et al., 1999). Whereas prior studies of temporal orienting used a detection task and just two SOAs, the use of both detection and discrimination tasks and three SOAs allowed us to measure a robust linear trend in performance across SOA that generalized across tasks.

Interactions Between Spatial and Temporal Orienting

The interaction between spatial and temporal orienting is reflected in statistical interactions that involve the bias and cuing variables. The highest order significant interaction involving these variables was the four-way interaction between task, bias, cuing, and SOA [$F(4,276) = 2.62$, $MS_e = 379.63$, $p < .05$]. We examined this interaction further by conducting separate analyses for each task. These analyses treated cuing effects (uncued RT − cued RT) as the dependent variable and bias and SOA as within-subjects independent variables. Note that when cuing effects serve as a dependent variable, an interaction between spatial and temporal orienting will produce a main effect of bias, rather than an interaction between cuing and bias. Furthermore, if an interaction between spatial and temporal orienting itself depends on SOA, the bias × SOA interaction ought to be significant.

Cuing effects are shown in Figure 3. Values greater than zero depict facilitation effects, whereas those less than zero depict IOR effects. Note that in all the task and bias conditions, cuing effects shifted in a negative direction with increases in SOA. This trend was reflected in significant main effects of SOA for both detection and discrimination tasks [$F(2,138) = 62.51$, $MS_e = 467.30$, $p < .001$, and $F(2,138) = 15.93$, $MS_e = 1{,}051.22$, $p < .001$, respectively].

Of central interest were effects that involved the bias factor. In the detection task, neither the main effect of bias nor the interaction between bias and SOA approached statistical significance (both ps $> .30$), suggesting that spatial and temporal orienting did not interact in this task. In contrast, in the discrimination task, although the main effect of bias was not significant ($p > .30$), the interaction between bias and SOA was significant [$F(4,138) = 3.04$, $MS_e = 1{,}051.22$, $p < .02$]. This result indicates that spatial and temporal orienting did interact in the discrimination task and, in particular, that this interaction depended on cue–target SOA.

We further examined this interaction in the discrimination task by evaluating whether it conformed to predictions set forth in the introduction. One prediction was that spatial-cuing effects at the 100-msec SOA ought to be larger for

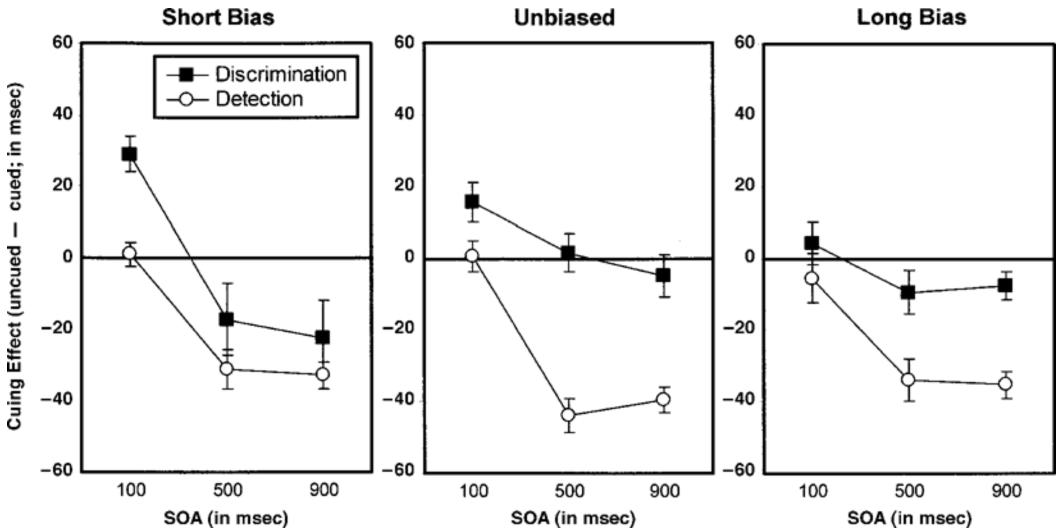

Figure 3. Cuing effects as a function of stimulus onset asynchrony (SOA; 100, 500, and 900 msec) and task (detection vs. discrimination) are presented in each panel. The results from the short-bias group are presented in the left panel, those from the unbiased group are presented in the middle panel, and those from the long-bias group are presented in the right panel. Positive values represent faster response times (RTs) for cued than for uncued targets, whereas negative values represent slower RTs for cued than for uncued targets (inhibition of return).

