

---

## RESEARCH ARTICLES

---

# Are spatial selection and identity extraction separable when attention is controlled endogenously?

SHAHAB GHORASHI

*University of British Columbia, Vancouver, British Columbia, Canada*

THOMAS M. SPALEK

*Simon Fraser University, Burnaby, British Columbia, Canada*

JAMES T. ENNS

*University of British Columbia, Vancouver, British Columbia, Canada*

AND

VINCENT DI LOLLO

*Simon Fraser University, Burnaby, British Columbia, Canada*

Visual search for a target involves two processes: spatial selection and identity extraction. Ghorashi, Enns, and Di Lollo (2008) found these processes to be independent and surmised that they were carried out along distinct visual pathways: dorsal and ventral, respectively. The two experiments that are described in the present article evaluated this hypothesis. Attentional-blink methodology was combined with voluntary spatial cuing in a visual search task: Intertarget lag was used to manipulate identity extraction; predictive cues were used to signal target locations. Central digit cues in Experiment 1 required participants to identify digits before voluntarily directing attention to a corresponding location, whereas flashed dots in Experiment 2 (indicating an opposite location) required attentional redeployment without prior cue identification. Consistent with the dual-pathway hypothesis, cuing was impaired only when the first target and the number cue competed for ventral-pathway mechanisms. Collectively, the results support the dual-pathway account of the separability of spatial selection and identity extraction.

---

A visual target that is presented in a field of distractors is identified more quickly and more accurately when its location is singled out by a temporally leading spatial cue (Colegate, Hoffman, & Eriksen, 1973; Eriksen & Hoffman, 1972). It is commonly agreed that a spatial cue acts to orient attention to a specific location in the visual field, and that attention then enhances target identification (e.g., Wolfe, 2007; Wolfe, Cave, & Franzel, 1989). Whether the mechanisms underlying the processes of spatial selection and identity extraction function independently or interact with one another has been investigated by Ghorashi, Di Lollo, and Klein (2007) and by Ghorashi, Enns, Klein, and Di Lollo (2009), who found the two factors to be separable. The present experiments examined whether this separability also occurs when the processes that are involved in attentional orienting are goal directed rather than stimulus driven, as was the case in the earlier studies.

Ghorashi et al. (2007; Ghorashi, Enns, & Di Lollo, 2008) combined two experimental paradigms to influence spatial selection and identity extraction separately within the same experiment. Spatial selection was manipulated by the presence or absence of a spatial cue that was displayed directly before the target in a visual search array. Identity extraction was manipulated by means of the phenomenon known as the *attentional blink* (AB), which is an impairment in the identification accuracy of the second of two targets that are inserted in a stream of distractors that are displayed in rapid serial visual presentation (RSVP). This second-target deficit is obtained when the temporal lag between the two targets is less than approximately 500 msec (Raymond, Shapiro, & Arnell, 1992); thus, identity extraction is impaired when the lag is short but not when it is long.

Theories of the AB differ as to what specific mechanisms mediate the loss of identification accuracy. Some

---

S. Ghorashi, ghorashi@psych.ubc.ca

---

invoke resource depletion (Duncan, Ward, & Shapiro, 1994), others propose a bottleneck between the registration of the second target and its later consolidation (Chun & Potter, 1995; Jolicœur & Dell'Acqua, 1998), and still others posit a loss of input control (Di Lollo, Kawahara, Ghorashi, & Enns, 2005; Olivers, Van der Stigchel, & Hulleman, 2007). Regardless of the specific mechanism, however, all theories attempt to explain the loss of identification accuracy that is the hallmark of the AB, and they use it as the dependent measure of choice to assess the magnitude of the deficit. Notably, none of these theories invokes loss of spatial information as a factor in the AB deficit. On the basis of these commonalities among the theories, we used the AB deficit as a tool of convenience to index any impairment in the process of extracting the identity of the second target.

Additive-factors logic (Sternberg, 1969) was employed by Ghorashi et al. (2009) to examine the separability of spatial selection, as manipulated by spatial cuing, and identity extraction, as manipulated by the AB. They reasoned that if cuing and the AB exhibit an orthogonal (additive) relationship, it would support the hypothesis that the underlying mechanisms are separable. If, on the other hand, cuing and the AB exhibit an interactive (multiplicative) relationship, the alternative hypothesis of interdependence would be supported, suggesting that spatial selection and identity extraction share common mechanisms. The results showed that the beneficial effect of the cue was the same when intertarget lag was short as when it was long. This means that the AB did not interfere with the processing of the spatial cue and, therefore, that the two processes were independent of one another.

Ghorashi et al. (2009) accounted for these findings by relating them to two major parallel pathways in primate vision: the dorsal and the ventral pathways. As well as being anatomically distinct, the two pathways are known to carry and process different types of information. Neurons in the dorsal stream are insensitive to color but respond readily to movement and low-contrast stimuli, attributes that make them suitable for processing spatial information. In contrast, neurons in the ventral stream are sensitive to color, have smaller receptive fields, and have slower conduction velocities, attributes that make them more suitable for processing the identity of objects. This functional specialization was first realized by Ungerleider and Mishkin (1982), who referred to the dorsal and the ventral pathways as the "where" and the "what" pathways, respectively.

