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Individual differences in dispositional focus of attention predict attentional blink magnitude

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When identifying two targets presented in a rapid serial visual presentation stream, one's accuracy on the second target is reduced if it is presented shortly (within 500 msec) after the first target—an attentional blink (AB). Individuals differ greatly in the size of their AB. One way to learn about the AB is to understand what underlies these individual differences. Recent studies have suggested that when a broadened or diffused attentional state is induced, the AB deficit can be attenuated. The present study examined whether natural (dispositional) individual differences in focus and diffusion of attention as assessed by the global/local task could predict performance on the AB task. Performance that was consistent with diffusion correlated negatively with AB size, and performance that was consistent with focusing correlated positively with AB size, showing that dispositional focus and diffusion of attention can predict individual differences in the AB. These findings are consistent with the Olivers and Nieuwenhuis (2006) overinvestment hypothesis.

It is difficult for humans to attend to multiple items at one time effectively. When participants are asked to report two targets from within a rapid serial visual presentation (RSVP) stream of stimuli, accuracy on the second target (T2) is markedly impaired when T2 is presented close temporally (within 200–500 msec) to the first target (T1), relative to longer target separations, resulting in an *attentional blink* (AB) (Raymond, Shapiro, & Arnell, 1992; Shapiro, Raymond, & Arnell, 1997; see also Dux & Marois, 2009, for a recent review).

Recent studies have shown that the AB can be attenuated with the introduction of an additional, simultaneous task (Olivers & Nieuwenhuis, 2005, 2006). These authors had participants imagine their vacation, or detect "yells" dispersed throughout a piece of music, while performing an AB task (Olivers & Nieuwenhuis, 2005). In a later study, participants performed a match-to-sample task in which random patterns of lines were presented before and after each AB stream (Olivers & Nieuwenhuis, 2006). Despite the task differences, the results were the same: Performing an additional task at the same time as the AB task reduced the magnitude of the AB.

These findings are counterintuitive, given that the AB is thought to result from limitations on attention (see, e.g., Chun & Potter, 1995; Raymond et al., 1992). It would seem that further taxing the system should result in *greater* deficits, not fewer. To explain this finding, Olivers and Nieuwenhuis (2005, 2006) proposed that when individuals are focused on identifying targets in an AB task, there is an overinvestment of attention to T1 and distractors in the RSVP stream. This allows T1 to receive attentional resources, but it also allows distractors, especially those presented near targets, to cross an activation threshold where they also receive attention. Olivers and Nieuwenhuis concluded that the additional tasks used in their studies led participants to diffuse, or spread out, their attention rather than overfocusing on the AB task. Olivers and Nieuwenhuis (2005, 2006) posited that each RSVP stream item receives less activation when individuals are forced to diffuse their attention through the use of an additional task. Under these conditions, only targets cross the threshold and receive attention, rendering distractors less effective competitors for attention and resulting in an attenuated AB. This is the *overinvestment hypothesis*.

Olivers and Nieuwenhuis's (2005, 2006) theory that diffusion of attention can attenuate the AB was supported by a recent study showing that an RSVP stream surrounded by an outward-moving starfield (thereby diffusing participants' attention) resulted in a smaller AB than when the starfield moved inward toward the RSVP stream or when it was stationary (Arend, Johnston, & Shapiro, 2006). The overinvestment hypothesis has also been supported by findings that induced positive affect can reduce the AB (Olivers & Nieuwenhuis, 2006), and by findings showing that individual differences in dispositional affect can predict the magnitude of the AB in that self-reported high positive trait affect is associated with smaller ABs, and self-reported high negative trait affect is associated with larger ABs (MacLean, Arnell, & Busseri, in press). The affect results support the overinvestment hypothesis, given that positive affect has pre-

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viously been shown to broaden attention, whereas negative affect has been shown to focus attention (see, e.g., Dreisbach & Goschke, 2004; Rowe, Hirsh, & Anderson, 2007).

Individual-differences studies of the AB have also shown that executive control of working memory predicts AB magnitude in that individuals with greater control have smaller ABs (Arnell, Stokes, MacLean, & Gicante, 2010; Colzato, Spapé, Pannebakker, & Hommel, 2007), and the ability to inhibit irrelevant distractors is related to smaller ABs (Arnell & Stubitz, in press; Dux & Marois, 2008). It is possible that individual variation in attentional focus and/or diffusion could also be related to individual performance on the AB task, and that individual differences in dispositional focus and/or diffusion of attention may influence the degree of distractor processing and working memory overload.

