

Multiple measures of dispositional global/local bias predict attentional blink magnitude

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Received: 9 October 2013 / Accepted: 20 June 2014 / Published online: 11 July 2014
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Abstract When the second of two targets (T2) is presented temporally close to the first target (T1) in a rapid serial visual presentation stream, accuracy to identify T2 is markedly reduced—an attentional blink (AB). While most individuals show an AB, Dale and Arnell (*Atten Percept Psychophys* 72(3):602–606, 2010) demonstrated that individual differences in dispositional attentional focus predicted AB performance, such that individuals who showed a natural bias toward the global level of Navon letter stimuli were less susceptible to the AB and showed a smaller AB effect. For the current study, we extended the findings of Dale and Arnell (*Atten Percept Psychophys* 72(3):602–606, 2010) through two experiments. In Experiment 1, we examined the relationship between dispositional global/local bias and the AB using a highly reliable hierarchical shape task measure. In Experiment 2, we examined whether three distinct global/local measures could predict AB performance. In both experiments, performance on the global/local tasks predicted subsequent AB performance, such that individuals with a greater preference for the global information showed a reduced AB. This supports previous findings, as well as recent models which discuss the role of attentional breadth in selective attention.

Introduction

When individuals are asked to report two targets from within a series of distractors in a rapid serial visual

presentation (RSVP) paradigm, accuracy for reporting the second target (T2) is significantly reduced when T2 is presented temporally close (within 500 ms) to the first target (T1), as compared to longer target separations (Raymond, Shapiro, & Arnell, 1992). This “attentional blink” (AB) is thought to reveal a limitation in selective attention (Chun & Potter, 1995; Raymond et al., 1992). In addition to suggestions that the AB results from fundamental processing limitations (e.g., Jolicoeur 1999; Jolicoeur & Dell’Acqua, 1998; Dell’Acqua, Dux, Wyble, & Jolicoeur, 2012; see Dux & Marois, 2009 for a review), there is evidence to suggest that strategic control over the allocation of attentional resources can also modulate the AB (Arend, Johnston, & Shapiro, 2006; Arnell & Stubit, 2010; MacLean & Arnell, 2011; Martens & Valchev, 2009; Nieuwenstein & Potter, 2006; Olivers & Nieuwenhuis, 2005, 2006).

Overinvestment and the AB

Olivers and Nieuwenhuis (2005) had participants perform a typical AB task, but one group of participants simultaneously performed a free association task in which they visualized a holiday or an imaginary grocery shopping trip while completing the AB task, while another group of participants concurrently listened to music/detected yells in a piece of music while performing an AB task. Counterintuitively, the groups who simultaneously performed an additional task showed an attenuated AB as compared to participants who completed the AB task on its own. A later study by Olivers and Nieuwenhuis (2006) had participants complete an AB task while simultaneously completing a match-to-sample task in which line patterns were presented before and after each AB stream. Again, they found that the AB was attenuated in the

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additional task group, as compared to controls who completed the task on its own.

Other studies have shown a similar pattern of results by directing attention away from the RSVP stream with the use of moving stimuli. For example, Taatgen, Juvina, Schipper, Borst, and Martens (2009) found a reduction in the AB when participants simultaneously attended to both an RSVP stream as well as a rotating dot. Similarly, Arend et al. (2006) demonstrated that an outward-moving star field surrounding the items in an AB task resulted in an attenuated AB as compared to when the star field was static, suggesting that the mere act of directing attention outwards can reduce the AB (see Kawahara, 2009 for an investigation of the parameters required to show a distractor-related reduction in the AB).

These findings were counterintuitive because one would expect that focusing your attention would allow you to more accurately detect targets. In addition, further dividing your attention by performing an additional task should result in greater dual-task performance impairments, not fewer, given that the AB is thought to result from attention being capacity limited. To explain these findings, Olivers and Nieuwenhuis (2005, 2006) proposed the overinvestment hypothesis. The overinvestment hypothesis suggests that when participants are focusing on attending to the targets in an AB task, they tend to overinvest their attention to all items (both targets and distractors) in the RSVP stream. Although participants overinvest attention to all stream items relative to what is required, they invest relatively more attention to items that resemble the target template or are temporally close to the targets. This allows T1, T2, and several irrelevant distractors to cross a minimum activation threshold required to allow items to compete for limited attentional processes that lead to consolidation of the item in working memory. This overcrowding in the second stage is particularly disadvantageous to T2, which enters the stage relatively late while T1 is already being consolidated. However, when a participant is forced to diffuse their attentional resources by performing an additional task, targets still cross the activation threshold, but irrelevant distractors are less likely to do so. There is, therefore, less competition for limited resources, and the AB is less likely to occur.

Individual differences

Support for the idea that overinvestment of attentional resources contributes to the AB can be found in several individual differences studies of the AB. Dispositional differences on a variety of tasks that have been linked to cognitive resource allocation predict performance on the AB. For example, studies have shown that individual differences in executive control of working memory predict

the size of the AB, such that individuals higher in working memory control (Arnell, Stokes, MacLean, & Gicanté, 2010; Colzato et al., 2007), and individuals who are better at inhibiting irrelevant distractors from entering working memory (Arnell & Stubitz, 2010; Dux & Marois, 2008; Martens & Valchev, 2009) show smaller ABs.

In addition, individuals with higher self-reported trait (MacLean, Arnell, & Busseri, 2010) and state (MacLean & Arnell, 2010; Vermeulen, 2010) positive affect, and individuals who report greater levels of openness to experience and extraversion (MacLean & Arnell, 2010), have also been shown to have smaller ABs. In contrast, individuals with higher self-reported trait (MacLean et al., 2010) and state (MacLean & Arnell, 2010; Vermeulen, 2010) negative affect, and greater neuroticism (MacLean & Arnell, 2010) show larger ABs. Low-arousal positive affect has previously been shown to result in a broadened attentional state (e.g., Fredrickson, 2001; Fredrickson & Branigan, 2005; Rowe, Hirsh, & Anderson, 2007), whereas high-arousal negative affect has been shown to relate to a focused or narrowed attentional state (e.g., Christianson & Loftus, 1990; Gasper & Clore, 2002); thus individuals high in trait positive affect presumably diffuse their attentional resources, and therefore are able to reduce the magnitude of their AB.

