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RESEARCH ARTICLE

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The attentional blink (AB) refers to the finding that performance on the second of two targets (T1 and T2) is impaired when the targets are presented at a target onset asynchrony (TOA) of less than 500 ms. One account of the AB assumes that the processing load of T1 leads to a loss of top-down control over stimulus selection. The present study tested this account by examining whether an endogenous spatial cue that indicates the location of a following T2 can facilitate T2 report even when the cue and T2 occur within the time window of the AB. Results from three experiments showed that endogenous cuing had a significant effect on T2 report, both during and outside of the AB; this cuing effect was modulated by both the cue-target onset asynchrony and by cue validity, while it was invariant to the AB. These results suggest that top-down control over target selection is not lost during the AB.

When observers monitor a rapid serial visual presentation (RSVP) of stimuli, such as letters, digits, words or pictures, and search for two targets in the stream, they usually have no difficulty in reporting the first target (T1) but they show a deficit in reporting the second target (T2), if the T2 appears within less than 500 ms from T1 (Broadbent and Broadbent 1987). The post-T1 interval during which report of T2 is impaired is referred to as an attentional blink (AB, Raymond et al. 1992).

During the last two decades, a number of models have been proposed to account for the AB (e.g., Broadbent and Broadbent 1987; Raymond et al. 1992; Shapiro et al. 1994; Chun and Potter 1995; Giesbrecht and Di Lollo 1998; Jolicoeur and Dell' Acqua 1998; Bowman and Wyble 2007; Olivers 2007). Most of these models share the assumption that the AB reflects the capacity limit of cognitive processing, the idea being that the consumption of cognitive resources in processing T1 causes the deficit in T2 report. Consistent with this interpretation, results from neuroimaging studies show that there is considerable overlap between the neural areas correlated with the AB bottleneck and those implicated in the capacity limits of visual short-term memory storage and in the phenomenon of psychological refractory period, with all tasks showing increased activation of a fronto-parietal network under conditions of high processing load (for an overview, see, Marois and Ivanoff 2005).

In a recent study, Di Lollo et al. (2005) proposed an account of how the processing load of T1 identification leads to the AB. According to this account, called the temporary loss of control (TLC) model, the sensory system is initially configured8 Tc0.0te7306.11b10.2 inpu7306.112.1(t6.1(e)] TJ

Do1.8(e)1(al.)pr-1.6.8(es)6.9 ofe(of)Tm[(Do1.8(e)1exe(ofclm[(Dude1 distractors following T1 may change the filter settings which are now under the control of the properties of the bottom-up input, resulting in difficulty in selecting T2 because the filter configuration no longer matches the specifications of T2. However, if the item following T1 is not a distractor, but a target that belongs to the same category as T1, the filter settings might not be changed, and this target could be selected and processed without problem. Supporting evidence for TLC comes from findings showing that the processing of T2 is not impaired when the items intervening between T1 and T2 are from the same category as T1 and T2 (Di Lollo et al. 2005; Kawahara et al. 2006; Olivers et al. 2007).

Although the AB has long been thought to be a consequence of the depletion of processing resources by T1, recent work suggests that there are in fact still processing resources available during the AB. For example, it has been shown that targets presented during the AB can in fact be accurately identified when they are precued by a stimulus that matches the attentional set for the targets (Nieuwenstein et al. 2005; Nieuwenstein 2006; see also, Olivers et al. 2007). Importantly, this cuing benefit for T2 does not incur a cost to T1 report, suggesting that not all resources are consumed in processing the first target. Work by Martens and Johnson (2005) further suggests that these remaining resources can be deployed in a purely endogenous fashion during the AB. In particular, this study showed that the AB is attenuated when observers are told on each trial what the target-onset asynchrony (TOA) will be, suggesting that they could somehow prepare for or deploy resources to the moment at which T2 was expected to occur. Given that this effect occurred in the absence of an exogenous cue, it must be concluded that resources were deployed on a voluntary basis even during the AB.