According to Ghorashi et al. (2009), the separability of spatial selection and identity extraction can be mapped directly on the functional distinction between dorsal and ventral streams. Specifically, they suggested that spatial selection is carried out mainly along the dorsal pathway, and that target identification is carried out principally along the ventral pathway. Within this conceptual framework, spatial selection and identity extraction are separable because they are mediated by mechanisms that are anatomically and functionally distinct.

This dual-pathway approach provided a good account of the separability of location and identity processes, be-

cause it was plausible to suppose that the cue (a briefly presented dot at the location of the upcoming target) and the target (a letter that was to be identified and discriminated from other letters) were processed along separate pathways. Inherent in this account is the prediction that the separation of location and identity processing will no longer be in evidence if the spatial cue requires processing mechanisms that are also required for the processing of the target. This would be the case in an experiment in which the spatial cue itself requires identification, thus engaging the same ventral-stream mechanisms that are required for identification of the target. The present study was designed to test this prediction.

## EXPERIMENT 1

Experiment 1 built on the experiments that were reported by Ghorashi et al. (2007) and by Ghorashi et al. (2009). As in those experiments, spatial selection was manipulated by the presence or absence of a spatial cue, and identity extraction was manipulated by presenting the second target within the period of the AB, at short intertarget lags, or beyond the AB. The major difference in the present experiment was that the spatial cue itself required identification.

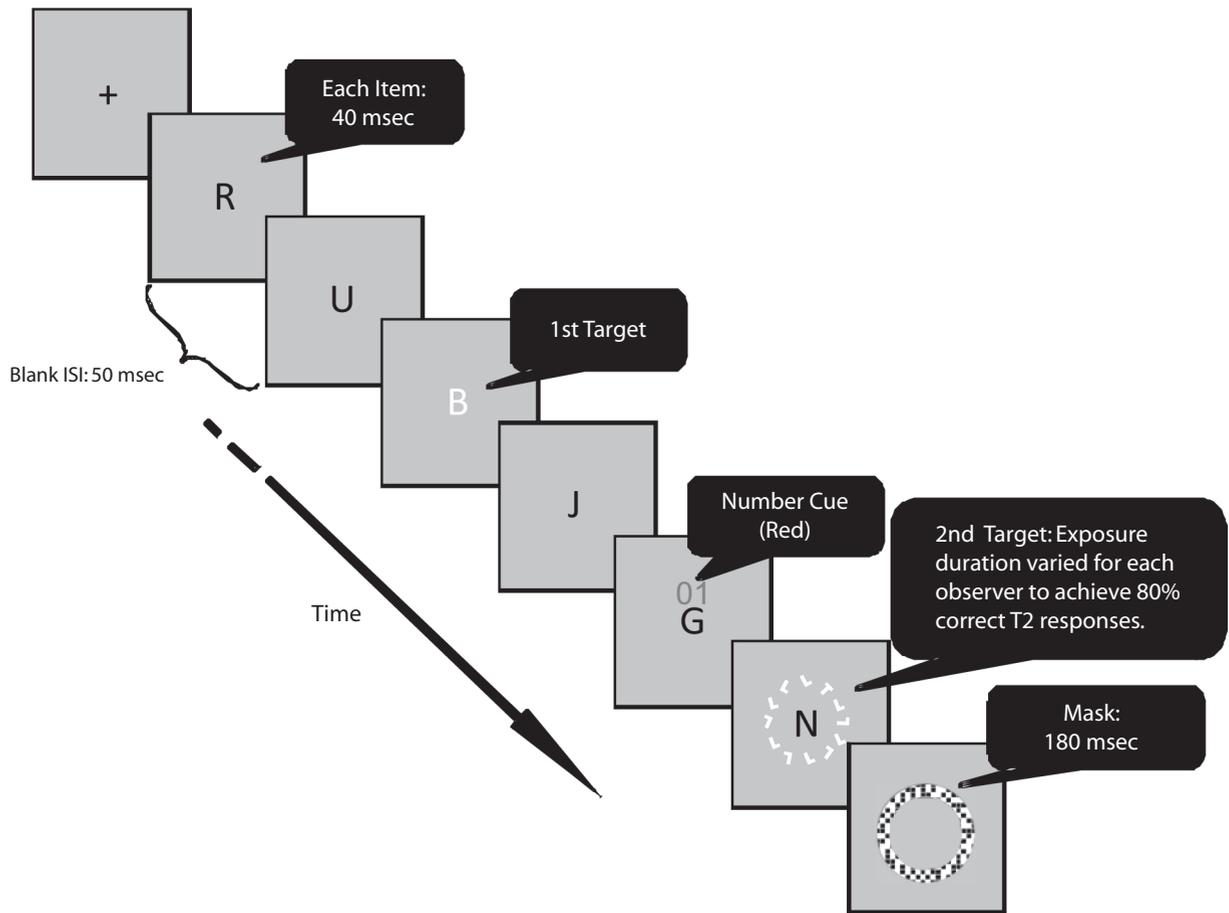
The display consisted of an RSVP stream of distractors (black letters) containing two targets. The first target was a white letter to be identified; the second target was a T that was tilted left or right and inserted in a circular search array of 11 rotated Ls, all arranged as in a clock face. The spatial cue was a red number between 01 and 12 that was presented just above the central RSVP stream, shortly before the presentation of the second target. The observers were told that the second target would be located at the clock location that was indicated by the number cue.