Electrophysiological measures of performance investment have also been shown to predict the AB. For example, Shapiro, Schmitz, Martens, Hommel, and Schnitzler (2006) used magnetoencephalography (MEG) to demonstrate that the probability of an AB occurring could be predicted by individual attentional resource investment to T1, such that greater individual AB magnitude was correlated with greater T1 peak amplitude. Using electroencephalography (EEG), Martens, Munneke, Smid, and Johnson (2006) showed that ‘non-blinkers’ (individuals who fail to show an AB with certain stimuli) had less activation to distractors and showed larger differences in neural activation between targets and distractors. MacLean and Arnell (2013) showed that individuals who had greater electrophysiological responses to performance feedback (reflective of investment in performance outcomes) on an AB task and a separate time-estimation task showed larger ABs. Furthermore, T2 performance has been linked to pre-trial attentional investment, measured as event-related alpha desynchronization (alpha ERD), such that greater pre-trial investment was associated with better T1 performance and better T2 performance at long lags, but worse T2 performance at short lags (MacLean & Arnell, 2011). This suggests that individuals who are focused on the task, or overinvest their attention into the targets, will be more susceptible to the AB effect. In general, the findings of these studies suggest that some aspect of control over the allocation of attentional resources can reduce the AB, and

that broadening the attentional scope can prevent the over-allocation of resources to irrelevant items.

Global/local processing

The above studies appear to provide convincing evidence that attentional focus/diffusion influences performance on the AB. However, as these studies did not directly measure focus/diffusion, but rather inferred this as the mechanism to explain the above relationships, they do not provide direct evidence that dispositional differences in attentional focus/diffusion per se influence AB performance. As such, it is important to directly measure individual differences in attentional breadth. One way to do so is with a global/local processing task. In a typical global/local task, participants are presented with a hierarchical stimulus which consists of a single large letter/shape/object (i.e., the global level) that is composed of several smaller letters/shapes/objects (i.e., the local level) (Navon, 1977; Kimchi & Palmer, 1982). The participant can either view the hierarchical stimuli at a broad, global level, or at a focused, local level. The hierarchical stimuli can be congruent, such that the global and local levels match (e.g., a large triangle made up of smaller triangles), or incongruent, such that the global and local levels do not match (e.g., a large triangle made up of smaller squares). Participants are usually required to report the identity of either the large (global) level, or the small (local) level as quickly as possible. The degree to which the global level interferes with time to report the local level on incongruent trials, relative to the degree to which the local level interferes with time to report the global level, is also calculated. A positive value indicates that there was greater global than local interference (“global precedence”), which suggests that there is a bias toward global information, and a broadening of attention (Navon, 1977). Conversely, a negative value indicates that there was more local than global interference (“local precedence”), which suggests a bias toward local information, and a narrowing of attention. Another common task variant asks participants to perform a forced-choice task in which they are simply required to choose one of the two sample hierarchical stimuli that best match a standard stimulus (Kimchi & Palmer, 1982). In this task, one of the sample figures will match the standard at the global level, and the other will match at the local level. The number of trials on which the global option was selected is then totaled, yielding a measure of global bias.

Interestingly, although many individuals show a general bias toward global information (Navon, 1977, 1981), there are large individual differences in global/local processing bias, such that some individuals show a strong preference for the global perceptual level (the forest), some a strong preference for the local perceptual level (a tree), and some

show no preference for either level. Importantly, this bias is reliable over more than a week (Dale & Arnell, 2013a). Thus, global/local tasks are an excellent tool for examining individual differences in attention breadth.

Dale and Arnell (2010) examined whether dispositional differences in performance on a traditional global/local Navon letter task could predict individual differences in AB performance. They found that greater global precedence on the Navon letter task was negatively correlated with AB magnitude, such that individuals who were higher in global precedence showed smaller ABs. This suggests that individuals who are naturally globally biased are less susceptible to the AB effect. These results are consistent with previous literature that has related differences in breadth and control of attention to reduced ABs.

Current study

Although Dale and Arnell (2010) clearly showed a relationship between dispositional global/local bias and AB performance, the Navon letter task has recently been shown to be one of the least reliable measures of global/local processing (see Dale & Arnell, 2013a). As such, it is possible that the relationship between global/local bias and the AB has been underestimated. In addition, Dale and Arnell (2013a) showed that three measures of global/local processing are uncorrelated with each other (i.e., the Navon letter task, the hierarchical shape task, and a high/low spatial frequency face task). This raises the possibility that these tasks may be measuring different aspects of global/local processing, and that the AB may be related to something unique to the Navon letter task. To examine this possibility, Experiment 1 of the current study was conducted to attempt to replicate the finding of Dale and Arnell (2010) using a more reliable individual differences measure of global/local processing. The ideal task is the hierarchical shape task developed by Kimchi and Palmer (1982), as it has been shown to be highly reliable over time (Dale & Arnell, 2013a), and is a straightforward measure of global/local bias.

Experiment 2 was conducted to examine whether the three global/local tasks used by Dale and Arnell (2013a) could each predict AB performance both on their own, and when combined into a single composite global/local measure. For example, if breadth of attention is related to the AB, and each of the three tasks measures a different unique aspect of breadth of attention, then we would expect unique relationships between the AB and each of the tasks, and that an overall score that includes all tasks may be a particularly effective predictor of the AB. However, if breadth of attention is related to the AB, but each of the three tasks explains the same variability in the AB, then we would expect each of the tasks to predict the AB, but none to

predict the unique variability in the AB over and above the others.

In addition, Dale and Arnell (2010) and Experiment 1 used an AB task in which the task differed for T1 and T2 (i.e., a switch AB task). As such, it is possible that attentional breadth somehow increased individuals' ability to overcome task switching costs, rather than reducing the AB per se. Therefore, Experiment 2 used both the switch and a no-switch version of the AB task from Dale and Arnell (2013b) to rule out this possibility.

Methods: experiment 1

Participants

Fifty-four Brock University undergraduate students (22 male), ranging in age from 18 to 30 years ($M = 21.2$, $SD = 2.9$), participated in Experiment 1 for course bonus credit. Fifteen participants were removed from the final analysis for having poor long-lag T2 sensitivity on the AB task (a difference of less than 40 % for hits %—false alarms %, averaged for lags 7 and 8; corresponding to a d' less than 0.96), suggesting that they were unable/unwilling to perform the task. As such, the total number of participants included in the final analysis was 39 (14 males). With an N of 39, we have power of at least 0.80 to find statistically significant correlations of 0.38 or larger at $p < 0.05$. The participants in both Experiment 1 and 2 reported normal or corrected-to-normal vision, and all had learned English before the age of 8. For both experiments, the participants performed the experiment one-on-one with the experimenter.

Apparatus

The computerized tasks for both experiments were presented using a Dell dual core desktop computer with a 17 in. CRT monitor, and were programmed and controlled using E-Prime software (Psychology Software Tools Inc.). The participants made responses via manual button presses on the computer keyboard.

Stimuli and design

Global/local shape task

This paper-and-pencil task was adapted from Kimchi and Palmer (1982) and Fredrickson and Branigan (2005). In this task, participants were presented with a booklet that contained 24 “shape triads”, each of which consisted of 3 hierarchical shapes that were arranged in a pyramid (see Fig. 1). The hierarchical shape at the top was called the “standard”, and

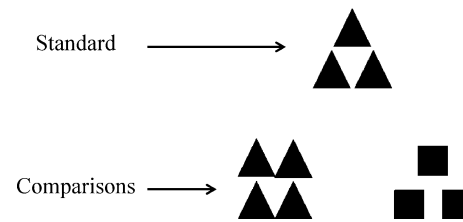


Fig. 1 Sample hierarchical shape triad from the global/local shape task

the two hierarchical shapes on the bottom were called the “comparisons”. For each triad, participants were instructed to circle the comparison shape that they felt best matched the standard shape. They were instructed to perform this task as quickly as possible using their first instinct.