The purpose of the present study was to confirm and further examine the extent to which observers maintain voluntary control over the deployment of processing resources during the AB. To this end, we used an endogenous cuing procedure to directly determine whether the function of prefrontal control system is intact during the AB. In this procedure, an arrow is presented in the center of the display that can indicate where an upcoming target will appear (e.g., Jonides 1981). Studies using arrow cues show that whether or not observers voluntarily orient their attention towards the cued location depends on the validity of the cue, with stronger cuing effects seen for highly predictive cues than for cues with a low validity (e.g., Jonides 1980; Posner 1980; Jonides 1983; Eriksen and Yeh 1985; Madden 1992; Riggio and Kirsner 1997). These results indicate that this type of cuing is contingent on the observers' intention to use the cue, and, thus under top-down control. Moreover, numerous neuroimaging studies have demonstrated that endogenous attentional orienting involves a fronto-parietal network (e.g., Hopfinger et al. 2000; Miller 2000; Corbetta and Shulman 2002; Miller and D'Esposito 2005; Praamstra et al. 2005; Rounis et al. 2006) in which the PFC is considered the "top" of the top-down control system which can modulate the activity of neurons in visual cortex independent of input information (e.g., Miller 2000; Miller and D'Esposito 2005). For example, a recent neuroimaging study by Vossel et al. (2006) demonstrated more activation in a fronto-parietal network for the endogenous cues with high validity (90%) than that with low validity (60%). These neural studies are congruent with LaBerge's activity-distribution model (e.g., LaBerge and Brown 1989; LaBerge et al. 1997) of spatial attention, in which top-down control processes of spatial attention, located in the dorsolateral prefrontal cortex (DLPFC), produce a selective activity distribution in posterior parietal cortex (PPC) that is enhanced through the thalamus to visual cortex. If the function of top-down control over attention located in PFC is temporally suspended during the period when T1 consolidation is underway, then the endogenous cuing effect would be impaired during the AB than outside of the AB (as hypothesized by Ghorashi et al. 2007). On the contrary, if the effect of endogenous cuing is not affected by the AB, the presumption of loss-of-control should be re-considered.

An argument might be raised based on the presumption that the different parts of PFC are involved in different aspects of top-down attentional control. For example, according to LaBerge (1997; see also LaBerge 2001), the dorsolateral prefrontal cortex (DLPFC) is selectively involved in voluntary control of spatial attention ("where" circuit), while the ventrolateral prefrontal cortex (VLPFC) is involved in voluntary control of attention for shape and color ("what" or "object" circuit). This entails that our measure of top-down controlled, spatial selection may not be sensitive to the disturbance of the object-based filtering mechanisms implicated in the loss of control account. Crucially, however, results from numerous recent neuroimaging studies have provided evidence against LaBerges's claim in showing that the fronto-parietal network that is recruited when subjects expect to see object or feature clearly overlaps with regions that are recruited by attending to location (for overviews, see Kanwisher and Wojciulik 2000; Corbetta and Shulman 2002; Yantis and Serences 2003; see also, Corbetta et al. 2005). A similar result was obtained in an ERP study that showed that control of spatial and non-spatial visual attention correlates with the same neural activity (e.g., Slagter et al. 2005). Thus, the same fronto-parietal network might be involved in the top-down control over spatial attention in the present study and the top-down control over input filter configuration in TLC model, and this provides fundament for our logic to test whether this network loses its control function during the AB.

To examine how endogenous spatial cuing is affected by the AB, we used the so-called “skeletal” two-target paradigm (Duncan et al. 1994; Ward et al. 1996) in which T1 and T2, presented in one of four locations, are immediately followed by pattern masks. A central arrow cue was inserted between the target presentations. If the function of top-down control is lost during the AB, the endogenous attentional orienting would not work and consequently the cuing effect should be reduced or eliminated compared with the cuing effect when the cue is presented outside of the AB period. If, on the other hand, the functioning of the prefrontal control system is intact during the AB, the cuing effects should be present both inside and outside of the AB.

