

Individual Differences in Global/Local Processing Bias
and the Attentional Blink

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DEDICATION

This dissertation is dedicated to my wonderful husband, Randy. Your encouragement, eternal patience, and unwavering love and support during this long process has made my dream a reality.

GENERAL ABSTRACT

When the second of two targets (T2) is presented temporally close to the first target (T1) in rapid serial visual presentation, accuracy to detect/identify T2 is markedly reduced as compared to longer target separations. This is known as the attentional blink (AB), and is thought to reflect a limitation of selective attention. While most individuals show an AB, research has demonstrated that individuals are variously susceptible to this effect. To explain these differences, Dale and Arnell (2010) examined whether dispositional differences in attentional breadth, as measured by the Navon letter task, could predict individual AB magnitude. They found that individuals who showed a natural bias toward the broad, global level of Navon letter stimuli were less susceptible to the AB as compared to individuals who showed a natural bias toward the detailed, local aspects of Navon letter stimuli. This suggests that individuals who naturally broaden their attention can overcome the AB. However, it was unclear how stable these individual differences were over time, and whether a variety of global/local tasks could predict AB performance. As such, the purpose of this dissertation was to investigate, through four empirical studies, the nature of individual differences in both global/local bias and the AB, and how these differences in attentional breadth can modulate AB performance. Study 1 was designed to examine the stability of dispositional global/local biases over time, as well as the relationships among three different global/local processing measures. Study 2 examined the stability of individual differences in the AB, as well as the relationship among two distinct AB tasks. Study 3 examined whether the three distinct global/local tasks used in Study 1 could predict performance on the two AB tasks from Study 2. Finally, Study 4 explored whether individual differences in global/local bias

could be manipulated by exposing participants to high/low spatial frequencies and Navon stimuli. In Study 1, I showed that dispositional differences in global/local bias were reliable over a period of at least a week, demonstrating that these individual biases may be trait-like. However, the three tasks that purportedly measure global/local bias were unrelated to each other, suggesting that they measure unique aspects of global/local processing. In Study 2, I found that individual variation in AB performance was also reliable over a period of at least a week, and that the two AB task versions were correlated. Study 3 showed that dispositional global/local biases, as measured by the three tasks from Study 1, predicted AB magnitude, such that individuals who were naturally globally biased had smaller ABs. Finally, in Study 4 I demonstrated that these dispositional global/local biases are resistant to both spatial frequency and Navon letter manipulations, indicating that these differences are robust and intractable. Overall, the results of the four studies in this dissertation help clarify the role of individual differences in attentional breadth in selective attention.

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CHAPTER 1: GENERAL INTRODUCTION

Selective attention plays a critical role in our cognitive experience. It allows us to select relevant information from our environment, elaborate this information, and bring it into conscious awareness, all while filtering out irrelevant information from receiving further processing (Broadbent, 1958; Treisman, 1960). This selection of only the most relevant information is crucial, because otherwise we would be overcome with the vast amount of useless, irrelevant information that is in our environment. However, attention is capacity limited, and thus we can only attend to a few items at a given time (Broadbent, 1958; Treisman, 1960). One way to examine this attentional limitation in the laboratory is by using the rapid serial visual presentation (RSVP) paradigm.

The Attentional Blink

In a typical RSVP task, participants are presented with a rapid stream of stimuli (i.e., letters, digits, words, pictures, shapes) that appear one at a time in the same spatial location for a short duration (usually 50-150 ms per item). Participants are typically asked to select and report one or two target items from within the stream, and accuracy for detecting/reporting targets is measured. The amount of time, or lag, between the presentations of two targets is varied by altering the number of intervening distractors that are presented between the two targets (e.g., lag 2 means that T2 comes two items after T1). Interestingly, when participants are asked to select two targets from the RSVP stream, and the lag between the first (T1) and second (T2) targets is relatively short (i.e., within ~500 ms or 5 items), accuracy for detecting/identifying T2 is markedly diminished as compared to longer target-lag separations (Raymond, Shapiro, & Arnell, 1992; See Figure 1-1). This is called the Attentional Blink (AB), and is thought to reflect a

limitation in selective attention and the resultant lapse in conscious awareness (Raymond et al., 1992).

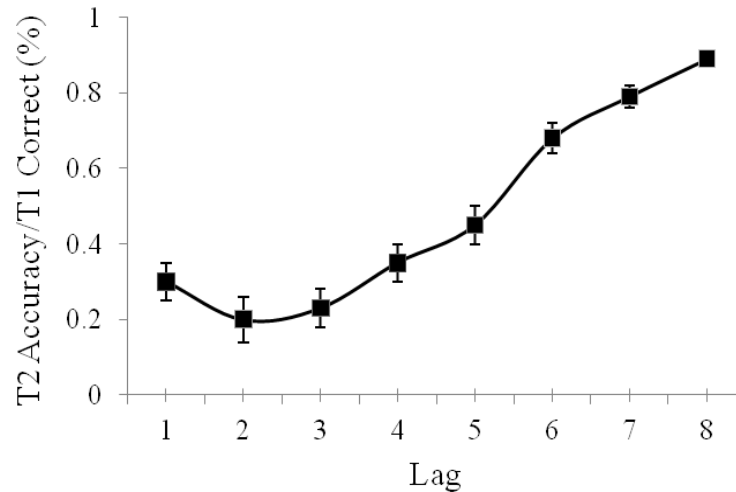


Figure 1-1. *Prototypical AB T2 accuracy as a function of lag in an AB task when T1 is correctly identified/detected.*

Since its inception, the AB has become a well-studied and important phenomenon in the attention literature. Its prominence is due to the fact that this is one of the only cognitive behavioural tasks that can provide an indication of the time-course of attentional selection, and consolidation, of incoming information. While there are no precise analogues in the real world, the AB phenomenon does inform us about why humans often have difficulty attending to multiple sequential pieces of information, such as when we are attempting to navigate a car through a busy city street. Additionally, the AB is a robust phenomenon that occurs across a variety of participants, with multiple types of stimuli, and even with non-visual modalities (such as auditory and tactile; Arnell & Jolicoeur, 1999). As such, the AB task is one of the prominent methods of studying how we attend to information in our environment, and allows us to investigate the limitations of selective attention.