Out of the 24 triads, 8 were “test” triads, and 16 were “fillers”. For the test triads, the hierarchical shapes consisted of 3–4 small (5×5 mm) triangles or squares (the local level) that produced a large (15×15 mm) triangle or square (the global level).¹ For the test triads, the comparison shapes both matched the standard, but one matched at the global level and the other matched at the local level (counterbalanced). The filler triads were created in a similar way, but with two notable differences. First, the local hierarchical shapes consisted of triangles, squares, circles or crosses that formed either a triangle or a square. Second, for the filler trials, only one of the comparison shapes matched the standard (at either the global or the local level, counterbalanced). To obtain an index of global processing bias/preference, the number of test triads in which the global comparison was selected was totaled for each participant. This resulted in a global score that ranged from 0 to 8, with 0 indicating a complete local bias, 4 indicating no bias for either level, and 8 indicating a complete global bias. Filler triads were not used to calculate global bias as they had only one correct response.

AB task

In this task, the participants were instructed to identify a single red letter (T1), and to detect the presence or absence

¹ Previous studies have shown that an overall global processing advantage often emerges when using traditional global/local stimuli (e.g., Navon, 1981). However, other studies (e.g., Kimchi & Palmer, 1982) have shown that this global advantage can be modulated by the relative size of the stimuli and by the number of local elements included in a global figure (i.e., the density of the figure). This is problematic for individual differences research, as this means that participants can become artificially biased toward global or local stimuli unless the stimuli are equated in terms of perceptual salience (e.g., Fredrickson & Branigan, 2005; Kimchi, 1992; Kimchi & Palmer, 1982). As such, we used the stimuli of Dale and Arnell (2013a, Experiment 1) for both Experiments 1 and 2 as these have been shown to have equally salient global and local levels, such that the stimuli are roughly global/local neutral.

of a black X (T2), from within a stream of 17 black distractor letters. The letters were presented in 18-point bolded New Courier font on a white background. The distractors and T1 were randomly drawn without replacement from all of the letters of the alphabet, except B, K, X, or Y. T1 was always presented as the seventh item in the stream, and T1 and T2 were separated by a lag of 1–8 items. T2 was a black X on 2/3rds of the trials (i.e., present), and was absent on 1/3rd of the trials. There were 120 trials in total. As this task was part of a larger individual differences study, participants performed this task twice (once at the beginning of the session, and once following two short cognitive tasks not reported here). There were no differences in mean performance from the first to the second block, $F < 1$, and performance on the two blocks was correlated 0.44, thus the means were collapsed across the two blocks, for a total of 240 AB trials.²

At the beginning of each trial, there was a 1,000 ms blank screen, followed by a 500 ms central fixation cross, then a second 1,000 ms blank, after which the first letter in the stimulus stream appeared in the center of the screen. Each letter was presented one at a time on the screen for 105 ms with no ISI. After the completion of each stream, the participants were instructed to identify the T1 letter by pressing the corresponding key on the keyboard, and then report whether the X had been present or absent (“0” key for absent, “1” key for present). Participants were instructed to perform as accurately as possible. To minimize false alarms, participants were instructed to only indicate that they saw the T2 X if they were reasonably sure that it was present.

Mean T1 accuracy was calculated by averaging mean T1 accuracy across lags, and mean T2 sensitivity was calculated by subtracting each participant’s overall false alarms from their T2 hits for each lag, conditionalized on T1 correct. To calculate AB magnitude, each participant’s mean short lag (2–4) T2 sensitivity was subtracted from their mean long-lag (7–8) T2 sensitivity where performance was at asymptote.

Procedure

After providing written consent, all participants performed the global/local task first, followed by the first block of AB trials.³ Participants completed the second block of AB

trials roughly 10 min after finishing the first. After completion of the study, participants were debriefed and compensated for their time. In total, this Experiment took approximately 1 h to complete.

Results: experiment 1

Global/local performance

The mean global shape task score was 3.82 (SD = 2.65) out of a maximum possible score of 8. The mean was not significantly different from 4 ($t(38) = -0.42$, $p = 0.68$, $d = -0.07$), indicating that the participants as a whole were not biased toward viewing either the global or the local stimulus level. The scores on this task ranged from 0 to 8, indicating that there were large individual differences in global bias. Accuracy on the filler trials was 0.94 (SD = 0.07), indicating that participants were performing the task as instructed. The internal consistency reliability of the global/local shape task was assessed using a split-half procedure wherein the trials were split into odd and even trials, and the odd and even halves were correlated. A Spearman–Brown procedure (Spearman, 1904) was then used to correct for using only half of the trials, thus allowing for a reliability estimate of the entire task (Nunnally, 1978). This task was found to be highly reliable, $r = 0.84$, with estimates that closely approximate those found by Dale and Arnell (2013a).

AB performance

For the AB task, overall T1 accuracy was high ($M = 0.88$; SD = 0.07), and did not differ as a function of lag, $F < 1$. A repeated-measures ANOVA conducted to examine whether T2 sensitivity differed as a function of lag, showed a significant main effect of lag, $F(7, 266) = 69.98$, $p < 0.001$, $\eta^2 = 0.65$, indicating the presence of an AB. The internal consistency reliability of the AB task was also assessed using the split-half procedure described above. The task was found to be moderately reliable, $r = 0.52$, and the reliability estimate was comparable to estimates obtained in a similar AB task by Dale, Dux, and Arnell (2013) and Dale and Arnell (2013b).

² One of the additional tasks was an unrelated cognitive maze task used as a filler and the other was a Navon task. In addition to having two blocks of AB trials, 120 AB trials in both blocks were further subdivided into 10 mini-blocks of 12 trials each, with a 1 min Navon letter task interspersed. The Navon task had no effect on the AB trials for the first versus second block, and there were no significant differences among these mini-blocks, $F < 1$, thus the data were ultimately collapsed both within block and across block.

³ When conducting an individual differences study, it is not ideal to counterbalance the tasks’ order across participants. Performance on the tasks may differ somewhat based on the order in which they are presented; therefore a participant’s relative score on a given task could be confounded with order variability if order was counterbalanced or random. This confound can be removed in individual differences studies using a constant task order, which is why all participants ran the tasks in the same order here.