Given that this task required identification of both the cue and the first target, it is plausible to assume that the two stimuli engaged processing mechanisms that were at least partly overlapping. In terms of the dual-pathway framework outlined above, this means that both stimuli engaged ventral-pathway mechanisms. Using additive-factors logic, we would expect that stimuli that share common underlying mechanisms would exhibit an interactive—rather than additive—relationship. In practice, we expected the effectiveness of the number cue to be impaired at short intertarget lags, when it must share processing mechanisms with the first target, but not at longer lags. Thus, instead of the independence that was reported by Ghorashi et al. (2009), we expected spatial cuing and the AB to exhibit an interactive relationship.

## Method

**Observers.** Twenty-nine undergraduate students at Simon Fraser University participated for course credit. All reported normal or corrected-to-normal vision.

**Apparatus and Stimuli.** Stimuli were displayed on an NEC AccuSync 70-color monitor that was refreshed at 75 Hz and was controlled by an IBM-compatible microcomputer. The background was midgray, and it contained a black fixation cross that subtended 0.5° of visual angle at the center of the screen. The stimuli in the central RSVP stream consisted of black uppercase letters (distractors)



**Figure 1.** Sequence of events on each trial in Experiment 1. On this trial, the second target was cued.

and a white uppercase letter (the first target), all subtending  $0.6^\circ$  vertically. The search array containing the second target consisted of 11 randomly rotated Ls and one tilted T (the target). The letters in the search array subtended  $0.5^\circ$  vertically. The T was tilted  $45^\circ$  either to the left or to the right. The stimuli in the search array were spaced regularly around an imaginary clock face of  $2.5^\circ$  radius, centered at fixation. The spatial cue was a red two-digit number between 01 and 12, subtending  $0.5^\circ$  vertically, that was chosen randomly on each trial. The number cue was presented in the same frame as the distractor item that preceded the second target in the RSVP stream, and it was positioned directly above the distractor item ( $1^\circ$  center-to-center).

**Procedure.** All displays were viewed from a distance of approximately 60 cm. At the beginning of each trial, the fixation cross was presented in the center of the screen. Observers initiated each trial by pressing the space bar, at which point the fixation cross disappeared and the RSVP sequence began after a random delay of 400–800 msec. The distractors (black letters) in the RSVP stream were drawn randomly, without replacement, from the English alphabet, except Q. Each letter was displayed for 40 msec and was separated from the next letter by an interstimulus interval (ISI) of 50 msec, during which the screen was blank. This resulted in a stimulus onset asynchrony (SOA) of 90 msec between successive items. The first target was preceded in the RSVP stream by between 5 and 10 distractors, at random.

The search array containing the second target was presented at one of three intertarget lags: lag 1 (in the frame directly following the first target), lag 3 (in the third frame after the first target), or lag 7 (in the seventh frame following the first target). At lags 3

and 7, distractors continued to be presented throughout the intertarget lag. There were two blocks of trials. In the *cue* block, a spatial cue—a red number between 01 and 12 that was presented just above the central RSVP stream—was presented for 40 msec in the RSVP frame that preceded the search array; thus, the SOA between the cue and the target was 90 msec. When the second target appeared at lag 1, the cue was presented concurrently with the first target. The observers were told that the second target would be located at the clock location that was indicated by the number cue. The *no-cue* block was the same as the cue block, except that the cue was not presented. The observers were instructed to take advantage of the spatial information that was provided by the cue. In brief, the design of Experiment 1 was a  $2$  (cue: present, absent)  $\times$   $3$  (lag: 1, 3, 7) within-subjects factorial.

The circular search was followed immediately by a 180-msec doughnut-shaped mask that completely covered the search array. Each pixel inside the mask was randomly colored black or white. The RSVP stream of distractors continued while the search array was displayed. Examples of the stimuli and the sequence of events on any given trial are illustrated in Figure 1. At the end of each trial, observers identified the first target by pressing the corresponding key on the keyboard, and then indicated whether the second target was tilted to the left or to the right by pressing the left or the right shift key.

The dependent measure in this experiment was the critical exposure duration ( $DUR_c$ ) for which the second target needed to be displayed in order to achieve 80% accuracy. The exposure duration of the circular search array containing the second target was varied dynamically by a threshold-tracking staircase procedure called *parameter*

estimation by sequential testing (PEST; Taylor & Creelman, 1967). PEST reduced the exposure duration when the observer's response accuracy exceeded the critical level, and it increased the exposure duration when accuracy was too low. A Wald (1947) sequential likelihood-ratio test determined whether the event proportion that had been yielded by the immediately preceding run of responses was greater than or less than 80%. The Wald routine was called only on trials in which the first target had been identified correctly.