Attenuating the AB

Although most individuals are susceptible to the AB and show large decrements in short-lag T2 accuracy as compared to long-lag T2 accuracy (i.e., large AB magnitudes), simple changes to the instructions, task requirements, and stimulus presentation conditions of targets and distractors can dramatically alter the traditional AB pattern. Interestingly, a set of studies showed that the AB can be attenuated, or even eliminated, by having participants perform a simultaneous additional task with an AB task (Olivers & Nieuwenhuis, 2005; 2006).

In their first study, Olivers and Nieuwenhuis (2005) had participants perform a standard AB task. However, some of the participants were simultaneously required to listen to a piece of music and detect the random shouts in the music while performing the AB task. Other participants were required to concurrently perform a visualization task in which they either reflected on a recent vacation, or planned a shopping trip in their head. Curiously, the participants who were required to perform an additional task, whether it involved listening to music or visualization, showed a counterintuitive decrease in the magnitude of their AB as compared to the control group who performed only the AB task. This was some of the first evidence to suggest that greater attentional focus is actually detrimental to dual-task performance, and may in fact lead to the occurrence of an AB.

In a second study, participants were again required to perform a standard AB task, but this time one group of participants performed a match-to-sample memory task during the AB task (Experiment 1), and a second group of participants were given instructions to “un-focus” their attention part way through the AB task (Experiment 3; Olivers &

Nieuwenhuis, 2006). For both experimental conditions, the AB size was markedly reduced as compared to controls who performed the AB task on its own.

Arend, Johnston, and Shapiro (2006) purposely directed the participants' attention toward or away from the AB task by using moving and static star field patterns that surrounded each stimulus in the AB stream. Interestingly, star fields that moved toward or away from the AB stream, and star fields that simply flickered, resulted in an attenuated AB, as compared to the static star field condition. Importantly, the reduction in the AB was especially pronounced in the condition in which the star field moved away from the AB stream, and thus drew attention outward (Arend et al., 2006). Therefore, consistent with the results of Olivers and Nieuwenhuis (2005; 2006), it appears that directing attentional focus away from the AB task actually improves performance.

These findings are counterintuitive, as the AB is thought to result from dual-task limitations that prevent attention from being given to T2 because attention is already occupied with T1 (e.g., Raymond et al., 1992; Chun & Potter, 1995). Thus, further taxing the system by introducing an additional task should theoretically *increase* AB magnitude, not result in better performance. To explain these findings, Olivers and Nieuwenhuis (2006) proposed the overinvestment hypothesis. The overinvestment hypothesis states that, during a typical AB task, participants focus or narrow their attention in on the RSVP stream in an attempt to identify targets. However, this narrowing of attention results in an *overinvestment* of attentional resources to all items in the RSVP stream. This overinvestment allows the items that match the target templates, and items temporally close to them, to cross an activation threshold where distractors then compete for limited resources. This prevents T2 from receiving attention if it is presented shortly after T1,

which results in an AB. However, when participants diffuse or broaden their attention via performing a simultaneous task, T1 and irrelevant distractors now receive less attention, thus only targets cross the activation threshold, thereby allowing T2 to receive enough attention on some trials resulting in an attenuated AB (see Figure 1-2 for a pictorial representation). Therefore, placing further attentional demands on the system essentially allows individuals to better distribute their limited attentional resources, thereby improving their performance on the AB task. Furthermore, actively directing attention away from the RSVP stream, as in the Arend et al. (2006) experiment, can actually aid in diffusing attention by broadening the attentional focus. As such, attentional breadth appears to play an important role in dual-task selection.

Interestingly, Olivers and Nieuwenhuis (2006) included a third experiment which showed that not only does performing a simultaneous additional task reduce the AB, but that presenting participants with emotional images before each AB trial can also influence performance (Experiment 2a). Participants were divided into three groups and were presented with either positive (e.g., smiling children), negative (e.g., a syringe puncturing an arm), or neutral (e.g., a cup) images prior to each AB trial. Interestingly, the group who viewed the positive images had smaller ABs than both the neutral and negative image groups, demonstrating that a positive affective state can also lead to a decrease in the AB. Positive affect has previously been shown to broaden attention (Fredrickson, 2001; Fredrickson & Branigan, 2005), and this broadening of attention appears to occur for both external visual space and internal representations (Rowe, Hirsch, & Anderson, 2007), thereby allowing for diffusion of attentional resources. Conversely, negative affect has been shown to narrow attention (e.g., Christianson &

Loftus, 1990; Fenske & Eastwood, 2003; Gasper & Clore, 2002). Thus the Olivers and Nieuwenhuis (2006) finding that positive pictures presented before the RSVP streams attenuated the AB can be interpreted within the context of the overinvestment hypothesis if one assumes that positive affect promoted a diffusion of attention.