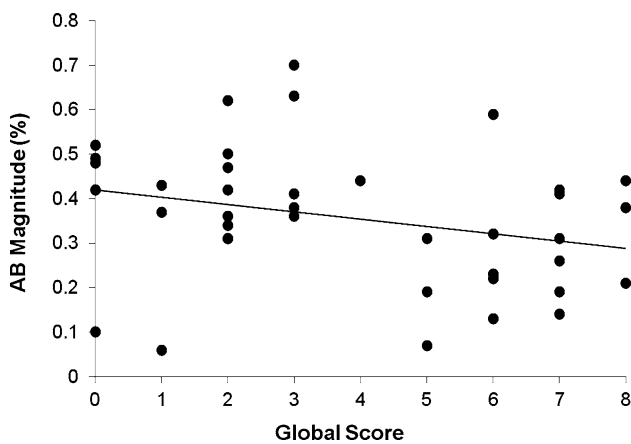


Fig. 2 Scatterplot depicting a negative Pearson r correlation between overall global shape task score and AB magnitude

Relationship between AB and global score

A Pearson r correlation analysis was then conducted to examine the relationship between the global score on the shape task and AB magnitude. The correlation between global score and AB magnitude approached significance, $r = -0.28$, $p = 0.09$, such that individuals with higher global scores had smaller ABs (see Fig. 2). Although not statistically significant, the pattern of results was in accordance with our hypothesis and suggests that global/local bias on a forced-choice global/local task can predict AB size.

In addition to examining the data on a continuum, the data were divided to further examine the differences in AB performance for individuals who were classified as globally versus locally biased. Participants who had scores that fell between 0 and 3 were classified as having low global bias scores ($n = 21$), and those who had scores that fell between 5 and 8 were classified as having high global bias scores ($n = 17$).⁴ The lone individual who scored a 4 was considered to be global/local “neutral”, thus their data were not included in this analysis. An independent samples t test using the AB estimates calculated above showed that the size of the AB differed for the high and low global score groups, $t(36) = 2.71$, $p = 0.01$, $d = 0.89$, which supports the idea that individuals who show a dispositional global bias are less susceptible to the AB.

One would predict that global score should influence short lag T2 performance (during the AB), but not long-lag T2 performance during the baseline period after the AB. To test this, a mixed-model ANOVA with lag as the within-

⁴ Note that while there are several issues surrounding the dichotomization of variables (see MacCallum, Zhang, Preacher, & Rucker, 2002), the data were split here as a supplement to the correlational analyses that were already conducted, and to allow for a better visualization of the pattern of results.

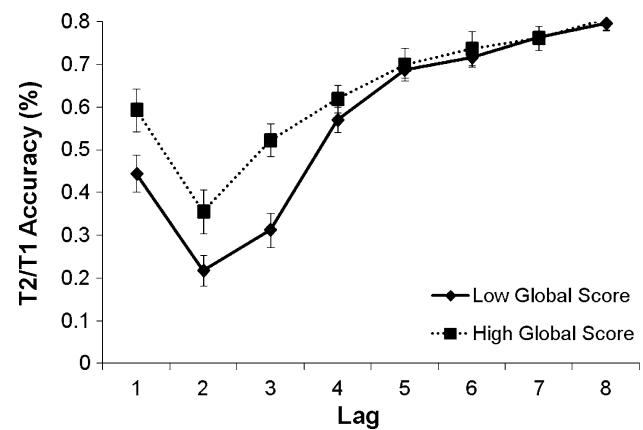


Fig. 3 Mean T2 accuracy given T1 correct as a function of lag in the AB task for high and low global score groups. Error bars represent the standard error for each condition mean

subjects factor and high/low global score as the between-subjects factor was performed to examine whether the AB pattern differed depending on whether a participant had a high or low global score (see Fig. 3). There was a significant main effect of lag, $F(7, 252) = 67.46$, $p < 0.001$, $\eta_p^2 = 0.65$, and the main effect of high/low global score approached significance ($p = 0.07$). Importantly, there was a significant interaction between lag and high/low global score, $F(7, 252) = 3.29$, $p = 0.002$, $\eta_p^2 = 0.08$, indicating that the AB differed depending on whether the participant had a high or a low global score. As is shown in Fig. 3, individuals with a high global score showed a smaller AB effect than did individuals with a low global score.

A post hoc examination of the pattern of AB data for the two groups showed that the two groups had the largest T2 sensitivity differences at lags 2 and 3, and that for both groups the AB was essentially over by lag 4. As such, including lag 4 in the calculation of AB magnitude may have reduced the estimate of AB size, resulting in an underestimation of the relationship between AB size and global score. Therefore, we recalculated AB magnitude to exclude lag 4. With this new estimate of AB size, the correlation between global score and AB magnitude was now statistically significant, $r = -0.33$, $p = 0.04$, demonstrating that global score predicts AB size.

Discussion: experiment 1

The results conformed to our hypothesis, such that greater global biases were associated with smaller ABs. This finding is also consistent with our previous study which examined Navon interference and AB magnitude (Dale & Arnell, 2010), as well as with other research which has examined the benefit of a broadened attentional focus while performing an AB task (e.g., Arend et al., 2006; Olivers &

Nieuwenhuis, 2005, 2006). Therefore, we can conclude that global processing is associated with a reduction in AB size as opposed to a specific attribute of the Navon letter task.

While we were able to replicate our previous finding using a different measure of dispositional global/local bias, as noted above, a recent study (Dale & Arnell, 2013a) has shown that individual performance on the Navon letter task used in Dale and Arnell (2010), and the global/local shape task used here, are uncorrelated to each other. That is, whereas both may be measuring some aspect of global/local processing, they are apparently measuring unique aspects of this construct. Dale and Arnell (2013a) also used a hybrid face task to examine individual differences in the use of high or low spatial frequency information. In this task, high spatial frequency information from one facial identity is superimposed over low spatial frequency information of another facial identity, and participants are asked to identify the face (Deruelle, Rondan, Salle-Collemiche, Bastard-Rosset, & Da Fonseca, 2008). Dale and Arnell (2013a) showed that the use of high or low spatial frequency information to identify faces was a highly reliable individual difference variable across more than a week (i.e., some participants showed a reliable bias to select the face that had been presented using only high spatial frequency information, whereas others showed a reliable bias to select the face that had been presented using only low spatial frequency information). Interestingly, this bias was also unrelated to global/local bias on either global/local task. As such, for Experiment 2, we decided to again examine the relationship between dispositional global/local bias and AB size, but this time using all three attentional/perceptual breadth measures from Dale and Arnell (2013a).

Method: experiment 2

Participants

Sixty-one undergraduate student volunteers (4 male) from Brock University initially participated in Experiment 2 for extra course credit. The participants ranged in age from 17 to 35 ($M = 19.6$, $SD = 3.3$). Twelve participants (1 male) were ultimately removed from the final analysis; 11 for having poor (less than 40 %; corresponding to a d' of less than 0.58) long-lag T2 sensitivity on the switch AB task (as in Experiment 1), and 1 participant for not completing the global/local measures. Thus, the total number of participants included in the final analysis was 49 (3 males). With an N of 49, we have power of at least 0.80 to find statistically significant correlations of 0.35 or larger at $p < 0.05$.