In each of the cue and no-cue blocks, there were three independent but intermixed PEST runs, one for each lag. The PEST end run consisted of 16 trials after three reversals in the direction of adjustment of exposure duration had been recorded. The final  $DUR_c$  score was the mean exposure duration of the search array over the last 16 trials of a given lag.  $DUR_c$  thus represented the duration of the mask-free interval that was necessary to achieve the critical level of second-target accuracy, separately for each observer. This procedure was adopted in order to avoid the 100% ceiling constraints that are imposed by the response scale when identification accuracy is used as the dependent measure.

### Results and Discussion

The mean percentages of correct responses for the first target, averaged over lags, were 88.5% and 95.2% for the cue and no-cue conditions, respectively. The mean  $DUR_c$  values for the second target at each lag are illustrated in Figure 2. An ANOVA that was performed on the data in Figure 2 had two within-subjects factors: cue (present, absent) and lag (1, 3, 7). The analysis revealed significant effects of cue [ $F(1,28) = 26.36, p < .001$ ] and lag [ $F(2,56) = 16.78, p < .001$ ]. The interaction effect was also significant [ $F(2,56) = 4.54, p = .015$ ].

Although it avoids ceiling effects, the PEST procedure is open to possible floor effects. A floor effect could occur if the exposure duration of the second target is decreased to the irreducible minimum of one refresh frame (13.3 msec). This was never the case in the present experiment, in which the lowest individual  $DUR_c$  that was recorded in any of the six conditions was 190 msec.

As can be seen in Figure 2, much shorter exposure durations were required when the location of the second target was cued. Also, a significant AB deficit was in evidence, with the values of  $DUR_c$  decreasing as lag was increased. The important consideration for the objective of the present study, however, is that the advantage that was conferred by the spatial cue was significantly smaller when the intertarget lag was short than when it was long. On the tenets of additive-factors logic, this suggests that the number cue and the letter target engaged common processing mechanisms.

This pattern of results is consistent with predictions from the dual-pathway framework that was outlined above. Given that both the number cue and the letter target required identification, it is plausible to assume that the two stimuli engaged common processing mechanisms within the ventral stream. Identification of the cue was then impaired at the shorter lags, when the necessary processing mechanisms were engaged in identifying the first target. The resulting delay in the processing of the identity of the cue caused a corresponding delay in the deployment of focal attention to the location of the second target. A longer  $DUR_c$  was then required in order to escape the trailing mask.

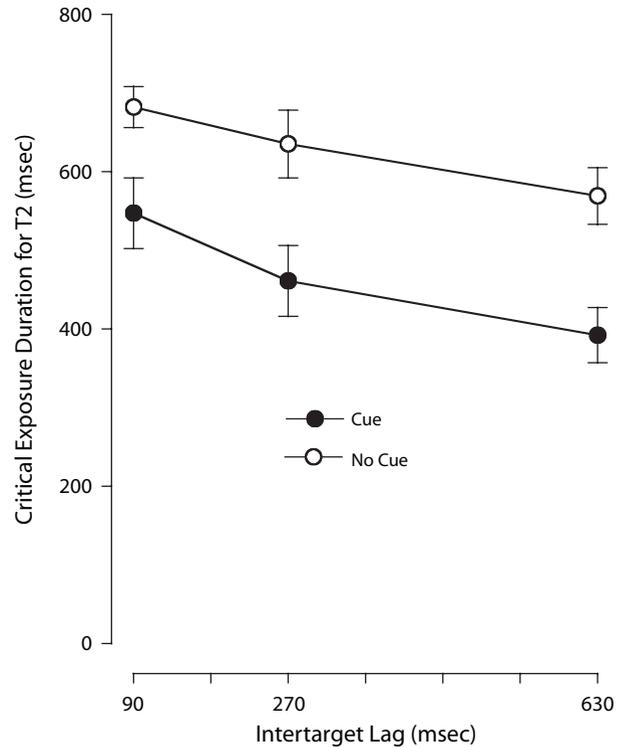


Figure 2. Results of Experiment 1. Bars represent one standard error of the mean. T2, second target. The number cue was colored red.

In contrast, no such impairment in the processing of the spatial cue was in evidence in the experiments of Ghorashi et al. (2009). This was because the cue (a dot demarcating the location of the second target) did not need to be identified. Without the need for identification, the cue did not engage the same mechanisms as did the first target (a letter to be identified) and was, therefore, processed along a different (dorsal) pathway.

A further issue arises regarding the impairment of cuing during the AB in the present experiment. Utilizing the information that was provided by the cue involved at least two sequential steps. The first was to identify the number cue; the second was to redirect focal attention to the clock location that had been indicated by the cue. The reduced effectiveness of the cue during the AB (Figure 2), therefore, could have arisen at either or both of these steps. Experiment 2 was designed to determine the source of interference. This was done by eliminating the first step (cue identification) but maintaining the second step (redirection of focal attention).