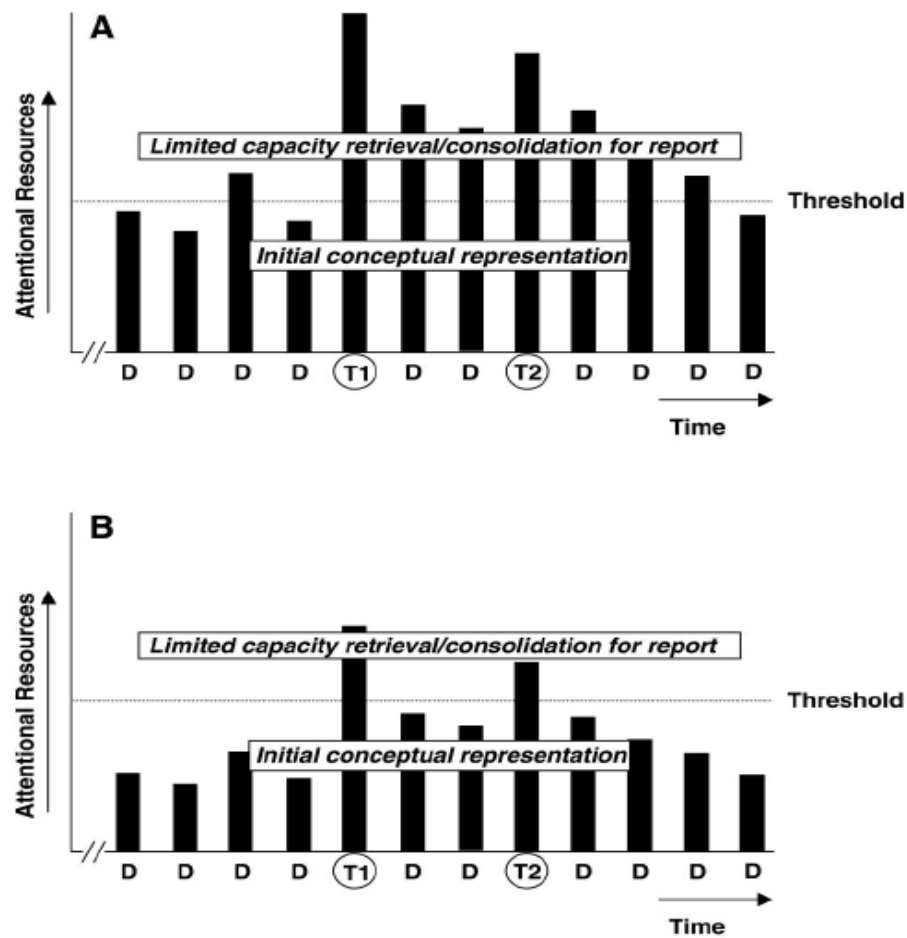


Figure 1-2. A pictorial representation of the overinvestment hypothesis (Olivers & Nieuwenhuis, 2006). Panel “A” illustrates what happens when attention is overinvested into the RSVP stream. Too many resources being invested in the stream has resulted in T1, T2, and surrounding distractors crossing an activation threshold and competing for consolidation. Panel “B” illustrates what happens when resources are diffused. Only T1 and T2 reach the consolidation threshold, and thus there is no competition, resulting in a reduced AB.

Finally, the AB can be attenuated by manipulating the task instructions such that participants treat the AB stream as a set, rather than as individual items, thus presumably broadening their attentional window. Potter and Nieuwenstein (2006) presented participants with an RSVP stream where each item was a different letter. Two of the letters were presented in red font, two in blue font, and two in green. On partial-report trials, participants were asked to report two letters of a particular colour (e.g., report the two red letters), whereas on whole-report trials participants were asked to report all six coloured letters. As expected, a significant AB occurred for the partial-report trials. However, the AB was virtually eliminated in the whole report condition. In a similar study, participants were asked to report either two digit distractors on their own or the sum of the two digit targets (Ferlazzo, Lucido, Di Nocera, Fagioli, & Sdoia, 2007). In the summed target condition, the AB was significantly reduced as compared to when participants were required to report each digit separately.

Other studies have shown that when T1 and T2 are seen as the same object evolving over time (such that T1 gradually morphs into T2), and thus are presumably represented by the same object file, the AB is reduced relative to when the two targets are distinct from each other (Kellie & Shapiro, 2004). Also, Di Lollo, Kawahara, Ghorashi, and Enns (2005) showed that when three targets are presented sequentially (TTT) that all belong to the same category (i.e., digits, or letters), the AB is dramatically reduced compared to when the second target is replaced by a distractor (TDT). Together, these results suggest that broadening the attentional span by having participants focus on the whole of the RSVP stream, or by presenting targets that are represented as a common set,

can reduce the AB. This corresponds nicely to the overinvestment hypothesis, as well as other research on the effects of attentional breadth and the AB.

Resource Allocation/Attentional Breadth

The idea that attentional breadth modulates the AB is supported by recent individual differences studies of the AB. For example, dispositional differences in self-reported state (MacLean & Arnell, 2010; Vermeulen, 2010) and trait (MacLean, Arnell, & Busseri, 2010) affect have been shown to predict individual differences in AB size, such that individuals higher in state and trait positive affect show smaller ABs, and individuals high in state and trait negative affect show larger ABs. Additionally, individuals who report higher levels of openness to experience and extraversion have been shown to produce smaller ABs, whereas individuals who report higher levels of neuroticism show larger ABs, as compared to individuals who report low levels of these traits (MacLean & Arnell, 2010).

Support for the overinvestment hypothesis can also be found from research that has explored the role of control over cognitive resources in AB magnitude. For example, individual differences in executive control of working memory predict AB size, such that individuals who have better working memory control show smaller ABs (Arnell, Stokes, MacLean, & Gicanté, 2011; Colzato, Spapé, Pannebakker, & Hommel, 2007) even after controlling for general intelligence and working memory capacity. Additionally, individuals who are better at inhibiting irrelevant information from entering working memory also show smaller ABs (Arnell & Stubitz, 2010; Dux & Marois, 2008; Martens & Valchev, 2009). Together, these results suggest that individuals who are better able to

control the deployment of their attentional resources to relevant material are less susceptible to the AB.

Finally, support for the idea that degree of attentional investment modulates the AB comes from research that has examined electrophysiological measures of attentional investment. For example, Martens, Munneke, Smid, and Johnson (2006) demonstrated that individuals who have no AB, called “non-blinkers”, show less electrophysiological activation to distractors, and show larger differences in activation between targets and distractors. Other research has shown that individuals who show greater performance-related feedback negativities (reflective of investment in performance appraisal) on the AB task and a time-estimation task have larger ABs (MacLean & Arnell, 2013). MacLean and Arnell (2011) showed that greater pre-trial attentional investment, as measured by event-related alpha desynchronization, was associated with poorer short-lag T2 accuracy (but better T1 and long-lag T2 accuracy) on the AB task. Together, the literature reviewed above demonstrates that effective control over the deployment and allocation of attentional resources modulates the AB such that individuals who overinvest their attention to targets and distractors in RSVP are more susceptible to the AB.