Stimuli and design

Global shape task

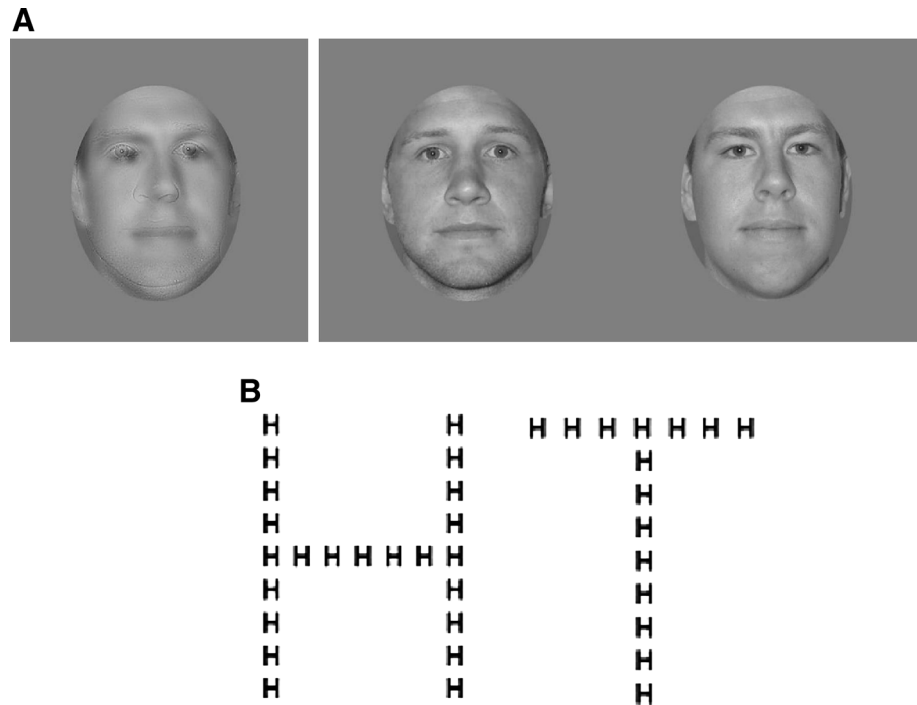
This task was the same as the one used in Experiment 1, with no alterations.

Global face task

For the face task, we acquired 27 male and 27 female normed young adult Caucasian faces with no facial hair from the Center for Vital Longevity Face Database (Minear & Park, 2004). The faces were cropped to remove head hair, converted to greyscale, and pasted onto a 480×480 pixel dark grey background so that they subtended approximately 16° of visual angle with an unrestrained viewing distance of approximately 55 cm. High (local) and low (global) spatial frequency (SF) versions of each face were constructed using Adobe Photoshop. To create the high SF faces, a high-pass filter was used so that the faces contained only SFs higher than 6 cycles/degree of visual angle (i.e., a radius of 1.5 pixels). To create the low SF faces, a Gaussian blur was used so that the faces only contained SFs lower than 2 cycles/degree of visual angle (i.e., a radius of 4.5 pixels). We then created hybrid faces by superimposing the high SF face of one identity over the low SF face of another identity (matched for gender, luminance, and size). A total of 54 hybrid faces were constructed, with each original identity contributing high SF information to one hybrid face and low SF information to another hybrid face (see Fig. 4a).

At the beginning of each trial, a fixation cross appeared in the center of the screen for 1,000 ms and was then replaced with a hybrid face which remained on the screen for 300 ms. The hybrid face then disappeared and was replaced with the two intact (non-filtered) faces that comprised the hybrid face; one on the left side of the screen and one on the right (counterbalanced). Each hybrid face was presented once for a total of 54 trials. On each trial, participants were asked to select the intact face that they felt best matched the hybrid face by pressing a labeled key on the keyboard (the “A” key for the face on the left, and the “L” key for the face on the right). Participants were instructed to use their first instinct when making this selection and responses were not speeded. To calculate global bias, we totaled the number of trials in which the participant selected the intact face that had contributed low SF (global) information to the hybrid. This yielded a score out of 54, such that higher numbers indicated a global bias, and low numbers indicated a local bias.

Fig. 4 a Sample stimuli from the global/local face task, with the hybrid face on the far left, and the two intact faces that comprised the hybrid on the right. **b** Sample Navon letter stimuli, with congruent letters on the left (i.e., the global and local levels match) and incongruent letters on the right (i.e., the global and local levels do not match)



Navon letter task

The Navon letter stimuli consisted of small (7×5 mm) “H’s” or “T’s” (the local letters) presented in black New Courier font that formed a large (70×50 mm) H or T (the global letter) (see Fig. 4b). Half of the Navon letters were congruent (i.e., the global and local letters were the same) and half were incongruent (i.e., the global and local letters were different), and these were randomly intermixed.

At the beginning of each trial, a fixation cross appeared in the center of the screen for 500 ms and was then replaced with a single Navon stimulus. Participants were instructed to identify either the large letter (globally directed block) or the smaller letters (locally directed block) by pressing the corresponding key on the keyboard as quickly as possible. The stimuli remained on the screen until the participant made a response. There were two globally directed and two locally directed blocks which alternated (everyone began with the global block). Each block contained 24 trials, for a total of 96 trials (48 globally directed and 48 locally directed).

To assess global/local performance, the RTs for each combination of task (global/local block), and condition (congruent/incongruent) were averaged for correct trials only. RTs that fell outside 3 standard deviations from the mean were removed. Measures of global interference and local interference were then calculated for each participant. Local interference was calculated as the degree to which the local letters interfered with RT on globally directed

trials (global incongruent RT–global congruent RT), and global interference was calculated as the degree to which the global letters interfered with RT on locally directed trials (local incongruent RT–local congruent RT). Finally, a measure of global precedence was calculated by subtracting the local interference score from the global interference score. A positive number indicated a global bias, whereas a negative number indicated a local bias.

AB

In addition to the three global/local tasks, the participants completed two different AB tasks; one with a T1/T2 task switch, and one without. The switch AB task was the same as the AB task used in Experiment 1, although there were some small differences. First, participants completed only 120 trials, rather than 240. Second, T1 could appear in either position 7 or position 10 in the stream.

The no-switch AB task was very similar to the switch AB task, but with the following differences. First, both T1 and T2 were now red letters that the participants had to identify. Second, the letters B, I, L, O, U, V, and X were excluded as possible target or distractor letters. Finally, each combination of T1 position (7 or 10) and T2 position (1–8) was presented 5 times, for a total of 80 trials.

For both AB task versions, AB magnitude was calculated by taking each participant’s mean short lag (2–4) T2 accuracy/sensitivity and subtracting it from their mean long-lag (7–8) T2 accuracy/sensitivity.