One way in which dispositional focus and diffusion of attention can be examined is with the global/local task (Navon, 1977). This task presents participants with Navon stimuli—large letters, shapes, or objects made up of smaller letters, shapes, or objects—and asks the participants to report either the large (global) or the small (local) elements as rapidly as possible (see Figure 1). Although changes in the relative size of the global and local elements have been shown to bias participants toward global or local information (Kinchla & Wolfe, 1979), Navon's (1977) *global precedence hypothesis* proposes that individuals will preferentially process the global stimuli in a scene. Indeed, most individuals are particularly susceptible to intrusions of the global stimuli on trials in which they are to report local stimuli (Navon, 1977). Some individuals show a more local bias, however, such as individuals from collectivist cultures (Davidoff, Fonteneau, & Fagot, 2008), musicians (Stoesz, Jakobson, Kilgour, & Lewycky, 2007), individuals with obsessive–compulsive disorder (Moritz & Wendt, 2006), and individuals with autism (Scherf, Luna, Kimchi, Minshew, & Behrmann, 2008). As such, this task gives a good indication of participants' global or local bias.

Researchers have recently begun to examine individual differences in global/local processing and affect. Gasper and Clore (2002) examined whether naturally occurring affective state could influence participants' bias toward global processing of Navon stimuli. They found that individuals who reported happier mood states were significantly more likely to compare a target figure with global aspects of sample figures, and individuals who reported sad moods were significantly more likely to report local aspects of the sample figures. Fredrickson and Branigan (2005) later replicated this result in a study that induced a spectrum of affective states in the participants (amused, content, neutral, angry, and anxious), showing that affect can influence the degree to which individuals focus or diffuse their attention when viewing Navon stimuli.

Figure 1. Sample Navon stimuli.

The goal of the present study was to examine whether individual performance differences on the global/local task can predict individual differences in AB magnitude. Specifically, globally biased processing has been associated with greater diffusion of attention; thus, global interference (the amount of interference from global items while the local task is performed) may negatively relate to AB magnitude, and local interference (the amount of interference from local items while the global task is performed) may positively relate to AB magnitude. If so, then global precedence (global interference − local interference) should be negatively related to AB magnitude, so that greater global precedence scores relate to smaller AB magnitude. A second possibility is that both global and local interference reflect focus on irrelevant material, and that diffusion is reflected in an absence of either level of interference. If so, then both global and local interference may be positively related to AB magnitude, and global precedence would not be expected to predict AB magnitude.

METHOD

Participants

Ninety-seven Brock University undergraduate student volunteers (65 women) ranging in age from 17 to 30 participated in this study. All participants had learned English before the age of 8 and had normal or corrected-to-normal vision, no self-reported color blindness, and no motor-movement problems. Participants were tested individually for under 2 h. A total of 13 participants were removed from the final analysis for having mean long lag (7 and 8) T2 sensitivity on the AB task that was less than .50, leaving 84 participants.

Apparatus

All computer tasks were presented using E-Prime software on a Dell desktop computer with dual-core processor and a 17-in. CRT monitor. All responses in the computer tasks were made via manual buttonpress on the computer keyboard.

Stimuli and Design

AB. For the AB task, participants viewed a series of letters presented one at a time rapidly in the center of a computer screen. Participants were asked to identify a lone white letter (T1) from within the stream of stimuli and to detect the presence or absence of a black X (T2). There were 19 letters in each stimulus stream, and T1 and T2 were separated by a lag of 1–8 items. T1 appeared in either Stream Position 7 or Stream Position 10. T2 was present on 67% of trials, and it was absent on 33% of trials. Each combination of T1 position and lag was presented five times; thus, T2 was present on 80 trials and absent on 40 trials, for a total of 120 trials.

Each trial began with a 1,000-msec wait period, followed by a 500-msec central fixation cross. The cross was replaced by the first letter in the stream. Each letter was presented individually on the screen for 110 msec with no blank interstimulus interval between letters. All distractors were presented in black New Courier 18-point font on a gray background. T1 appeared in white font. For each trial, each distractor and T1 were randomly drawn without replacement from all letters of the alphabet except X. After the stream was complete, participants entered the T1 letter identity on the keypad and reported the presence or absence of T2 ("k" for present, "l" for absent). Responses were not speeded.