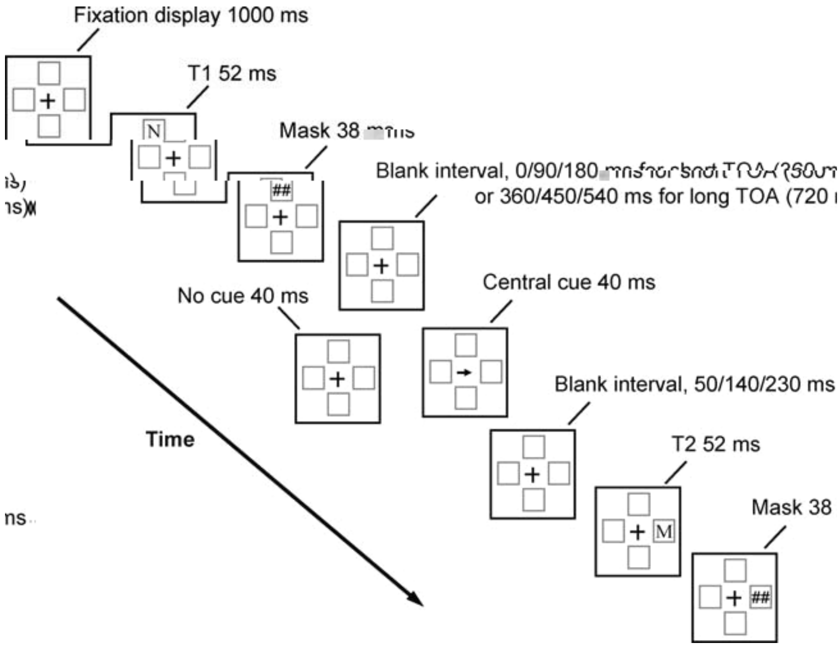
Given that cue validity plays a significant role in modulating the size of endogenous cuing effects in spatial orienting (e.g., Jonides 1980, 1983; Posner 1980; Eriksen and Yeh 1985; Madden 1992; Riggio and Kirsner 1997; Vossel et al. 2006), we manipulated the cue validity of the central cue, both inside and outside the AB period, across three experiments. In Experiment 1, we used a cue validity of 100% to test whether the central cuing works in the AB context. Then, in Experiment 2, we used a cue validity of 50% to demonstrate that the observers could ignore uninformative cues both inside and outside of the AB. In Experiment 3, the cue validity was 80%, thereby allowing for an assessment of the effects of both valid and invalid cues under condition in which the cue is expected to be valid.

An additional purpose of Experiment 2 (with a cue validity of 50%) was to confirm that any effects of the arrow cue were indeed due to an endogenous shift of attention. As previous work suggests, there are cases in which symbolic cues such as eye gazes or arrows have been found to direct attention in exogenous manner (e.g., Hommel et al. 2001; Ristic et al. 2002). The hallmark of this exogenous component to orienting attention in response to a symbolic cue is that target performance is enhanced even when the cues are non-predictive (i.e., 50% validity). Consequently, if there were to be an exogenous component to orienting in response to the arrow cue we used, the results from Experiment 2 would reveal this, as in this experiment, the cue validity was 50%.

Method

Sixty right-handed students (30 males and 30 females) from Peking University were recruited to participate in the experiments in return for monetary compensation. Their age ranged from 20 to 28, and averaged on 22 ± 3.5 years. All the participants reported having normal or corrected-to-normal eyesight. They were randomly assigned to the three experiments, with 10 males and 10 females for each experiment.