Procedure

All participants completed the tasks in the same order. Participants began with the global shape task, followed by the switch AB task. Following the switch AB task, participants received a short (5 min) break, after which they completed the no-switch AB task, the global face task, and the Navon letter task. Although the 5-min break was enforced, participants were also permitted to take short breaks between tasks if they felt fatigued. At the conclusion of the experiment, participants were debriefed and compensated for their time. In total, this experiment took approximately 1.5 h to complete.

Results: experiment 2

Global/local performance

Global shape task

The mean global shape task score was 3.41 (SD = 2.25) out of a maximum possible score of 8. The mean was not significantly different from 4, $t(48) = -1.85$, $p = 0.07$, $d = -0.26$, indicating that the participants as a whole were not biased toward viewing either the global or the local stimulus level. The individual scores on this task ranged from 0 to 7, indicating that there were large individual differences in global bias. Accuracy on the filler trials was 0.96 (SD = 0.06), indicating that participants were performing the task as instructed. As with study 1, internal consistency reliability estimates were obtained using a split-half correlation with a Spearman–Brown correction. The global shape task was highly reliable, $r = 0.74$, with a reliability estimate that was comparable to that found by Dale and Arnell (2013a).

Global face task

The mean global face task score was 29.71 (SD = 5.96) out of a maximum possible score of 54. As such, just over half of the trials were classified at the global perceptual level. This global advantage was statistically significant when compared with a chance score of 27, $t(48) = 3.19$, $p = 0.003$, $d = 0.45$. However, there was a great deal of individual variability in this task, with scores that ranged from 18 to 46. An internal consistency reliability estimate demonstrated that this task was moderately reliable, $r = 0.56$, albeit with a lower reliability estimate than that reported by Dale and Arnell (2013a) for a similar task.

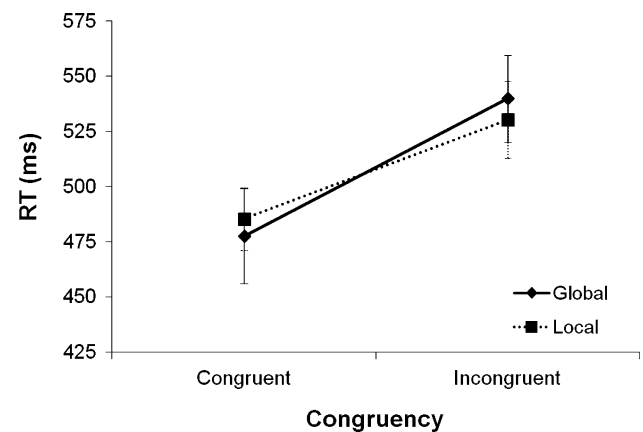


Fig. 5 Mean RTs for the globally and locally directed trials of the Navon letter task as a function of congruency. Error bars represent the standard error for each condition mean

Navon letter task

The mean Navon letter task RTs are presented in Fig. 5 as a function of stimulus level (i.e., global/local) and congruency (i.e., incongruent/congruent). A 2 (level) X 2 (congruency) repeated-measures ANOVA showed a significant main effect of congruency, $F(1, 48) = 78.07$, $p < 0.001$, $\eta_p^2 = 0.46$, but no main effect of level, $F(1, 48) = 0.006$, $p = 0.94$, $\eta_p^2 = 0.003$, and no interaction between level and congruency, $F(1, 48) = 1.62$, $p = 0.21$, $\eta_p^2 = 0.005$. This indicates that there was no overall global or local advantage on this task. Indeed, global precedence scores ranged from -224.88 to 487.74 on this task, indicating that there were large individual differences.

The mean error rate was 4 %, indicating that participants were performing the task as instructed. A 2 (level) X 2 (congruency) repeated-measures ANOVA on the error data showed that there was a significant main effect of congruency, $F(1, 48) = 36.42$, $p < 0.001$, $\eta_p^2 = 0.43$, such that participants had more errors on incongruent as compared to congruent trials. However, there was no effect of stimulus level, or an interaction between level and congruency, all p 's > 0.10 .

Finally, an internal reliability estimate indicated quite poor reliability for this task, $r = 0.21$, replicating the results of Dale and Arnell (2013a).

AB performance

Switch AB task

For the switch AB task, T1 accuracy was high overall ($M = 0.91$; SD = 0.07), and did not differ as a function of lag, $F < 1$. T2 sensitivity was calculated by subtracting each participant's overall false alarms from their T2 hits for

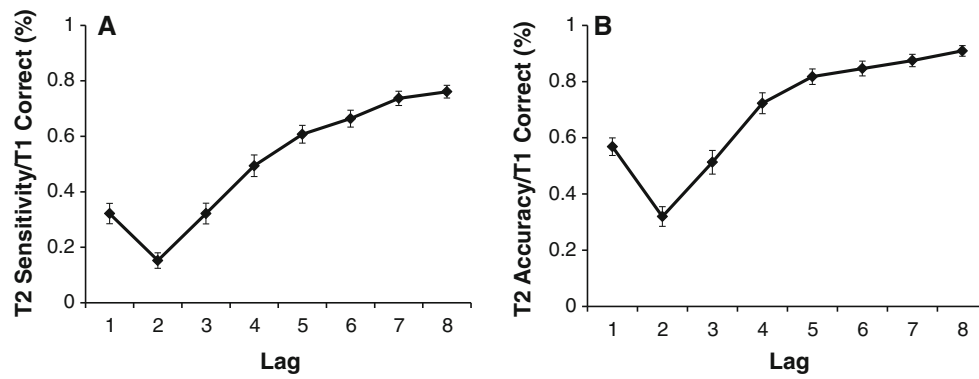


Fig. 6 **a** Mean T2 sensitivity given T1 correct as a function of lag for the switch AB task. **b** Mean T2 accuracy given T1 correct as a function of lag for the no-switch AB task. Error bars represent the standard error for each condition mean

each lag, conditionalized on T1 being correct. A repeated-measures ANOVA on T2 sensitivity scores showed a significant main effect of lag, $F(7, 336) = 80.81$, $p < 0.001$, $\eta_p^2 = 0.63$, indicating the presence of an AB (see Fig. 6a). The switch AB task had moderate reliability, $r = 0.54$, with an estimate that is comparable to that found in Experiment 1, as well as to the estimates reported by both Dale et al. (2013), and Dale and Arnell (2013b).

No-switch AB task

For the no-switch AB task, T1 accuracy was fairly high overall ($M = 0.78$; $SD = 0.12$), and did not differ as a function of lag, $F < 1$. T2 accuracy was conditionalized on T1 correct. A repeated-measures ANOVA performed on T2 accuracy showed a significant main effect of lag, $F(7, 336) = 72.52$, $p < 0.001$, $\eta_p^2 = 0.60$, indicating that an AB was present (see Fig. 6b). Similar to the switch AB task, the reliability of the no-switch task was moderate, $r = 0.56$, and was comparable to that found in Experiment 1, and to the estimates reported by both Dale et al. (2013), and Dale and Arnell (2013b).