the short-bias condition than for the long-bias condition. A one-way ANOVA on cuing effects for the 100-msec SOA revealed a significant effect of bias [$F(2,69) = 5.03$, $MS_e = 727.65$, $p < .01$; see Figure 3]. Fisher's LSD tests indicated that the cuing effect for the short-bias condition (29 msec) differed significantly from that for the long-bias condition (4 msec), whereas the difference between the short-bias and the unbiased conditions (15 msec) approached significance ($p < .10$). Thus, the first prediction was confirmed. The second prediction was that, as a function of the larger attention capture effect just described, the transition from facilitation to IOR might be delayed and IOR effects might be smaller for the short-bias group than for the other two groups. A quick look at Figure 3 reveals that this prediction was not confirmed. The prediction is contradicted most clearly by the relative sizes of the IOR effects at the two longer SOAs. If anything, the IOR effects are larger, rather than smaller, in the short-bias condition than in the other two conditions.[5]

Other Significant Effects

As is clear in Figures 2 and 3, responses were much faster in the detection task than in the discrimination task. This difference was reflected in a significant main effect of task in the overall analysis [$F(1,138) = 200.87$, $MS_e = 30{,}495.28$, $p < .001$]. Although there were several other significant effects in this analysis, all were qualified by a higher order interaction, described above, and as such are not discussed further.

Errors

In the detection task, the false alarm rates on catch trials were 7.0%, 10.4%, and 1.8%, respectively, for the unbiased, short-bias, and long-bias conditions. Since cuing and SOA conditions are indistinguishable on catch trials, no further analyses were conducted on false alarms. Percentages of misses on target trials, collapsed across subjects, are displayed in Table 1. These data were submitted to an ANOVA that treated bias as a between-subjects variable and cuing and SOA as within-subjects variables. This analysis revealed a significant main effect of bias [$F(2,69) = 4.82$, $MS_e = 42.05$, $p < .05$]. Examination of the means suggests that more misses occurred in the short-bias condition (3.1%) than in either the unbiased (1.0%) or the long-bias (1.2%) condition. There was also a significant interaction between bias and SOA [$F(4,138) = 3.53$, $MS_e = 7.59$, $p < .01$], suggesting that this effect was particularly large at the longest SOA. There were no other significant effects in this analysis.

In the discrimination task, errors consisted of trials on which the subjects made either an incorrect response or no response. Error percentages for each condition, collapsed across subjects, are displayed in Table 1. An ANOVA similar to that conducted on the detection task data revealed only a significant main effect of SOA [$F(2,138) = 3.70$, $MS_e = 10.74$, $p < .05$], with the fewest errors occurring in the long-SOA condition.

CONCLUSION

Following Folk et al. (1992; see also Klein, 2000), we proposed that temporal expectancy can affect attentional set and that, in turn, exogenous spatial-cuing effects may depend on temporal expectancy. Our results revealed such a dependency, although only in the discrimination task. In addition, the prediction that temporal expectancy would selectively affect one of two separate components of spatial-cuing effects was not supported. As such, although the present results illustrate that temporal expectancy can modulate exogenous spatial-cuing effects, the theoretical proposal outlined in the introduction must be reconsidered.

Given robust temporal-orienting effects in both tasks but an interaction between temporal and spatial orienting only in the discrimination task, it seems possible that temporal-orienting effects (see Figure 2) and the interaction between temporal and spatial orienting (see Figure 3) depend on different processes. For example, the temporal expectancy manipulation may have altered the preparatory state of the subjects in both tasks, thus explaining the pattern of temporal-orienting effects in Figure 2. However, temporal expectancy also may have altered strategic aspects of processing related to when attention was disengaged from the cued location. Although it is not immediately clear why a high proportion of short-SOA trials would produce an abrupt shift of attention away from the cued location (see the left panel of Figure 3), the notion that disengagement of attention can be affected by factors unrelated to the spatial predictability of cues is worthy of further study.