To control for individual differences in the bias to respond "present" to T2, the T2 false alarm rate was subtracted from the T2 hit rate for each participant, yielding T2 sensitivity at each lag. AB magnitude was calculated as mean T2 sensitivity at short lags (1–3), where T2 sensitivity was markedly lower, subtracted from mean T2 sensitivity at long lags (7–8), so that a larger difference reflected a greater effect of T1–T2 lag and a larger AB. The sum of each participant's T2 sensitivities across all lags was used as a measure of that participant's overall T2 sensitivity. T2 performance was conditionalized on T1 correct performance in all cases, as is typical for AB studies.

Global/local. All participants completed the AB task before the global/local task.[1] On each trial of the global/local task, participants were presented with a Navon stimulus (a large letter that was constructed of smaller letters; e.g., an H made out of Ts) in the center of the screen. Global letters (60 × 45 mm) were 10 times as large as the smaller local letters (6 × 4.5 mm), and the viewing distance was approximately 75 cm from the computer screen for all participants. All letters appeared in black New Courier font on a white background. Participants were required to quickly report either the identity of the smaller letters (local trials) or the identity of the large letter (global trials) by pressing the corresponding key on the keyboard. The only letters that were presented were Hs or Ts. Half of the trials in each condition were letter congruent (an H made of small Hs, or a T made of small Ts), and half were letter incongruent (an H made of small Ts, or a T made of small Hs). Global and local trials were presented in alternating blocks, with 24 trials in each of four blocks for a total of 96 trials. All participants began with the global block. Each trial began with a 500-msec central fixation cross on the screen, after which the Navon stimulus appeared on the screen and remained until the participant made a button response indicating the identity of the target.

Response times (RTs) were examined for each combination of participant, task, and condition, and RTs that fell outside three standard deviations from the mean were removed. Global and local interference, global precedence, and mean global and mean local RT were calculated for each participant. Local interference was measured as the degree to which local features on the global–incongruent trials interfered with RT (global–incongruent RT − global–congruent RT) and global interference was measured as the degree to which global features on the local–incongruent trials interfered with RT (local–incongruent RT − local–congruent RT). Keeping with convention (see, e.g., Navon, 1981), global precedence was measured for each participant by subtracting the participant's RT estimate for local interference from the participant's RT estimate for global interference.

RESULTS

Global/Local

Mean letter-identification RTs for the global/local task are presented in Figure 2 as a function of whether participants performed the global or the local task and whether the information across global/local levels was congruent or incongruent. Mean RTs were analyzed using a 2 × 2 (global/local task by congruency) repeated measures ANOVA. There was a significant main effect of global/local task in which RTs were faster for global trials than for local trials [$F(1,83) = 34.61$, $p < .001$]. There was also a significant main effect of congruency, indicating that RTs were significantly faster on congruent trials than on incongruent trials [$F(1,83) = 132.78$, $p < .001$]. The interaction between feature size and congruency was not significant, indicating that local interference was equal in magnitude to global interference ($F < 1$).

The mean error rate on the global/local task was 5%. A 2 × 2 (congruency × global/local task) repeated measures ANOVA was also conducted on the mean error data for this task. Errors were greater for incongruent trials than for congruent trials [$F(1,83) = 80.39$, $p < .001$], errors were greater

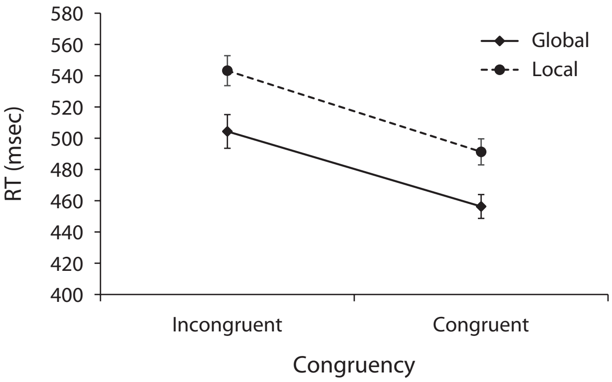

Figure 2. Mean response times (RTs) on global and local tasks as a function of target congruency. Error bars represent the standard error for each condition mean.

for global trials than for local trials [$F(1,83) = 19.59$, $p < .001$], and a significant interaction between compatibility and task revealed that congruency had more effect on global trials than on local trials [$F(1,83) = 8.71$, $p = .004$].[2]

AB

Mean T1 accuracy was .94 ($SD = .052$), and accuracy did not significantly differ as a function of lag ($F < 1$). Participants were divided into quartiles on the basis of their performance on the global/local task—specifically, their scores on the local-interference measure. Participants whose scores fell within the first quartile ($n = 21$) were classified as having low local interference, and participants whose scores fell within the fourth quartile ($n = 22$) were classified as having high local interference. Figure 3 shows the mean performance on the AB task for the highest and lowest quartiles of participants.