### EXPERIMENT 2

In Experiment 2, the number cue that was used in Experiment 1 was replaced with a small dot that was presented at the clock location opposite the location of the target in the search array. This eliminated the requirement to identify the cue, but it maintained the requirement to redirect focal attention to the target's location.<sup>1</sup>

## Method

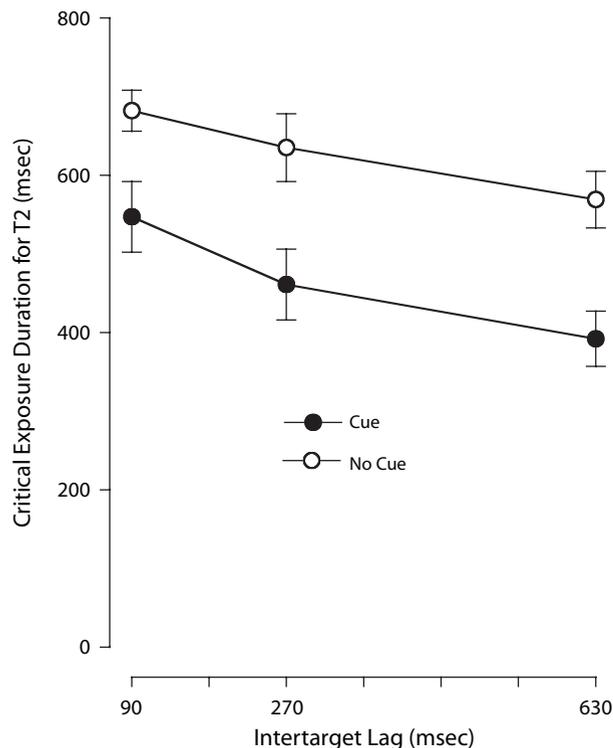
**Observers.** Twenty-two undergraduate students at Simon Fraser University participated for course credit. None had participated in Experiment 1, and all reported normal or corrected-to-normal vision.

**Apparatus, Stimuli, and Procedure.** These were the same as in Experiment 1, except for the spatial cue. Instead of being a number cue, the cue consisted of a small white dot that was presented in the clock location opposite the target in the search array. Observers were told that the target would always appear at the location opposite the cue.

## Results

The mean percentages of correct responses for the first target, averaged over lags, were 92.7% and 94.3% for the cue and no-cue conditions, respectively. The mean  $DUR_c$  values for the second target at each lag are illustrated in Figure 3. An ANOVA that was performed on the data in Figure 3 had two within-subjects factors: cue (present, absent) and lag (1, 3, 7). The analysis revealed significant effects of cue [ $F(1,21) = 15.24, p = .001$ ] and lag [ $F(2,42) = 11.06, p < .001$ ]. The interaction effect was not significant ( $F < 1$ ). The lowest individual  $DUR_c$  that was recorded in any of the six conditions was 77 msec, consistent with the absence of a floor effect.

As was the case in Experiment 1, much shorter exposure durations were required when the location of the second target was cued. Also, a significant AB deficit was in evidence, with the values of  $DUR_c$  decreasing as intertarget lag was increased. In contrast to the outcome of Experiment 1, however, the advantage that was conferred by the spatial cue was invariant with intertarget lag.



**Figure 3.** Results of Experiment 2. Bars represent one standard error of the mean. T2, second target.

The main objective of Experiment 2 was to decide whether the reduced effectiveness of the cue at the shorter lags in Experiment 1 (Figure 2) arose from interference with the process of identifying the number cue or from interference with the redeployment of focal attention to the location that was denoted by the cue. The results strongly suggest that the interference arose not from the requirement to redeploy focal attention, which was common to both experiments, but from the requirement to identify the spatial cue, which was unique to Experiment 1.

The finding that the values of  $DUR_c$  were invariant with intertarget lag (Figure 3) strongly suggests that attention could be redeployed without additional cost, even while the system was busy processing the first target. On the tenets of additive-factors logic, this suggests that attentional redeployment and target identification are mediated by separate mechanisms that enable the two processes to be performed concurrently. From the perspective of the dual-pathway hypothesis, these results are consistent with the proposition that the cue and the target were processed along the dorsal and ventral pathways, respectively.

One additional aspect of the present results deserves comment. In neither Experiment 1 nor Experiment 2 was there any evidence of *lag-1 sparing*, which is a paradoxical absence or attenuation of the AB deficit when the second target is presented directly after the first, in the RSVP position known as “lag 1.” As was reported in a review of the literature (Visser, Bischof, & Di Lollo, 1999), lag-1 sparing does not occur when the second target is presented in a different (and unattended; see Jefferies, Ghorashi, Kawahara, & Di Lollo, 2007) spatial location relative to the first target. In addition, the magnitude of lag-1 sparing tends to be attenuated when the two targets involve different tasks. Both of these conditions applied in Experiments 1 and 2, with consequent absence of lag-1 sparing.

## GENERAL DISCUSSION

Earlier work has shown that the processes of spatial selection and identity extraction are separable (Ghorashi et al., 2009). A dual-pathway account of this separability was proposed in Ghorashi et al. (2009) on the assumption that the cue and the target were processed along separate visual pathways. The spatial cue (a dot denoting the location of the target within a search array) was said to be processed along the dorsal pathway, whereas the target (a letter to be identified) was said to be processed along the ventral pathway. The principal objective of the present study was to examine some implications of this account. On the well-supported assumption that stimulus identification is carried out along the ventral pathway (Ungerleider & Mishkin, 1982), the dual-pathway account would predict that independence will no longer be in evidence if both the cue and the target need to be identified.