The experiments were run in a dimly illuminated room, with stimuli presented on a 17” CRT monitor running at a resolution of 1,024 × 768 pixels. Stimulus presentation and recording of participants’ responses were controlled by Presentation software (http://nbs.neuro-bs.com/). The stimulus display consisted of a white central fixation cross [with the RGB values (255, 255, 255)] that was surrounded by four



A schematic representation of the trial procedure for Experiments 1–3

for 38 ms. On cued trials, an arrow that pointed to either the left or the right location was presented for 40 ms at the location of the fixation cross. Depending on the CTOA, this arrow could appear at different points in time from T1. For example, when the TOA was 360 ms and the CTOA was 270 ms, the cue appeared immediately following the offset of the T1 mask. The task for the participants was to report the identities of T1 and T2 in their presentation order. If both T1 and T2 were reported as right identities but in reversal order, they were marked as correct report.

In Experiment 1, there were 40 trials for each combination of CTOA and TOA in the cued condition, and there were 120 trials for each TOA in the uncued condition. Thus Experiment 1 consisted of 480 trials. These trials were divided into five testing blocks, with each block containing 96 trials. In Experiment 2, there were 40 cued trials for each combination of CTOA, cue validity and TOA, and 240 uncued trials for each TOA. Therefore, Experiment 2 had 960 trials which were divided into 10 testing blocks. In Experiment 3, there were 36 invalid cue trials and 144 valid cue trials for each combination of CTOA and TOA, and 540 uncued trials for each TOA, yielding a total of 2,160 trials. This experiment was conducted in three separate sessions, each conducted on a different day in the same week. Each session had six testing blocks with 120 trials in each block. Trials from different experimental conditions were equally distributed into different testing blocks and there was an interval of 1–2 min between the blocks. Participants received 60 practice trials before they began the experiment.

Participants were instructed to maintain fixation on the central cross and to try to avoid making eye movements during a trial. They reported the targets by typing them in the order of appearance at the end of each trial. They were also informed of the validity of the cue before they began the experiment.

The average performance for report of T1 was 92, 90 and 92% for Experiments 1, 2 and 3, respectively (for the accuracy and standard error for each condition, see Table 1). There were no main effects or interactions of the factors cuing and TOA on T1 accuracy (> 0.1). Data analyses were then conducted on T2-identification performance. These analyses only included trials in which T1 was correctly reported (i.e., T2|T1). Figures 2, 3 and 4 show the means and standard errors for accuracy of T2|T1 in different experimental conditions from Experiments 1–3.

Experiment 1: 100% cue validity

Mean accuracy scores for T2|T1 were entered into a 2 (TOA) × 4 (cue condition: uncued, and cues with CTOA of 90, 180, 270 ms) ANOVA. The main effect of TOA was significant, (1, 19) = 133.34, < 0.001, with better T2 report at the long TOA than that at the short TOA (85 versus 63% correct). The main effect of cue condition was significant, (3, 57) = 41.91, < 0.001, with the lowest accuracy for the CTOA of 90 ms (mean = 67%), the highest accuracy for the CTOA of 270 ms (mean = 82%), and intermediate levels of performance for the uncued condition (mean = 73%), and the cued condition with an CTOA of

Means and standard errors of T1 accuracy (in %) from Experiments 1–3

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180 ms (mean = 78%). Pair-wise comparison of T2 performance in the four cue conditions showed that each of these differences was significant at an alpha corrected for multiple comparisons using Bonferroni adjustment (all ’s < 0.0083). These results indicate that, compared to the uncued condition, T2 performance was enhanced in the cued condition when the CTOA was 180 or 270 ms, while it was relatively impaired for cued trials with a CTOA of 90 ms. Importantly, the interaction between TOA and cue condition was not significant, (3, 57) = 1.92, > 0.1, indicating that the central cues influenced T2 performance to the same extent however short or long the TOA was. Thus, endogenous cuing did not appear to be affected by the AB.

Experiment 2: 50% cue validity

We performed separate analyses for the effects of valid and invalid cues in Experiment 2.