A mixed-model ANOVA with lag as the within-participants factor and high/low local interference as

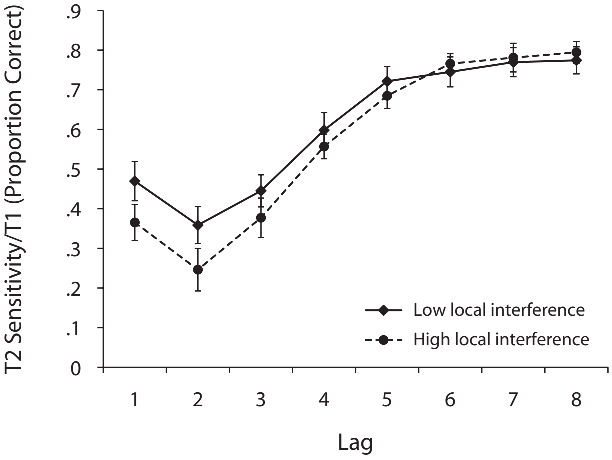

Figure 3. T2 sensitivity (proportion hits − proportion false alarms) given T1 correct performance as a function of lag in the attentional blink task for high- and low-local-interference groups. Error bars represent the standard error for each condition mean.

the between-participants factor was conducted on T2 sensitivities. There was a significant main effect of lag [$F(7,287) = 56.72$, $p < .001$], demonstrating an overall AB. There was no significant main effect of high/low local interference [$F(1,41) = 2.22$, $p = .14$], but there was a significant interaction between lag and high/low local interference [$F(7,287) = 6.68$, $p = .01$]. As shown in Figure 3, participants who were high in local interference showed larger lag-dependent T2-sensitivity changes than did participants who were low in local interference.[3]

Correlational Analyses

Correlational analyses were conducted to further examine the relationship between AB variables and the global/local task measures (see Table 1). As we hypothesized, AB magnitude was related to global/local performance. There was a significant positive relationship between AB magnitude and local interference, in which larger ABs were associated with greater influence of local features on global trials (thus suggesting a more local bias). Global interference was not significantly related to AB magnitude. Indeed, local interference was significantly related to AB magnitude even when the variability due to global interference was partialed out (semipartial $r = .27$, $p < .02$). Global precedence and AB magnitude showed a significant negative correlation, where higher global-precedence scores predicted smaller ABs. No relationship was found between overall RT on global or local trials and AB magnitude.

DISCUSSION

As we predicted, greater interference from the local elements of Navon stimuli was associated with greater AB magnitude. In contrast, interference from the global elements of Navon stimuli was not associated with greater AB magnitude. Consequently, greater global precedence (a measure of global bias) predicted smaller AB magnitude. This pattern of results suggests that it is not simply the amount of interference from irrelevant dimensions that predicts AB magnitude, but the preoccupation with local features (or local precedence) in particular. Indeed, local interference was a significant predictor of AB magnitude even when variability due to global interference was removed.

Researchers have argued that a preoccupation with local features (local precedence) results from focused attention, and that a bias toward global features (high global precedence) results from diffused attention (e.g., Fredrickson & Branigan, 2005; Gasper & Clore, 2002). The present results suggest that diffusion of attention predicts the AB given that there may be less focus on irrelevant local information without necessarily increasing a bias toward processing global information in the global/local task (i.e., that diffusion may predict the AB on the basis of avoidance of unnecessary local processing, without a corresponding increase in global processing).