Global/Local Processing

One way in which attentional breadth can be directly examined in the laboratory is through the use of a global/local task. In a traditional global/local task, participants are presented with hierarchical letters called “Navon stimuli” (Navon, 1977) that consist of a large, single letter that is composed of smaller letters (e.g., a large “H” made of smaller “Ts”; see Figure 1-3). The large letter represents the global perceptual level, whereas the smaller letters represent the local perceptual level. The Navon letters can either be

congruent (i.e., the global and local levels match) or incongruent (i.e., the global and local levels do not match). Participants are generally instructed to report either the broad, global level or the detailed, local level as quickly as possible. Other variants on this task involve presenting hierarchical digits, shapes, and pictures.

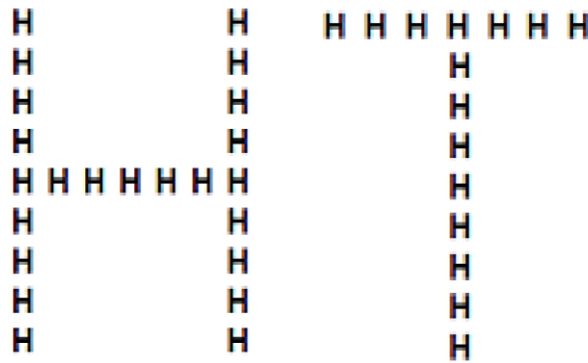


Figure 1-3. *Sample Navon letter stimuli*

To assess global or local bias, the response time (RT) for the incongruent versus the congruent trials on both locally and globally-directed trials is calculated. The degree to which the global information interferes with RT to report the local level is a measure of global bias (i.e., global interference), and the degree to which the local information interferes with RT to report the global level is a measure of local bias (i.e., local interference; Navon, 1977). Finally, a measure of overall global bias, called global precedence, can be obtained by finding the numerical difference between global and local interference scores. Another global/local task variant involves having participants perform a forced-choice task in which they are required to choose one of two comparison hierarchical stimuli that best match a standard stimulus (Kimchi & Palmer, 1982). In this task, one of the comparison figures matches the standard at the local level, whereas one matches the standard at the global level. The number of global selections is then totaled, providing a measure of global bias.

Although much of the initial research on global/local processing suggested that most individuals are globally biased (Navon, 1977; 1981), more recent research has shown that there is a great deal of individual variability in global/local preference. For instance, individuals from remote cultures (Davidoff, Fonteneau, & Fagot, 2008), individuals who follow a strict religious order (i.e., Dutch Calvinists; Colzato, van den Wildenberg, & Hommel, 2008), individuals with musical training (Stoesz, Jakobson, Kilgour, & Lewycky, 2007), and individuals with psychological disorders such as autism (Scherf, Luna, Kimchi, Minshew, & Behrmann, 2008), depression (Basso, Schefft, Ris, & Dember, 1996), or obsessive-compulsive disorder (Moritz & Wendt, 2006) have all been shown to have strong biases for local information when performing a global/local task. Additionally, East Asian individuals tend to show a stronger global advantage than individuals from Western cultures (McKone et al., 2010), and individuals who are naturally more positive and optimistic tend to be more globally biased (Basso et al., 1996). As such, the global/local task is a good tool for assessing individual differences in attentional breadth.

Global/Local and the AB

Given the utility of the Navon letter task as a measure of individual attentional breadth, I recently examined whether dispositional differences in performance on a traditional global/local Navon letter task could predict individual differences in AB performance (Dale & Arnell, 2010). I found that individuals who had greater local interference (i.e., were distracted by the local information during globally-directed trials) showed larger ABs, as compared to individuals who had less local interference. Additionally, individuals who had higher levels of global precedence (i.e., showed more

interference from the global as compared to the local level) had significantly smaller ABs than individuals who were less globally biased. This suggests that individuals who are naturally biased toward the global perceptual level are less susceptible to the AB effect, whereas individuals who had a tendency to focus their attention were more susceptible to the AB effect. These results are consistent with previous literature that suggests a relationship between breadth and control of attention and the AB.

Current Research Questions

Although my previous work (Dale & Arnell, 2010) showed that an established measure of attentional breadth predicts AB performance, it also raised a multitude of questions. It was still unclear how stable individual differences in global/local precedence were, how stable performance on the AB task was, and whether diffusion/focus could be manipulated within an individual. It was also unclear whether global/local bias per se related to the AB, or if there was some aspect of overcoming interference that led to the relationship. The purpose of the following four studies was to clarify some of these questions in order to provide a clearer idea of how attentional breadth relates to AB performance.

Study 1: Global/Local Stability. The purpose of Study 1 was to examine whether individual differences in global/local processing bias are reliable over time using some common global/local measures. No study had yet examined whether these dispositional biases remain stable over time, thus it was important to establish whether these differences were transient and dependent on the participant's state during testing, or if these were fixed, trait-like biases. The reliability of two variables represents the upper bound of the relationship that can be expected between them, and given the fact that these

measures were now being used to predict performance on other cognitive tasks, it is especially important to establish the reliability of the measures. Additionally, there are multiple global/local measures currently in use, thus it is also important to examine whether these seemingly similar tasks were measuring the same underlying construct.

In two different experiments, participants were required to complete three distinct global/local tasks that have been used previously: a traditional Navon letter task, a forced-choice hierarchical shape task, and a high/low spatial frequency face task. Whereas the Navon letter task and the hierarchical shape task were selected because they are commonly used measures of global/local processing, the spatial frequency face task was a somewhat novel global/local measure that was derived from Deruelle, Rondan, Salle-Collemiche, Bastard-Rosset, and Da Fonséca (2008). This task was developed based on the finding that global information carries mainly low spatial frequencies (i.e., few pixels or cycles per degree of visual angle), whereas local information carries mainly high spatial frequencies (i.e., many pixels or cycles per degree of visual angle; Schulman & Wilson, 1987). Therefore, individuals who show a preference for low spatial frequency information are said to be globally biased, whereas individuals who show a preference for high spatial frequency information are said to be locally biased.