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A 2 (TOA) × 4 (cue condition: uncued, and cues with CTOA of 90, 180, and 270 ms) ANOVA was conducted for T2|T1 in the uncued and valid cuing conditions of

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Experiment 2. The main effect of TOA was significant, $(1, 19) = 171.63$, < 0.001, with lower accuracy for T2 identification at the short TOA (mean = 63%) than at the long TOA (mean = 83%). The main effect of cue condition approached significance, $(3, 57) = 2.39$, $= 0.078$. Bonferroni-corrected pair-wise comparisons revealed that none of the pair-wise differences between T2 reporting in different cue conditions reached significance. Moreover, the interaction between TOA and cue condition was not significant, $(3, 57) < 1$. Thus, in contrast to Experiment 1, there were no significant effects of valid central cues.

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The comparison of T2|T1 for the uncued condition and the condition with invalid cues showed a significant main effect of TOA, $(1, 19) = 335.87$, < 0.001, with lower accuracy at the short TOA (mean = 63%) than at the long TOA (mean = 82%). The main effect of cue condition approached significance, $(3, 57) = 2.46$, $= 0.072$, but pair-wise comparisons revealed no significant differences between the four conditions. The interaction between TOA and cue condition approached significance, $(3, 57) = 2.69$, $= 0.055$. Further analyses showed that the main effect of cue condition approached significance at the short TOA, $(3,57) = 2.74$, $= 0.052$. At the long TOA, the main effect of cue condition also approached significance, $(3, 57) = 2.28$, $= 0.089$. The Bonferroni-corrected pair-wise comparisons showed that only the difference between invalid cues with the 90 and the 180 ms CTOA was significant, $< .0083$. These results suggest that, relative to the uncued condition, the invalid cues did not affect T2 performance.

Experiment 3: 80% cue validity

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The T2|T1 accuracy for the valid cue and the uncued conditions were entered into a 2 (TOA) × 4 (cue condition: uncued, and cues with CTOA of 90, 180, and 270 ms) ANOVA. The main effect of TOA was significant, $(1, 19) = 80.07$, < 0.001, with lower T2 performance at the short TOA (mean = 60%) than at the long TOA (mean = 72%). The main effect of cue condition was significant, $(3, 57) = 20.70$, < 0.001, with the highest accuracy at the 270 ms CTOA (mean = 69%), the lowest performance at the 90 ms CTOA (mean = 62%), and an intermediate level of performance for the uncued condition (mean = 66%) and the 180 ms CTOA (mean = 66%) condition. Each of the pair-wise differences between the different cue conditions was significant, < 0.0083, except for the difference between the uncued condition and the 180 ms CTOA condition, > 0.1. The interaction between TOA and cue condition was not significant, $(3, 57) = 1.16$, > 0.1, indicating that the pattern of cuing effects was the same at the short and the long TOAs.

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The analyses of T2|T1 for trials with invalid cues revealed a significant main effect of TOA, $(1, 19) = 115.61$, < 0.001, with lower T2 performance at the short TOA (mean = 55%) than at the long TOA (mean = 68%). The main effect of cue condition was significant, $(3, 57) = 8.76$, < 0.001, with the highest T2 accuracy for the uncued condition (mean = 66%), the lowest T2 accuracy for the 270 ms CTOA (mean = 59%), and medium performance for the 180 ms CTOA (mean = 60%) and the 90 ms CTOA (mean = 62%). Bonferroni-corrected pair-wise comparisons showed that all pair-wise differences between the uncued condition and the conditions with invalid cues were significant (< 0.0083) except for the difference between the uncued condition and the 90 ms CTOA condition, which approached significance ($= 0.06$). There were no significant differences between the three conditions with invalid cues, all 's > 0.1. The interaction between TOA and cue condition was not significant, $(3, 57) < 1$.