Combined AB score

As previous research has shown that these switch and no-switch AB tasks share variability (see Dale & Arnell, 2013b; Dale et al., 2013), and were significantly correlated here ($r = 0.33$, $p = 0.02$), a combined AB measure was calculated to better estimate individual AB magnitude. To create this measure, the AB magnitude scores for each task were first standardized, and then averaged together to create a combined AB magnitude score.

Relationship between AB and global scores

To examine the relationship between AB magnitude and each of the three measures of global/local processing,

Pearson r correlation analyses were performed. AB magnitude and global face scores were significantly negatively correlated ($r = -0.38$, $p = 0.007$), such that individuals who were more likely to select the global (low frequency information) face had smaller ABs. A similar pattern of results was found with the global shape task ($r = -0.31$, $p = 0.03$), such that individuals who were more likely to select the global comparison image had smaller ABs. The global precedence scores from the Navon letter task, however, were not significantly correlated with AB size ($r = -0.18$, $p = 0.21$). In general, however, it does appear that individuals who show a global preference are less susceptible to the AB.

Previous work from our lab has shown that although the three global/local tasks used here are all good individual difference measures of dispositional global/local bias, they are uncorrelated with each other (Dale & Arnell, 2013a). A similar result was found with the current study such that global shape and global face scores ($r = 0.11$), the global shape and global precedence scores ($r = 0.01$), and the global face and global precedence scores ($r = -0.05$) were all uncorrelated. This suggests that if each task is actually measuring global/local processing, they are each measuring a unique aspect of this construct. Indeed, when a simultaneous regression analysis was performed on the present data with all three global/local measures as predictors of AB magnitude, the global face score ($sr = -0.36$, $p = 0.007$) and the global shape score ($sr = -0.26$, $p = 0.05$) each explained significant unique variance in AB magnitude (i.e., variance in the AB not explained by the other predictors). In addition, the three global/local measures together explained a significant 25.5 % of the variance in AB size, $R = 0.51$, $F(3, 45) = 5.13$, $p = 0.004$. Global precedence on its own, however, was not a significant unique predictor of AB magnitude ($sr = -0.20$, $p = 0.13$).

A composite global score was then created that combined the three global/local measures, thus allowing us to

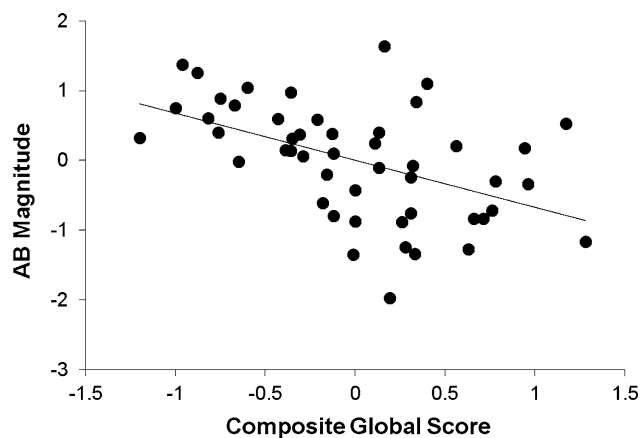


Fig. 7 Scatterplot depicting a significant negative Pearson r correlation between the mean composite global score and combined AB magnitude

have a more complete measure of global/local bias for each individual. Each of the three global scores (shapes, faces, and global precedence) was converted to z -scores, and then averaged together to create a composite. A Pearson r correlation analysis was performed to examine the relationship between the composite global score and AB magnitude. Composite global score and AB magnitude were significantly negatively correlated, $r = -0.49$, $p < 0.001$, such that individuals with higher global scores had smaller ABs, and vice versa (see Fig. 7). This nicely shows that the composite global score was better able to predict AB magnitude than was each predictor on its own. In addition, when we examined the two AB tasks individually, the composite global score was a significant predictor of both switch AB magnitude, and no-switch AB magnitude, $r = -0.49$, $p < 0.001$ and $r = -0.31$, $p = 0.01$, respectively.

As with Experiment 1, we then divided the data on the composite global scores to further compare the shape of the AB function for those with low and high global bias. Participants who had negative global bias z -scores were classified as having low global bias scores ($n = 24$), and those who had positive z -scores were classified as having high global bias scores ($n = 25$). An independent samples t test showed that AB magnitude, as calculated above, differed for high and low global score groups, $t(47) = 3.11$, $p = 0.003$, $d = 0.89$, such that the high global score group had smaller ABs. A mixed-model ANOVA with lag as the within-subjects factor and high/low composite global score as the between-subjects factor was then performed (see Fig. 8). There was a significant main effect of lag, $F(7, 329) = 132.80$, $p < 0.001$, $\eta_p^2 = 0.74$, but no main effect of high/low global score ($p = 0.16$). Importantly, however, there was a significant interaction between lag and high/low global score, $F(7,$

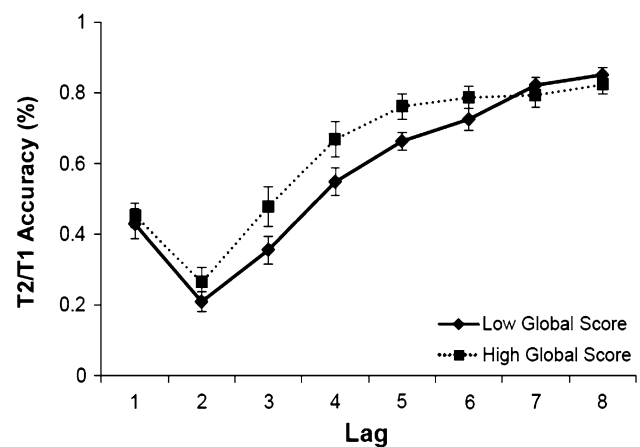


Fig. 8 Mean T2 accuracy given T1 correct as a function of lag in the AB task for individuals with high and low composite global scores. Error bars represent the standard error for each condition mean

$329) = 2.58$, $p = 0.01$, $\eta_p^2 = 0.05$, indicating that AB magnitude differed depending on whether the participant had a high or a low global score. Indeed, Fig. 8 shows that individuals with a high global score showed a smaller AB effect than did individuals with a low global score.

General discussion

Previous research has demonstrated that individuals who have high levels of global precedence on the Navon letter task show smaller ABs as compared to those who have low levels of global precedence (Dale & Arnell, 2010). This suggests that some aspect of attentional broadening may improve an individual's ability to effectively allocate their attentional resources to targets in an AB task. However, global bias calculated using the Navon letter task has been shown to have fairly low reliability (Dale & Arnell, 2013a), and Dale and Arnell (2013a) recently showed that three different purported measures of global/local processing are unrelated to each other. As such, the primary purpose of the current study was to examine, through two experiments, whether a variety of dispositional global/local bias measures could predict AB size. We examined both a more reliable measure of global/local processing bias (Experiment 1), and a combination of three commonly used measures of global/local processing (Experiment 2) to predict AB magnitude in two different AB tasks. In both experiments we showed that, following Dale and Arnell (2010), individuals who were naturally biased toward the broad, global, features of a hierarchical or hybrid stimulus were also less susceptible to the AB.