Participants completed all three tasks, and then returned 7-10 days later to again complete these three tasks. I found that individual differences in global/local biases are moderately-to-highly reliable over time, with the Navon letter task being the least reliable, suggesting that dispositional global/local bias is a trait-like characteristic. Interestingly, I also showed that the three global/local tasks were uncorrelated with each

other, suggesting that if these tasks are indeed measuring global/local processing, they are measuring unique aspects of global/local processing.

Study 2: AB Reliability. For Study 2, I examined the reliability of two different versions of the AB task over time. As with individual differences in global/local, the reliability of individual differences in AB performance had yet to be established using the same AB task over time, thus I was interested in examining whether performance on the AB remained stable over time, and whether different AB task versions were correlated with each other.

For this study, participants completed two different versions of the AB task (one where T1 and T2 required the same task, and one where T1 and T2 tasks differed such that a task-set switch was required between the targets), and then returned 7-10 days later to again complete these two tasks. The goal was to examine both the test-retest and internal consistency reliability of the two AB task versions, and to establish whether performance on these two very different AB tasks would be correlated. Performance on the two AB tasks was shown to be highly reliable over time, and was also significantly correlated. This suggests that AB performance is quite stable over time, and also suggests that the choice of AB task will not affect the results (as it presumably does with the global/local tasks).

Study 3: Diffusion and the AB. For Study 3, I examined whether performance on all three of the global/local tasks used in Study 1 could predict performance on the two AB tasks used in Study 2. My previous work (Dale & Arnell, 2010) suggested that individuals who are locally biased, as measured with the Navon interference task, showed larger ABs. However, I was interested in whether this finding could be replicated using

more reliable measures of global/local processing (such as the face and shape tasks), because my previous work (Dale & Arnell, 2010) used the Navon letter task which, as shown in Study 1 (Chapter 2) has since been shown to be the *least* reliable measure of global/local processing. As such, Experiment 1 examined whether global/local biases, as measured by a highly reliable hierarchical shape task, could predict AB magnitude. Additionally, Experiment 2 was conducted to examine whether all three global/local tasks from Study 1 (Chapter 2) could predict AB magnitude. These three tasks were used because Study 1 showed that while two of the three tasks were highly reliable measures of dispositional global/local bias, none of the tasks were related to each other. Therefore, I was interested in whether these three seemingly different measures of global/local could all predict AB magnitude. In accordance with Dale and Arnell (2010), individuals in both experiments who were more biased toward the global perceptual level had smaller AB magnitudes, as compared to individuals who were biased toward the local perceptual level. Additionally, two of the three global/local tasks predicted AB magnitude uniquely, such that the amount of explained variance in AB magnitude increased when the combination of all three global/local tasks was used as a predictor. This suggests that various aspects of naturally occurring attentional breadth results in better selective attention performance.

Study 4: Global/Local Manipulation. Study 4 was an attempt to modulate dispositional global/local biases by exposing individuals to high/low spatial frequency stimuli and/or Navon letters. If individuals who are globally biased perform better on tasks of selective attention, then it is possible that inducing a globally-focused state might also improve AB performance, so the purpose of this study was to examine whether it is

possible to actually alter dispositional global/local focus. Research has shown that global/local processing can be influenced by external tasks that are designed to broaden attention (e.g., Förster & Dannenberg, 2010). However, no one has examined whether dispositional global/local processing can be influenced by repeated exposure to global/local stimuli and low or high spatial frequency information.

Global/local bias was measured using the hierarchical shape task, high/low spatial frequency face task, and the traditional Navon letter task described in Study 1.

Global/local biases were manipulated by exposing participants to high/low spatial frequency faces, high/low spatial frequency gratings, and Navon letter stimuli. Through a series of 5 experiments, there were no changes from pre-to post-manipulation in all but one experimental condition. This suggests that dispositional global/local biases are relatively stable and are resistant to global/local and spatial frequency manipulations.

Overall, the results of the four studies in this dissertation show that naturally occurring differences in global/local bias and AB magnitude are reliable over the course of at least a week, and that global/local bias is resistant to priming by exposure to spatial frequency information. Additionally, these individual differences in global/local bias, as assessed by a variety of global/local processing measures, predict AB magnitude such that greater breadth is associated with smaller ABs. These findings help clarify the role of individual differences in attentional breadth in AB magnitude. As selective attention is so crucial to our conscious experience, these findings are especially important given that they show that pre-existing, potentially trait-like differences in our attentional focus can influence how we select information from our environment, and thus impact how we view, and interact with, objects and information in our world. The fact that these

differences in attentional breadth exist, that they are intractable, and that they influence our ability to attend to multiple items at one time, may begin to explain why some individuals have difficulty with shifting their attentional focus, dividing their attention, or focusing their attention.

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CHAPTER 2

Study 1: Investigating the Stability of and Relationships among Global/Local Processing Measures¹

Abstract

Global/local stimuli have been used to estimate global processing biases in individuals, groups, and in response to various manipulations. Throughout the literature, multiple different versions of global/local stimuli have been used, such as traditional hierarchical letters and numbers, abstract hierarchical shapes, and high and low spatial frequency gratings and faces. However, it is currently unclear how reliable or stable performance is on these measures within individuals over time, and whether these seemingly different measures are tapping into the same underlying process. As such, the purpose of the current study was to examine the stability of individual performance on three distinct global/local measures over time, and to examine the relationships among these measures. Through two experiments I examined the reliability of, and relationships among, standard Navon letters with a traditional interference task, hierarchical shapes in a forced-choice task, and a task that presented superimposed high and low-pass spatial frequency faces with a forced-choice task. In both experiments, participants completed all three tasks, and returned 7-10 days later to again complete the same tasks. The degree of global/local bias within an individual was found to be highly reliable in the hierarchical shape task and the spatial frequency face task, but less reliable in the traditional Navon letter task. Interestingly, in both experiments I found that none of the three measures of global bias were related to each other. Therefore, although these measures do appear to be reliable over time, they may be tapping into distinct aspects of global/local processing.

¹ This chapter is based on the published article: Dale, G., & Arnell, K. M. (2013). Investigating the stability of and relationships among global/local processing measures. *Attention, Perception, & Psychophysics*, 75(3), 394-406.