The aim of the present study was to determine if and how the capacity to endogenously orient spatial attention is affected by the AB. To this end, we examined the effects of arrow cues on the ability to report a second target that appeared during or after the AB induced by a leading first target. The arrow indicated the location where T2 could appear. The validity of the cue was varied across three experiments, with 100% valid cues in Experiment 1, 50% valid cues in Experiment 2 and 80% valid cues in Experiment 3.

Results from the three experiments can be summarized as follows. An AB was observed in each experiment, with T2 report being worse when the time interval between T1 and T2 was short (360 ms) than when the interval was long (720 ms). The effects of valid and invalid cues on T2 performance were modest, yet they appeared to be systematic. Valid cues led to better performance on T2 when the time interval between the cue and T2 was relatively long (i.e., with CTOAs of 180 or 270 ms) but only in Experiments 1 and 3 where cues were 100 and 80% valid, respectively. Invalid cues, in contrast, led to worse performance for reporting T2 in Experiment 3 where the cue was expected to be valid. For trials with a CTOA of 90 ms, both valid and invalid cues produced a decrement in T2 report, perhaps due to the fact that the arrow captured attention at its own blink period. However, this inconsistency may be explained if one assumes that different mechanisms are involved in endogenous spatial orienting and in the allocation of resources in response to a potential target. As argued by LaBerge and Brown (1989) (see also LaBerge et al. 1997; LaBerge 2001), endogenous orienting of attention may involve a slow build up of attentional resources at the location where a target is expected to appear. This state of preparatory attention may encompass one or multiple locations depending on top-down goals (e.g., Jefferies et al. 2007) and it can be conceived of as a gradient of attention-related activity across the visual field. When a (potential) target appears, a different type of attentional response is elicited. This response is focal, transient, and intense, and therefore capable of facilitating identification of targets that are briefly presented and masked (Nakayama and Mackeben 1989). Crucially, it is this form of transient attention that has been implicated in explanations of the AB (Nieuwenhuis et al. 2005; Bowman and Wyble 2007; Olivers 2007). In particular, it is thought that target detection invokes transient attention, thereby benefiting the encoding of items that appear within a window of about 100 ms following the onset of the target (this explains the so-called “sparing” of T2 identification seen when T2 follows T1 at TOAs of less than 100 ms. see Potter et al. 1998). More important, this transient form of attention is also considered to be the locus of the selection delays seen for targets presented during the AB. For example, one proposal is that consolidating T1 into short-term memory inhibits the mechanism that mediates transient attention so as to ensure that no new inputs can intrude and interfere with the ongoing processing of T1 (B. Wyble et al., submitted). In this view, the delayed engagement of attention during an AB reflects the fact that more time (and target input) is needed to overcome this inhibition so that a second episode of transient attention can be launched.

Thus, transient attention appears to constitute a critical part of the mechanism that gives rise to delayed selection in the AB. On the other hand, the processes that implement top-down goals through setting the weights for different features or locations appear to be unaffected by the processing demands of encoding T1 into short-term memory.

In conclusion, the present findings show that the processes underlying the voluntary deployment of attention to a particular location are not affected by the AB. In this regard, the present study corroborates previous work that also provided evidence consistent with the possibility that top-down control over resource allocation and stimulus selection is not lost during the AB (e.g., Martens and Johnson 2005; Nieuwenstein et al. 2005; Nieuwenstein 2006). Together, these results make a compelling case against the claim that the processing load of T1 identification leads to a temporary loss of top-down control over selective attention (Di Lollo et al. 2005; Kawahara et al. 2006).