This prediction was supported in Experiment 1, in which the spatial cue consisted of a number that, once identified, denoted the location of the target within a circular search array. The effectiveness of the cue was impaired when it was presented while the hypothesized ventral-stream mechanisms were engaged in identifying a

letter target. Experiment 2 tested whether that impairment was attributable to interference with the process of cue identification, or with the process of redeploying attention to the location that was indicated by the cue. This was done by replacing the number cue with a dot cue that was presented at a location opposite that of the target in the circular array. This eliminated the need for cue identification but maintained the requirement to redeploy the attentional focus. The results strongly suggest that identification and attentional reorienting are independent processes, thus implicating cue identification as the source of impairment in Experiment 1.<sup>2</sup>

The present results have direct implications for models in which two sources of attentional control have been juxtaposed: voluntary (goal directed; e.g., Folk, Remington, & Johnston, 1992) and automatic (involuntary, stimulus driven; e.g., Theeuwes, 1992, 1993). A common requirement in Experiments 1 and 2 was to redeploy the focus of attention to a new location. In this sense, both experiments required some degree of goal-directed voluntary attentional control. Despite this commonality, the outcomes of the two experiments differed fundamentally. It is likely that other factors, notably the requirement for cue identification, played a role. The pattern of results in Experiments 1 and 2 strongly suggests that the critical determinant of independence between cuing and the AB was not whether the control of attention was voluntary or automatic, but whether or not the cue needed to be identified in order to redeploy the focus of attention.

From the perspective of the dual-pathway model that has been advocated here, this means that cuing and the AB show evidence of interdependence only when the cue and the first target are processed along the same pathway. On this account, the evidence for interdependence that was obtained in Experiment 1 stems from the idea that both stimuli engaged common identification mechanisms along the ventral pathway. In contrast, in Experiment 2 the cue engaged dorsal-stream but not ventral-stream mechanisms, thus avoiding overlap with ventral-stream mechanisms that were engaged in identifying the first target, and yielding evidence for independence.

A strong version of the dual-stream model would predict that interdependence need not be limited to ventral-stream processing: It should also be in evidence if both the cue and the target engage common processing mechanisms along the dorsal pathway. A possible problem in testing this hypothesis might arise, however, when one considers the high rates of processing in the dorsal stream. Namely, processing of the first target might be completed before the onset of the cue, thus obviating any evidence of interdependence. Addressing this issue, however, is beyond the scope of the present study.

### Comparison With Related Studies

The relationship between spatial cuing and the AB has been investigated by Zhang, Shao, Nieuwenstein, and Zhou (2008), who set out to determine whether endogenous (goal-directed) attentional control is impaired during the AB. The cue was an arrow that was presented in the center of the screen and that pointed to the location

of the upcoming second target (a letter to be identified). Accuracy of second-target identification was higher in the cued than in the uncued condition. Importantly, the benefit that was conferred by the cue was invariant with intertarget lag. Zhang et al. interpreted this result to indicate that endogenous cuing is unimpaired during the AB. In support of the claim that arrow cues control attention endogenously, Zhang et al. reported that arrow cues, when uninformative, could be ignored; however, this claim is disputed. A substantial body of evidence strongly suggests that arrow cues exert attentional control exogenously (Hommel, Pratt, Colzato, & Godijn, 2001; Ristic, Friesen, & Kingstone, 2002; Stevens, West, Al-Aidroos, Weger, & Pratt, 2008). This issue is obviously in need of further investigation.

At any rate, if arrow cues are regarded as exerting endogenous control, Zhang et al.'s (2008) findings would be inconsistent with the outcome of the present Experiment 1, in which endogenous cuing was shown to be impaired during the AB. This inconsistency can be resolved by invoking one of two assumptions. The first assumption is that arrow cues may be processed along the dorsal pathway if they are spatial indicators. This could arise from innate visual biases or through the acquisition of overlearned visual habits. The second assumption is that attention may be controlled in a goal-directed manner, not only for the nonspatial attentional functions that are governed by the ventral pathway, but also for the spatial functions that are subserved by the dorsal pathway. Evidence supporting this assumption can be found in the literature on masked priming (Cressman, Franks, Enns, & Chua, 2007; Vorberg, Mattler, Heinecke, Schmidt, & Schwarzbach, 2003), which indicates that although an arrow followed by a metacontrast mask may not result in conscious perception (a ventral process), it can nonetheless contribute to a substantial degree of motor priming (dorsal process).

Under either of these assumptions, the evidence for independence between cuing and the AB that was reported by Zhang et al. (2008) can be explained on the grounds that the arrow cue and the first target (a letter) were processed along separate pathways. From this perspective, Zhang et al.'s experiment was homologous to the present Experiment 2. Both experiments included elements of endogenous attentional control in that the focus of attention was redirected from the location of the cue to a new location. Notably, both experiments yielded evidence of independent processing. We suggest that both results can be explained in the same way—namely, that the spatial cue was processed along the dorsal stream and the first target was processed along the ventral stream.