In Experiment 1, we showed that performance on the Kimchi and Palmer (1982) hierarchical shape task successfully predicted AB magnitude, such that individuals

who chose more global comparison shapes also showed smaller ABs. This provided further support for the idea that a dispositional global bias can lead to better selective attention performance. In Experiment 2, we showed that performance on the hierarchical shape task (Kimchi & Palmer, 1982), and a high/low spatial frequency face task (Deruelle et al., 2008) predicted AB size, such that individuals who showed a larger global bias had smaller ABs. This correlation was significant for both of these global/local measures, and both measures predicted unique variance in the AB. As such, we ultimately combined the scores from all three measures to create a composite global/local bias score, thus providing a more complete measure of global bias. This composite global score was strongly correlated with AB magnitude, such that individuals who had a high composite global score showed smaller ABs as compared to those who had a low global score. It should be noted, however, that unlike in Dale and Arnell (2010) global precedence on the Navon letter task did not significantly predict AB magnitude. One possibility for this lack of relationship could be that the Navon letter task is a less reliable measure of individual differences in global/local processing bias, thus these individual differences may not have been accurately captured by this task (see Dale & Arnell, 2013a).

Global bias scores not only predicted AB magnitude when the two AB scores were combined, but also predicted AB magnitude in both the switch and no-switch versions of the AB task in Experiment 2. This was important to show because although Dale and Arnell (2010) showed that global precedence on the Navon letter task predicted AB magnitude on a switch AB task, they did not include a no-switch AB task. This raised the possibility that attentional breadth may actually predict task-set switch costs (i.e., individuals with greater attentional breadth having smaller task switch costs), rather than susceptibility to the AB. The present finding that global bias predicted AB magnitude on both a switch and a no-switch AB task provides good evidence that attentional breadth is related to the AB itself, and not simply to the ability to overcome task switch costs.

The global face task is not, strictly speaking, a global/local task, although local information is higher spatial frequency than global information. Finding that global bias on the spatial frequency face task predicts that the AB also extends the results to show that individual differences in the use of high or low spatial frequency information can predict the AB even when hierarchical stimuli are not used.

These results, taken together, provide support for the overinvestment hypothesis (Olivers & Nieuwenhuis, 2006), which suggests that broadening or diffusing attention can reduce overinvestment to irrelevant distractors and T1, thus attenuating the AB. Individuals who have a natural tendency to view the broader picture, as indexed by a larger

global bias, might therefore be less likely to overinvest attentional resources to T1 and distractors, leading to a reduction in their AB. These findings also provide support for other models of the AB that stress the role of cognitive control over attentional resource deployment, (e.g., Di Lollo, Kawahara, Gorashi, & Enns, 2005; Olivers & Meeter, 2008; Taatgen et al., 2009) and the importance of effectively ignoring irrelevant information (Arnell & Stubitz, 2010; Dux & Marois, 2008; Martens & Valchev, 2009).

In addition to possibly modulating the level of investment, individual differences in breadth of attention may predict the AB by setting how participants conceptualize the task. For example, the AB is attenuated dramatically when three targets are positioned sequentially with no intervening distractors (Di Lollo et al., 2005), when T1 is morphed into T2 across the RSVP sequence (Kellie & Shapiro, 2004), and when task instructions lead the participants to view T1 and T2 as part of the same set, rather than as two separate items (Nieuwenstein & Potter, 2006). These findings suggest that when T1 and T2 are placed within the same broad attentional window T2 performance is relatively uncompromised. It is possible that individuals with greater attentional breadth are more likely to set a broad temporal window that encompasses both T1 and T2, whereas individuals with a more local focus may build more temporally focused windows.

The present findings are also consistent with much of the research on the AB and individual differences. For example, attentional breadth has been linked to affect, such that positive affect has been shown to broaden attention, whereas negative affect has been shown to narrow attention (e.g., Fredrickson & Branigan, 2005; Gasper & Clore, 2002). Affect in turn has been shown to correlate with AB magnitude (e.g., MacLean & Arnell, 2010; MacLean et al., 2010; Vermeulen, 2010) where positive affect is associated with smaller ABs and negative affect with larger ABs. Therefore, it is possible that individual differences in affect may lead to differences in attentional scope, and that attentional breadth may mediate the relationship between affect and AB performance.

Beyond the AB, the finding that individual differences in attentional breadth are quite stable over time and predict dual-task costs in the AB paradigm leads to the intriguing possibility that breadth of attention may also have implications for performance on a variety of selective attention paradigms and in everyday life.

In addition, the possibility was raised that individuals who are globally biased might group the targets in the AB task into a single set, rather than treating them as individual items. If this grouping is a natural byproduct of being globally biased, then perhaps individuals who show a global bias are more likely to group individual items into

larger sets in other areas of their life. For example, they might have more inclusive and broader categories of objects or people in their everyday lives, which could influence a host of behaviors and processes, such as the ability to recognize other-race faces, or make remote associations between dissimilar words or objects.

Finally, if dispositional global/local bias influences the AB, might biasing individuals into a more global or local state influence performance on other attentional tasks? There is evidence that individuals who are trained to play action video games (such as first-person shooter games), and thus presumably develop the ability to multitask/broaden their attention, show great improvements on a variety of visual attention tasks, including the AB (Green & Bavelier, 2003). Therefore, this raises the interesting possibility that individual global or local biases could be altered, either temporarily or permanently, thus leading to improvements (or impairments) in performance on tasks for which a broadened attentional scope is beneficial (but see Dale & Arnell, 2014).

While it is clear that there is some relationship between global/local processing and the AB, it is still uncertain how global/local bias may modulate attentional selection. This is made especially difficult by the fact that the three global/local tasks used in this study have been shown to be uncorrelated with each other (Dale & Arnell, 2013a) and each predicted unique variability in the AB here, suggesting that there are a number of different processes at play that each contribute to individual differences in selective attention. The present results support the idea that breadth of attention predicts the AB, but that global/local is not a unitary construct, and that this measure of attentional and perceptual breadth is multifaceted and in need of further investigation. Regardless, the present results provide compelling evidence that individual differences in attentional breadth, as assessed using a variety of global/local tasks, predict individual differences in the magnitude of the AB effect.

Acknowledgments This work was funded by grants from the National Sciences and Engineering Research Council (NSERC), the Canadian Foundation for Innovation (CFI), and the Ontario Innovation Trust (OIF) to the second author. We thank Blaire Dube, Baris Bagcilar, and Tabatha Methot for their assistance with data collection.

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