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Bowman H, Wyble B (2007) The simultaneous type, serial token model of temporal attention and working memory. Psychol Rev 114:38–70

Broadbent DE, Broadbent MHP (1987) From From detection to identification—response to multiple targets in rapid serial visual presentation. Percept Psychophys 42:105–113

Chun MM (1997) Temporal binding errors are redistributed by the attentional blink. Percept Psychophys 59:1191–1199

Chun MM, Potter MC (1995) A two-stage model for multiple target detection in rapid serial visual presentation. J Exp Psychol Hum Percept Perform 21:109–127

Corbetta M, Shulman GL (2002) Control of goal-directed and stimulus-driven attention in the brain. Nat Rev Neurosci 3:201–215

Corbetta M, Tansy AP, Stanley CM, Astafiev SV, Snyder AZ, Shulman GL (2005) A functional MRI study of preparatory signals for spatial location and objects. Neuropsychologia 43:2041–2056

Di Lollo V, Kawahara J, Ghorashi SMS, Enns JT (2005) The attentional blink: resource depletion or temporary loss of control? Psychol Res-Psychol Forsch 69:191–200

Duncan J, Ward R, Shapiro K (1994) Direct measurement of attentional dwell time in human vision. Nature 369:313–315

Eriksen CW, Yeh YY (1985) Allocation of attention in the visual-field. J Exp Psychol Hum Percept Perform 11:583–597

Ghorashi SMS, Di Lollo V, Klein RM (2007) Attentional orienting in response to peripheral cues survives the attentional blink. Vis Cogn 15:87–90

Giesbrecht B, Di Lollo V (1998) Beyond the attentional blink: visual masking by object substitution. J Exp Psychol Hum Percept Perform 24:1454–1466

Hommel B, Pratt J, Colzato L, Godijn R (2001) Symbolic control of visual attention. Psychol Sci 12:360–365

Hopfinger JB, Buonocore MH, Mangun GR (2000) The neural mechanisms of top-down attentional control. Nat Neurosci 3:284–291

Isaak MI, Shapiro KL, Martin J (1999) The attentional blink reflects retrieval competition among multiple rapid serial visual presentation items: tests of an interference model. J Exp Psychol Hum Percept Perform 25:1774–1792

Jefferies LN, Ghorashi SM, Kawahara J, Di Lollo V (2007) Ignorance is bliss: the role of observer expectation in dynamic spatial tuning of the attentional focus. Percep Psychophys (in press)

Jiang YH, Chun MM (2001) The influence of temporal selection on spatial selection and distractor interference: an attentional blink study. J Exp Psychol Hum Percept Perform 27:664–679

Jolicoeur P, Dell’ Acqua R (1998) The demonstration of short-term consolidation. Cognit Psychol 36:138–202

Jonides J (1980) Towards a model of the minds eyes movement. Can J Psychol 34:103–112 (Revue Canadienne De Psychologie)

Jonides J (1981) Voluntary versus automatic control over the mind’s eye’s movement. In: Long JB, Baddeley AD (eds) Attention and performance IX. Lawrence Erlbaum, Hillsdale, pp 187–203

Jonides J (1983) Further toward a model of the minds eyes movement. Bull Psychon Soc 21:247–250

Kanwisher N, Wojciulik E (2000) Visual attention: insights from brain imaging. Nat Rev Neurosci 1:91–100

Kawahara JI, Kumada T, Di Lollo V (2006) The attentional blink is governed by a temporary loss of control. Psychon Bull Rev 13:886–890

LaBerge D (1997) Attention, awareness, and the triangular circuit. Conscious Cogn 6:149–181

LaBerge D (2001) Attention, consciousness, and electrical wave activity within the cortical column. Int J Psychophysiol 43:5–24

LaBerge D, Brown V (1989) Theory of attentional operations in shape identification. Psychol Rev 96:101–124

LaBerge D, Carlson RL, Williams JK, Bunney BG (1997) Shifting attention in visual space: tests of moving-spotlight models versus an activity-distribution model. J Exp Psychol Hum Percept Perform 23:1380–1392

Madden DJ (1992) Selective Selective attention and visual-search—revision of an allocation model and application to age-differences. J Exp Psychol Hum Percept Perform 18:821–836

Marois R, Ivanoff J (2005) Capacity limits of information processing in the brain. Trends Cogn Sci 9:296–305