The results here are consistent with the overinvestment hypothesis of Olivers and Nieuwenhuis (2005, 2006), which states that the AB occurs when individuals overfocus their attention on the items in the AB stream, thus overinvesting valuable attentional resources and creating more competition for further processing. When individuals diffuse their attention, they invest less in each item and are better able to distribute their attentional resources, thus reducing the competition for attentional resources and reducing their resultant AB. These findings are also consonant with newer executive-control models of the AB that emphasize cognitive control over influence from irrelevant distractors—for example, the temporary loss of control model (Di Lollo, Kawahara, Ghorashi, & Enns, 2005), the boost and bounce model (Olivers & Meeter, 2008), and the threaded cognition model (Taatgen, Juvina, Schipper, Borst, & Martens, 2009).

Given the link between positive affect and diffused attention and the link between negative affect and focused attention, the present results are consistent with those of MacLean et al. (in press), who showed that trait-positive affect is associated with smaller ABs and trait-negative affect is associated with larger ABs. The present results are also consistent with results showing that less inhibition of irrelevant distractors in the AB task (Dux & Marois, 2008) or in a visual working memory task (Arnell & Stubitz, in press) is predictive of larger ABs. Indeed, individual differences in affect may underlie the degree of focus or

Table 1
Means (and Standard Deviations) of the Cognitive-Performance Measures With Pearson Zero-Order Correlations Between All Pairs of Measures, Using an Alpha of .05 for Significance

	M	*SD*	AB Magnitude	T1 Accuracy	T2 Sensitivity	Global RT	Local RT	Global Interference	Local Interference
AB magnitude	.42	.21	–	–	–	–	–	–	–
T1 accuracy	.94	.05	.04	–	–	–	–	–	–
T2 sensitivity	.58	.12	−.43**	.38**	–	–	–	–	–
Global overall RT	471	68	.04	−.12	−.17	–	–	–	–
Local overall RT	505	74	−.09	−.12	−.11	.73**	–	–	–
Global interference	48	44	−.07	.04	.02	.21	.24*	–	–
Local interference	53	63	.26*	−.01	−.11	.46**	.20	.10	–
Global precedence	−5	73	−.27*	.03	.11	−.27*	−.03	.51**	−.81**

Note—$N = 84$. T1 accuracy is expressed in percent correct. T2 sensitivity is expressed in hits minus false alarms. Attentional blink (AB) magnitude is the difference between T2 sensitivity at long lags (7 and 8) and T2 sensitivity at short lags (1, 2, and 3). Global and local overall response times (RTs) are expressed in milliseconds. Global interference is the RT difference between local–incongruent and local–congruent trials, and it is expressed in milliseconds. Local interference is the RT difference between global–incongruent and global–congruent trials, and it is expressed in milliseconds. Global precedence is the difference between global interference and local interference, and it is expressed in milliseconds. $^{*}p < .05$. $^{**}p < .01$.

diffusion, which could modulate the degree of distractor processing and the resultant AB.

In conclusion, the main contribution of the present study was to show that individual differences in a well-established measure of attentional focus and diffusion are related to AB magnitude—specifically, that greater local focus is related to larger AB magnitude. This is the first study to show that a cognitive measure of dispositional focus can relate to the AB, a finding that lends itself to future research on individual differences in attentional allocation and AB performance.

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NOTES

1. A constant (as opposed to counterbalanced) task order was used for two reasons. The first was that we wanted participants to approach the AB task with their typical dispositional style of focus or diffusion, and this may have been less likely if their natural style was modulated to some degree by being asked to attend to global/local information in the global/local task just before performing the AB task. The second reason was that task order is typically constant in individual-differences studies, given that performance on tasks may differ somewhat on the basis of task order. A participant's relative score on a given task would have been confounded with order variability if task order had been counterbalanced. This confounding can be removed in individual-differences studies, in which means are not being compared across tasks by using a constant task order.

2. Because the faster RTs that were observed on global trials were also accompanied by more errors, the main effect of the global/local manipulation does show a speed–accuracy trade-off. Also, the error data suggest more local interference than global interference, so the RT data may slightly underestimate the amount of local interference in this task. Note, however, that all participants performed the global/local blocks in the same order, so comparing the amount of interference in global and local conditions is not entirely appropriate here. What is important for the present study is not whether the data show more global or local interference overall, but rather whether an individual's global or local interference pattern relative to other participants can predict the relative magnitude of that individual's AB.

3. The same analysis was performed when participants were grouped according to their global precedence scores, and the same pattern of results was observed (i.e., individuals with high global precedence had greater T2 sensitivity at short lags than did individuals with low global precedence, with no difference in T2 sensitivity at long lags).

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