REFERENCES

Coull, J. T., Frith, C. D., Buchel, C., & Nobre, A. C. (2000). Orienting attention in time: Behavioral and neuroanatomical distinction between exogenous and endogenous shifts. *Neurospychologia*, **38**, 808-819.

Danziger, S., & Kingstone, A. (1999). Unmasking the inhibition of return phenomenon. *Perception & Psychophysics*, **61**, 1024-1037.

Folk, C. L., Remington, R. W., & Johnston, J. C. (1992). Involuntary covert orienting is contingent on attentional control settings. *Journal of Experimental Psychology: Human Perception & Performance*, **18**, 1030-1044.

Klein, R. M. (2000). Inhibition of return. *Trends in Cognitive Sciences*, **4**, 138-147.

Lupiá ez, J., & Milliken, B. (1999). Inhibition of return and the attentional set for integrating versus differentiating information. *Journal of General Psychology*, **126**, 392-418.

Lupiá ez, J., Milliken, B., Solano, C., Weaver, B., & Tipper, S. P. (2001). On the strategic modulation of the time course of facilitation and inhibition of return. *Quarterly Journal of Experimental Psychology*, **54A**, 753-773.

Miniussi, C., Wilding, E. L., Coull, J. T., & Nobre, A. C. (1999). Orienting attention in time: Modulation of brain potentials. *Brain*, **122**, 1507-1518.

Niemi, P., & Näätänen, R. (1981). Foreperiod and simple reaction time. *Psychological Bulletin*, **89**, 133-162.

Posner, M. I., & Cohen, Y. (1984). Components of visual orienting. In H. Bouma & D. G. Bouwhuis (Eds.), *Attention and performance X: Control of language processes* (pp. 531-556). Hillsdale, NJ: Erlbaum.

Ruz, M., & Lupiá ez, J. (2002). A review of attentional capture: On its automaticity and sensitivity to endogenous control. *Psicológica*, **23**, 283-309.

Schneider, W. (1988). Micro Experimental Laboratory: An integrated system for IBM PC compatibles. *Behavior Research Methods, Instruments, & Computers*, **20**, 206-217.

Van Selst, M. A., & JolicÄur, P. (1994). A solution of the effect of sample size on outlier elimination. *Quarterly Journal of Experimental Psychology*, **47A**, 631-650.

NOTES

1. After completing the present study, we became aware of a set of experiments conducted by Andrea Berger (personal communication) in which spatial and temporal orienting were examined together in the same experiment. The procedure was similar to that described here, with the exception that performance was measured only in a detection task, rather than in both detection and discrimination tasks. In accord with the results presented here, Berger found no influence of the proportion of trials presented at each SOA in detection tasks.

2. The detection and discrimination tasks were initially completed as separate experiments. They are presented here as a between-subjects variable for expository purposes.

3. Van Selst and Jolicœur's (1994) outlier procedure adopts outlier criteria that are sensitive to the number of observations in a cell, thus ensuring that the proportion of outliers excluded is not affected systematically by cell size.

4. It is worth noting that a facilitation effect was not observed in the 100-msec SOA condition when the detection task was considered alone. Although the well-known findings of Posner and Cohen (1984) suggest that this result is anomalous, a close look at the remainder of the literature on exogenous spatial cuing suggests otherwise. A facilitation effect at short cue–target SOAs is not always observed. We count as important the fact that IOR was not present at the 100-msec SOA and that it was present at longer cue–target SOAs, a pattern that has been observed with reasonable consistency in studies similar to ours.

5. To evaluate this prediction, we also conducted an ANOVA on cuing effects that treated bias as a between-subjects variable and SOA (500/900 msec) as a within-subjects variable. For the prediction to hold, there ought to be a main effect of bias, with the smallest IOR effects in the short-SOA bias condition or perhaps an interaction between bias and SOA. In fact, there were no significant effects in the analysis ($p > .10$). Indeed, the statistical effect that should have been most sensitive to this prediction was the main effect of bias on cuing effects when all three SOAs were included in the analysis (see the earlier analysis), and as has been noted, this effect was clearly not significant ($p > .30$).

(Manuscript received October 24, 2001;
revision accepted for publication August 8, 2002.)