Martens S, Johnson A (2005) Timing attention: cuing target onset interval attenuates the attentional blink. Mem Cogn 33:234–240

Miller EK (2000) The prefrontal cortex and cognitive control. Nat Rev Neurosci 1:59–65

Miller BT, D'Esposito M (2005) Searching for "the top" in top-down control. Neuron 48:535–538

Muller HJ, Rabbitt PMA (1989) Reflexive and voluntary orienting of visual-attention—time course of activation and resistance to interruption. J Exp Psychol Hum Percept Perform 15:315–330

Nakayama K, Mackeben M (1989) Sustained and transient components of focal visual-attention. Vision Res 29:1631–1647

Nieuwenhuis S, Gilzenrat MS, Holmes BD, Cohen JD (2005) The role of the locus coeruleus in mediating the attentional blink: a neurocomputational theory. J Exp Psychol Gen 134:291–307

Nieuwenstein MR (2006) Top-down controlled, delayed selection in the attentional blink. J Exp Psychol Hum Percept Perform 32:973–985

Nieuwenstein MR, Chun MM, van der Lubbe RHJ, Hooge ITC (2005) Delayed attentional engagement in the attentional blink. J Exp Psychol Hum Percept Perform 31:1463–1475

Olivers CNL (2007) The time course of attention: it's better than we thought. Curr Dir Psychol Sci 16:11–15

Olivers CNL, van der Stigchel S, Hulleman J (2007) Spreading the sparing: against a limited-capacity account of the attentional blink. Psychol Res Psychol Forsch 71:126–139

Posner MI (1980) Orienting of attention. Q J Exp Psychol 32:3–25

Potter MC, Chun MM, Banks BS, Muckenhoupt M (1998) Two attentional deficits in serial target search: the visual attentional blink and an amodal task-switch deficit. J Exp Psychol Learn Mem Cogn 24:979–992

Praamstra P, Boutsen L, Humphreys GW (2005) Frontoparietal control of spatial attention and motor intention in human EEG. J Neurophysiol 94:764–774

Raymond JE, Shapiro KL, Arnell KM (1992) Temporary suppression of visual processing in an RSVP task—an attentional blink. J Exp Psychol Hum Percept Perform 18:849–860

Riggio L, Kirsner K (1997) The relationship between central cues and peripheral cues in covert visual orientation. Percept Psychophys 59:885–899

Ristic J, Friesen CK, Kingstone A (2002) Are eyes special? it depends on how you look at it. Psychon Bull Rev 9:507–513

Rounis E, Stephan KE, Lee L, Siebner HR, Pesenti A, Friston KJ, Rothwell JC, Frackowiak RSJ (2006) Acute changes in frontoparietal activity after repetitive transcranial magnetic stimulation over the dorsolateral prefrontal cortex in a cued reaction time task. J Neurosci 26:9629–9638

Shapiro KL, Raymond JE, Arnell KM (1994) Attention to visual pattern information produces the attentional blink in rapid serial visual presentation. J Exp Psychol Hum Percept Perform 20:357–371

Slagter HA, Kok A, Mol N, Talsma D, Kenemans JL (2005) Generating spatial and nonspatial attentional control: an ERP study. Psychophysiology 42:428–439

Vossel S, Thiel CM, Fink GR (2006) Cue validity modulates the neural correlates of covert endogenous orienting of attention in parietal and frontal cortex. Neuroimage 32:1257–1264

Vul E, Nieuwenstein MR, Kanwisher N (2007) Temporal selection is suppressed, delayed, and diffused during the attentional blink. Psychol Sci (in press)

Ward R, Duncan J, Shapiro K (1996) The slow time-course of visual attention. Cogn Psychol 30:79–109

Yantis S, Serences JT (2003) Cortical mechanisms of space-based and object-based attentional control. Curr Opin Neurobiol 13:187–193