Zhang et al.'s (2008) conclusion that endogenous cuing is not impaired during the AB is also at odds with results that were reported in an electrophysiological study by Dell'Acqua, Sessa, Jolicœur, and Robitaille (2006), who concluded that endogenous control of spatial attention is impaired during the AB. The dependent measure in Dell'Acqua et al.'s study was the amplitude of the N2pc (an enhancement of the posterior N2 wave at electrode sites that are contralateral to the target). The displays con-

sisted of two concurrent RSVP streams of letter distractors, one on either side of fixation. Two pairs of targets were inserted in the stream: The first target was a pair of digits, and the second target a pair of outline squares—one colored red, the other green—each with a gap on one side. The color of the second target was prespecified separately for each observer, who reported which side of that square contained the gap. The results showed that the magnitude of the N2pc was drastically reduced when the second target was presented during the period of the AB.

This result fits nicely within the dual-pathway model that has been advocated here, in which interdependence between cuing and the AB occurs when the cue and the first target are processed along the same pathway. The experiment of Dell'Acqua et al. (2006) did not contain an explicit stimulus cue. It did, however, require a discrimination between the two squares on the basis of color. In this task, therefore, attentional control was clearly endogenous. When the second target was presented during the period of the AB, the color discrimination had to be carried out concurrently with the identification of the first target. Considering that color processing and identification of alphanumeric stimuli are carried out along the ventral pathway (see, e.g., Ungerleider & Mishkin, 1982), it follows that the first target and the defining feature of the second target were processed along the same pathway. Interference between the two processes during the period of the AB then followed, much as it did in the present Experiment 1.

### Concluding Comments

Are spatial selection and identity extraction separable processes? If what is meant by “spatial selection” is the process of redeploying the focus of attention, the evidence strongly suggests that it is separable from the process of identity extraction. The issue of separability becomes clouded, however, when spatial selection is manipulated by spatial cues that index the location of a target to be identified. In this case, the evidence can lead to a seemingly contradictory conclusion. Namely, if the cue itself requires identification along the same processing pathway as the target, then the results may point to interdependence. That interdependence, however, is caused by interference between two processes of identification, not by interference between the processes of spatial selection and identity extraction.

This distinction was revealed in the present study by a juxtaposition of the outcomes of Experiments 1 and 2. In Experiment 1, the process of spatial selection was confounded with that of cue identification, producing the appearance of interdependence of spatial selection and identity extraction. That was not the case in Experiment 2, in which the cue did not require identification, thus disambiguating the processes of spatial selection and identity extraction, and producing clear evidence for their separability.

We conclude that spatial selection and identity extraction are separable in principle. Notably, this separability does not depend on whether attention is controlled exogenously or endogenously. Rather, separability follows

from the idea that spatial selection and identity extraction are mediated by distinct underlying mechanisms.

### AUTHOR NOTE

This work was supported by a PGS-D grant from the Natural Sciences and Engineering Research Council of Canada to S.G. and by Discovery Grants from the Natural Sciences and Engineering Research Council of Canada to T.M.S., J.T.E., and V.D.L. Correspondence concerning this article should be addressed to S. Ghorashi, Department of Psychology, University of British Columbia, 2136 West Mall, Vancouver, BC, V6T 1Z4 Canada (e-mail: ghorashi@psych.ubc.ca).