Introduction

Visual stimuli can often be viewed at either a broad global level (e.g., the forest) or at a more detailed local level (e.g., a tree). Researchers often investigate a bias toward global or local information with hierarchical global/local stimuli known as “Navon stimuli” (Navon, 1977, 1981). Navon stimuli are typically large, single letters that are comprised of smaller letters (see Figure 2-1a, Navon, 1977). Variations can involve hierarchical shapes (Kimchi & Palmer, 1982) or objects (Fink et al., 1997).

For Navon stimuli, the large element represents the global perceptual level, whereas the smaller elements represent the local perceptual level. The elements at the two different levels can either be the same (congruent) or different (incongruent). Participants are usually directed to attend to either the global or the local level, and to identify the stimulus at that level as quickly as possible. Results using hierarchical stimuli typically show more interference of the global information when trying to focus on the local information than the reverse (i.e., global advantage). This suggests that the processing of the broad aspects of a stimulus takes precedence over the processing of finer, more detailed aspects (Navon, 1981).

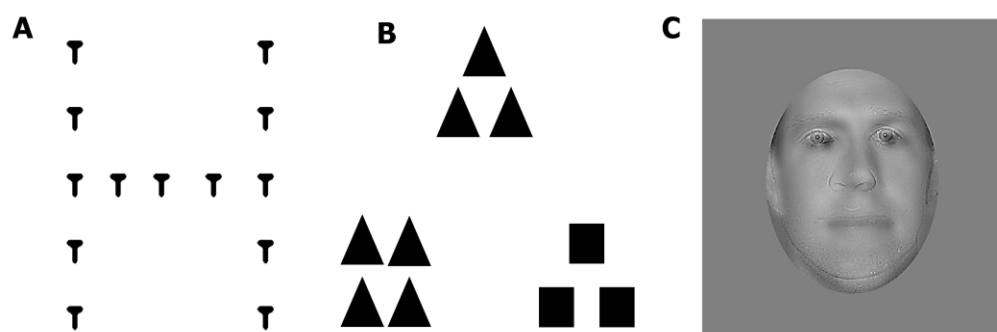


Figure 2-1. *A) Sample incongruent Navon letter from the Navon letter task. B) Sample test shape triad from the global/local shape task. C) Sample hybrid face stimulus from global/local face task.*

Individual Differences

Whereas a global advantage is generally observed with Navon stimuli, evidence suggests that the degree of individual bias towards global information can be altered by varying stimulus parameters, such as the aspect ratio of the local to global items (Kimchi, 1992; Yovel, Yovel, & Levy, 2001), the overall visual angle (Kinchla & Wolfe, 1979), or the exposure duration (Paquet & Merikle, 1984). Kimchi and Palmer (1982) in particular have shown that the relative number and size of elements in a global/local hierarchical figure can greatly influence whether or not a global advantage emerges. Specifically, the use of relatively few large-size local elements within the global pattern promotes a local processing advantage, whereas the use of many smaller local elements within the global pattern promotes a global processing advantage.

In addition, individuals have been shown to vary widely in terms of their degree of *dispositional* global or local bias. Some individuals have a natural bias for global information, some have a natural bias for local information, and some show little to no bias (Dale & Arnell, 2010). A variety of participant characteristics affect the degree of individual global or local bias. For example, older individuals (e.g. Lux, Marshall, Thimm, & Fink, 2008), individuals induced into a state of negative affect (Gasper & Clore, 2002), individuals from remote cultures (Davidoff, Fonteneau, & Fagot, 2008), and musicians (Stoesz, Jakobson, Kilgour, & Lewycky, 2007) all appear to show a larger local than global bias. Conversely, individuals from collectivist cultures show more of a global bias (McKone et al., 2010), as do individuals who have been induced into a positive affective state (Fredrickson & Branigan, 2005). Thus, a global advantage is not apparent in all individuals, nor is it absolute.

One way in which these individual differences in global/local bias can be captured is through the use of neutral global/local stimuli, in which both the global and local levels are equally salient (Fredrickson & Branigan, 2005). While a global advantage typically emerges, using a sparser hierarchical display (fewer local elements), or equating the salience of the figures can allow for greater variability in responses (Fredrickson & Branigan, 2005; Kimchi & Palmer, 1982), thus effectively capturing natural differences in individual global/local bias. Using this rationale, Dale and Arnell (2010) showed that individual differences in dispositional global bias, as assessed by a Navon letter interference task, predicted dual-task attention costs in the attentional blink paradigm, where greater global bias was associated with smaller attentional blinks. Martin and Macrae (2010) have also estimated individual differences in global processing bias using a global/local Navon letter task, and showed that when individuals with a large global bias performed a face recognition task, they produced a larger face inversion effect thought to reflect the degree of holistic face processing than did individuals with weak global bias.

Despite the fact that researchers have begun to use global/local bias as an individual differences variable, we have yet to determine whether an individual's global/local preference is a stable trait that persists over time. Therefore, the primary purpose of the current study is to examine the stability of performance over time on three very distinct global/local tasks, in order to determine whether individual global/local bias is a stable individual differences variable.

In addition to the popular computerized Navon letter task (Navon, 1981) discussed above, two other tasks were included that have also been used to assess

differences in global/local processing bias across groups. One of these was a paper and pencil hierarchical shape task adapted from Kimchi and Palmer (1982) and Fredrickson and Branigan (2005). In this task participants were shown a hierarchical “standard” figure where the global shape was made-up of several local shapes (e.g., a square made of triangles). Participants were then asked to choose which of two “comparison” hierarchical figures (squares or triangles) best matched a standard figure. One of the comparison figures matched the standard at the global level, and one at the local level (see Figure 2-1b). This task has been used to show that both the number and size of the local elements in a figure can influence the magnitude of the global/local advantage (Kimchi & Palmer, 1982). It has also been used to show that induced state affect can modulate the global/local processing advantage, such that positive states promote a global processing bias (Fredrickson & Branigan, 2005), and negative states promote a local processing bias (Gasper & Clore, 2002).

In a third task, hierarchical stimuli were not used. Instead, two faces of different individuals were displayed superimposed on the computer screen. One face contained only high spatial frequency information, and the other face contained only low spatial frequency information. Participants were then shown both unfiltered faces, and were asked to choose which of the two faces had just been presented (see Figure 2-1c). Using this task, Deruelle et al. (2008) showed that when matching faces for identity or emotion, children with autistic spectrum disorders showed a greater preference for local information relative to control children.

As noted above, performance on hierarchical stimulus tasks often shows a global processing advantage. However, the direction (global or local) and degree of the

advantage can be modulated by changes in the relative size and number of local elements relative to the global shape (Kimchi, 1992; Kimchi & Palmer, 1982). Following the rationale of Fredrickson and Branigan (2005), pilot testing and existing literature were used to create stimuli that were global/local neutral (i.e., stimuli likely to induce no overall global/local advantage in the sample as a whole) so that the natural inclination of the participant would not be enhanced or countered by stimuli that promote a particular bias.

In addition to examining the reliability of the measures, I was also interested in examining the relationships among the three distinct global/local processing tasks. Two of the three global/local processing tasks that I selected have previously been used as an index of general global/local processing bias, whereas the third task is a spatial frequency task that is associated with global/local processing. Various global/local measures are used as if they measure the same thing; however, the degree to which each of these tasks relates to each other is currently unknown.

Experiment 1: Method

Participants.

Sixty Brock University undergraduate students (56 women) ranging in age from 17 to 33 years ($M = 19.6$) voluntarily participated in this experiment. All participants reported learning English before the age of 8, and reported normal or corrected-to-normal vision. Participants completed a 1 hour testing session, followed by a second 1 hour session 7-10 days later. A total of five individuals did not return for the second session, and were removed from the analyses, leaving a total of 55 participants. All participants

completed a global/local face task first, followed by a global/local shape task, and then a global/local Navon letter task.

Apparatus.

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

Stimuli and Design.

Global/Local Face Task. This task was adapted from Deruelle et al. (2008). Twenty-seven male and 27 female normed young adult faces with neutral expressions and no facial hair were obtained from The Center for Vital Longevity Face Database (Minear & Park, 2004). The faces were cropped to remove head hair, converted to grayscale, and were pasted onto a 480 x 480 pixel dark grey background so that they subtended approximately 16° of visual angle with an unrestrained viewing distance of approximately 55 cm. High-pass and low-pass spatial frequency faces were then constructed in Adobe Photoshop from the original 54 faces (one high and one low for each face). High-pass filtered faces were constructed by using a high-pass filter in Photoshop, and contained only spatial frequencies higher than 6 cycles/degree of visual angle (i.e., a radius of 1.5 pixels)². Low-pass filtered faces were constructed by using a Gaussian blur in Photoshop, and contained only spatial frequencies lower than 2 cycles/degree of visual angle (i.e., a radius of 4.5 pixels). High/low pass hybrid faces were then created by superimposing the high-pass face of one person over the low-pass face of another person (matched for gender). The high- and low-pass filtered faces were

² To convert Adobe Photoshop radius into cycles/degree, I used the following formula: $\tan^{-1}(\text{radius/viewing distance})$ or $\tan^{-1}(\text{PPC/viewing distance})$.

equated for luminance and size, and were roughly equal in salience. A total of 54 hybrid faces were constructed, with each original face contributing high frequency information to one hybrid face and low frequency information to another hybrid face (see Figure 2-1c).

Each trial began with a 1000 ms fixation cross, after which a hybrid face appeared in the center of the screen for 300 ms. It was then replaced by the two original (unfiltered) faces that comprised the hybrid face (i.e., one intact face whose high frequency information was used in the hybrid and another intact face whose low frequency information was used in the hybrid). One of the intact faces was presented on the left side of the screen, and one on the right (counterbalanced). Participants were asked to select the original face that they thought best matched the hybrid face by pressing the corresponding key on the keyboard. These faces remained on the screen until the participant made a response. Responses were not speeded, but participants were encouraged to go with their first instinct. Each participant performed 54 trials. For each participant a global face score was calculated as the total number of trials out of 54 where the participant selected the face whose low frequency information had been used in the face hybrid. Therefore, a high global face score suggests a bias for global processing, whereas a low global face score suggests a bias for local processing.

Global/Local Shape Task. Participants were presented with a booklet that contained global/local shape triads, adapted from Kimchi and Palmer (1982) and Fredrickson and Branigan (2005). Shape triads were comprised of three hierarchical shapes arranged with a standard figure on top, and two comparison figures on the bottom (see Figure 2-1b). In each case, participants were required to circle the comparison figure

that they felt best matched the standard figure. They were instructed to use their first instinct and proceed as quickly as possible.

There were 8 test triads and 16 filler triads that were intermixed, for a total of 24 triads. The hierarchical shapes in each test triad consisted of 3-4 small (5 x 5 mm) square or triangle shapes (local level) that formed a larger (15 x 15 mm) square or triangle (global level). For the test triads, both comparison figures matched the standard figure, but one matched at the global level (the overall shape outline matched the standard), and one matched at the local level (the smaller shape matched the standard). The hierarchical shapes in each filler triad were comprised of 3-4 small (5 x 5 mm) circles, squares, triangles, or crosses (local level) that formed a larger (15 x 15 mm) square or triangle (global level). I chose sparse hierarchical figures in order to better detect individual differences in global/local bias, as per Fredrickson and Branigan (2005).

After completion of the task, the total number of test triads where the global comparison shape was selected was calculated for each participant, resulting in a global score that could range from 0 to 8. Therefore, a high total reflects a global bias, and a low total reflects a local bias. Filler triads had only one correct response (half with global correct, and half with local correct), thus they were not used as an index of global/local bias.