### REFERENCES

- CHUN, M. M., & POTTER, M. C. (1995). A two-stage model for multiple target detection in rapid serial visual presentation. *Journal of Experimental Psychology: Human Perception & Performance*, **21**, 109-127.
- COLEGATE, R. L., HOFFMAN, J. E., & ERIKSEN, C. W. (1973). Selective encoding from multielement visual displays. *Perception & Psychophysics*, **14**, 217-224.
- CRESSMAN, E. K., FRANKS, I. M., ENNS, J. T., & CHUA, R. (2007). On-line control of pointing is modified by unseen visual shapes. *Consciousness & Cognition*, **16**, 265-275.
- DELL'ACQUA, R., SESSA, P., JOLICÉUR, P., & ROBITAILLE, N. (2006). Spatial attention freezes during the attentional blink. *Psychophysiology*, **43**, 394-400.
- DI LOLLO, V., KAWAHARA, J.-I., GHORASHI, S. M. S., & ENNS, J. T. (2005). The attentional blink: Resource depletion or temporary loss of control? *Psychological Research*, **69**, 191-200.
- DUNCAN, J., WARD, R., & SHAPIRO, K. L. (1994). Direct measurement of attentional dwell time in human vision. *Nature*, **369**, 313-315.
- ERIKSEN, C. W., & HOFFMAN, J. E. (1972). Temporal and spatial characteristics of selective encoding from visual displays. *Perception & Psychophysics*, **12**, 201-204.
- 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.
- GHORASHI, S. M. S., DI LOLLO, V., & KLEIN, R. M. (2007). Attentional orienting in response to peripheral cues survives the attentional blink. *Visual Cognition*, **15**, 87-90.
- GHORASHI, S. [M. S.], ENNS, J. T., & DI LOLLO, V. (2008, November). *Spatial orienting is not impaired during the attentional blink*. Poster presented at the 49th Annual Meeting of the Psychonomic Society, Chicago.
- GHORASHI, S. [M. S.], ENNS, J. T., KLEIN, R. M., & DI LOLLO, V. (2009). *Spatial selection is separable from identity extraction in visual search*. Manuscript submitted for publication.
- HOMMEL, B., PRATT, J., COLZATO, L., & GODDIN, R. (2001). Symbolic control of visual attention. *Psychological Science*, **12**, 360-365.
- JEFFERIES, L. N., GHORASHI, S., KAWAHARA, J.-I., & DI LOLLO, V. (2007). Ignorance is bliss: The role of observer expectation in dynamic spatial tuning of the attentional focus. *Perception & Psychophysics*, **69**, 1162-1174.
- JOLICÉUR, P., & DELL'ACQUA, R. (1998). The demonstration of short-term consolidation. *Cognitive Psychology*, **36**, 138-202.
- MILNER, A. D., & GOODALE, M. A. (1995). *The visual brain in action*. Oxford: Oxford University Press.
- OLIVERS, C. N. L., VAN DER STIGCHEL, S., & HULLEMAN, J. (2007). Spreading the sparing: Against a limited-capacity account of the attentional blink. *Psychological Research*, **71**, 126-139.
- RAYMOND, J. E., SHAPIRO, K. L., & ARNELL, K. M. (1992). Temporary suppression of visual processing in an RSVP task: An attentional blink? *Journal of Experimental Psychology: Human Perception & Performance*, **18**, 849-860.
- RISTIC, J., FRIESEN, C. K., & KINGSTONE, A. (2002). Are eyes special? It depends on how you look at it. *Psychonomic Bulletin & Review*, **9**, 507-513.
- STERNBERG, S. (1969). The discovery of processing stages: Extensions of Donder's method. In W. G. Koster (Ed.), *Attention and performance II* (pp. 276-315). Amsterdam: North-Holland.
- STEVENS, S. A., WEST, G. L., AL-AIDROOS, N., WEGER, U. W., &

- PRATT, J. (2008). Testing whether gaze cues and arrow cues produce reflexive or volitional shifts of attention. *Psychonomic Bulletin & Review*, **15**, 1148-1153.
- TAYLOR, M. M., & CREELMAN, C. D. (1967). PEST: Efficient estimates on probability functions. *Journal of the Acoustical Society of America*, **41**, 782-787.
- THEEUWES, J. (1992). Perceptual selectivity for color and form. *Perception & Psychophysics*, **51**, 599-606.
- THEEUWES, J. (1993). Visual selective attention: A theoretical analysis. *Acta Psychologica*, **83**, 93-154.
- UNGERLEIDER, L. G., & MISHKIN, M. (1982). Two cortical visual systems. In D. J. Ingle, M. A. Goodale, & R. J. W. Mansfield (Eds.), *Analysis of visual behavior* (pp. 549-586). Cambridge, MA: MIT Press.
- VAN ESSEN, D. C., & DEYOE, E. A. (1995). Concurrent processing in the primate visual cortex. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 383-400). Cambridge, MA: MIT Press.
- VISSER, T. A. W., BISCHOF, W. F., & DI LOLLO, V. (1999). Attentional switching in spatial and nonspatial domains: Evidence from the attentional blink. *Psychological Bulletin*, **125**, 458-469.
- VORBERG, D., MATTLER, U., HEINECKE, A., SCHMIDT, T., & SCHWARZBACH, J. (2003). Different time courses for visual perception and action priming. *Proceedings of the National Academy of Sciences*, **100**, 6275-6280.
- WALD, A. (1947). *Sequential analysis*. New York: Wiley.
- WOLFE, J. M. (2007). Guided Search 4.0: Current progress with a model of visual search. In W. D. Gray (Ed.), *Integrated models of cognitive systems* (pp. 99-119). New York: Oxford University Press.
- WOLFE, J. M., CAVE, K. R., & FRANZEL, S. L. (1989). Guided search: An alternative to the feature integration model for visual search. *Journal of Experimental Psychology: Human Perception & Performance*, **15**, 419-433.
- ZHANG, D., SHAO, L., NIEUWENSTEIN, M., & ZHOU, X. (2008). Top-down control is not lost in the attentional blink: Evidence from intact endogenous cuing. *Experimental Brain Research*, **185**, 287-295.

#### NOTE

1. We thank D. Stephen Lindsay for suggesting this counteracting manipulation.

2. An alternative to this dual-pathway account can be couched in the assumption that spatial selection and identity extraction take place along a single pathway but at different processing stages. Although logically possible, this alternative becomes less plausible in the face of the known brain neuroanatomy and neurophysiology (see, e.g., Van Essen & DeYoe, 1995) and of the corresponding psychophysical and neuropsychological evidence (see, e.g., Milner & Goodale, 1995; Ungerleider & Mishkin, 1982) indicating that spatial and identity information tend to be processed along separate dorsal and ventral pathways, respectively. We thank an anonymous reviewer for suggesting this alternative account.

(Manuscript received January 17, 2009;  
revision accepted for publication March 8, 2009.)