Global/Local Navon Letter Task. Each trial began with a 500 ms central fixation cross, after which a single Navon stimulus was presented in the center of the computer screen. The Navon stimuli were large letters constructed of smaller letters (e.g. an “H” made out of “T”s; see Figure 2-1a.). Global letters (70 x 50 mm) were 10 times as large as the local letters (7 x 5 mm). The viewing distance was approximately 55 cm,

unrestrained. Pilot testing suggested that the global and local levels were roughly equal in salience. All letters appeared in black New Courier font on a white background. The letters that were presented could be “H” or “T”. Half of the trials in each condition were congruent (an “H” made of small H’s or a “T” made of small T’s) and half were incongruent (an “H” made of small T’s or a “T” made of small H’s), and these were randomly mixed within each block. Global and local trials were presented in alternating blocks, with 24 trials in each of 4 blocks for a total of 96 trials. All participants began with the global block³. 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 stimulus remained on the screen until the participant made a response.

RTs were examined for each combination of participant, task (global/local report), and condition (congruent/incongruent). RTs for incorrect trials and RTs that fell outside three standard deviations from the mean were removed. Mean local and global RT, and local and global interference were then calculated for each participant. Local interference was calculated as the degree to which local features influenced performance on the global trials (global incongruent RT – global congruent RT), and global interference was measured as the degree to which global features influenced performance on the local trials (local incongruent RT – local congruent RT).

³ All participants completed the Navon letter task blocks in the same order so that estimates of the participants’ global and local interference were not confounded with block order. When conducting an individual differences study, it is not ideal to counterbalance the tasks or blocks across participants. Performance on tasks/blocks 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 by using a constant task order.

Experiment 1: Results

Face Task

The mean session 1 global face score was 29.75 ($SD = 5.93$), and the mean session 2 global face score was 29.44 ($SD = 7.33$) out of 54. This indicates that just over half of the trials were classified at the global level in each session. The slight global advantage was significant statistically in each session (p 's $< .018$) compared to chance performance of 27, however the small size of the differences from 27 suggests that the stimuli did not greatly bias the participants overall into choosing the global or local face. There were large individual differences in task performance with average scores across sessions ranging from 17 to 45 out of 54.

Shape Task

The mean session 1 global shape score was 3.36 ($SD = 2.21$), and the mean session 2 global shape score was 4.11 ($SD = 2.51$) out of 8. Compared to 4, which would reflect chance performance, mean scores across the participants showed a small, but significant, local bias in session 1, $t(54)=2.14$, $p = .037$, but no bias in session 2 ($p = .74$) or overall across sessions ($p = .38$), suggesting that the stimuli left lots of room for dispositional differences in global/local bias to emerge. Indeed, there were large individual differences in task performance with average scores across sessions ranging from 0 to 7.5 out of 8. Accuracy on the filler trials was .96 ($SD = .06$) and .95 ($SD = .07$) for session 1 and 2 respectively, indicating that participants were performing the task as instructed.

Navon Letter Task

Mean letter identification RTs for session 1 and session 2 of the computerized Navon letter task are presented in Figure 2-2ab as a function of global or local task block, and congruence/incongruence of global and local levels. Mean RTs were analyzed using a 2 x 2 (task by congruency) repeated measures ANOVA. For session 1, there was a significant main effect of congruency, with faster RTs on congruent trials than on incongruent trials, $F(1, 54) = 35.93$, $p < .001$, $\eta_p^2 = .40$. There was no significant main effect of global/local block, $F < 1$. Additionally, the interaction between feature size and congruency was not significant, indicating that local and global interference were equal in magnitude, $F < 1$.

For session 2, there was again a significant main effect of congruency, with faster RTs on congruent trials than on incongruent trials, $F(1, 54) = 39.77$, $p < .001$, $\eta_p^2 = .42$. There was also a significant main effect of stimulus feature level, where RTs were faster on global trials than on local trials, $F(1, 54) = 11.34$, $p = .001$, $\eta_p^2 = .17$. Once again, the interaction between feature size and congruency was not significant, indicating that local and global interference were equal in magnitude, $F < 1$. Therefore, as intended, the stimuli did not bias the participants, as a group, toward global or local processing, leaving lots of room for dispositional variation in global/local bias. Indeed, across sessions average global interference scores ranged from -95 ms to 144 ms.

The mean error rates in the Navon letter task were 5% and 4% for sessions 1 and 2 respectively. A 2 x 2 (congruency by global/local task) repeated measures ANOVA on the mean error data for each session showed that errors were greater for incongruent trials than congruent trials, $F(1, 54) = 36.91$, $p < .001$, $\eta_p^2 = .41$ and $F(1, 54) = 42.10$, $p < .001$, $\eta_p^2 = .42$.

= .44 for sessions 1 and 2 respectively. There was no main effect of stimulus level, nor an interaction of congruence and stimulus level for either session, all F 's < 1.

Test-Retest Reliability

As an index of test-retest reliability, the Pearson correlation coefficients between scores on session 1 versus session 2 were examined individually for each of the three global/local tasks. Global/local bias on the face task was shown to be highly reliable over time, as was global/local bias for the shape task (see bolded values in Table 2-1 and Figure 2-3abc). The test-retest reliability of the Navon letter task, however, was quite low, albeit significant. When I examined the mean Navon letter global and local RTs across session, both had high test-retest reliability ($r = .66$ and $.73$ respectively). This suggests that while the RTs were highly reliable, the measure of interference was not⁴.

Relationships among the Measures

The relationships among the three different measures of global/local processing bias were examined by correlating the scores for each test session. Interestingly, none of the measures were significantly related to each other either within a session or across sessions (see non-bolded values in Table 2-1). When the scores for each of the three tasks were collapsed across the two sessions, there was once again no significant relationship amongst the three measures, such that global face and global shape scores correlated .03 (.04 disattenuated), global face and global interference correlated -.13 (-.28 disattenuated), and global shape and global interference correlated .12 (.24 disattenuated; all p 's > .33; see Figure 2-4abc).

⁴ One may be concerned that the relatively poor reliability on the Navon letter task results solely from the use of a difference score to estimate global interference. However, almost the same reliabilities were observed when incongruent local RTs on session 1 were used to predict incongruent local RTs on session 2, with the variability from local congruent RTs partialled out for each session ($r = .30$ in Study 1 and $r = .20$ in Study 2).

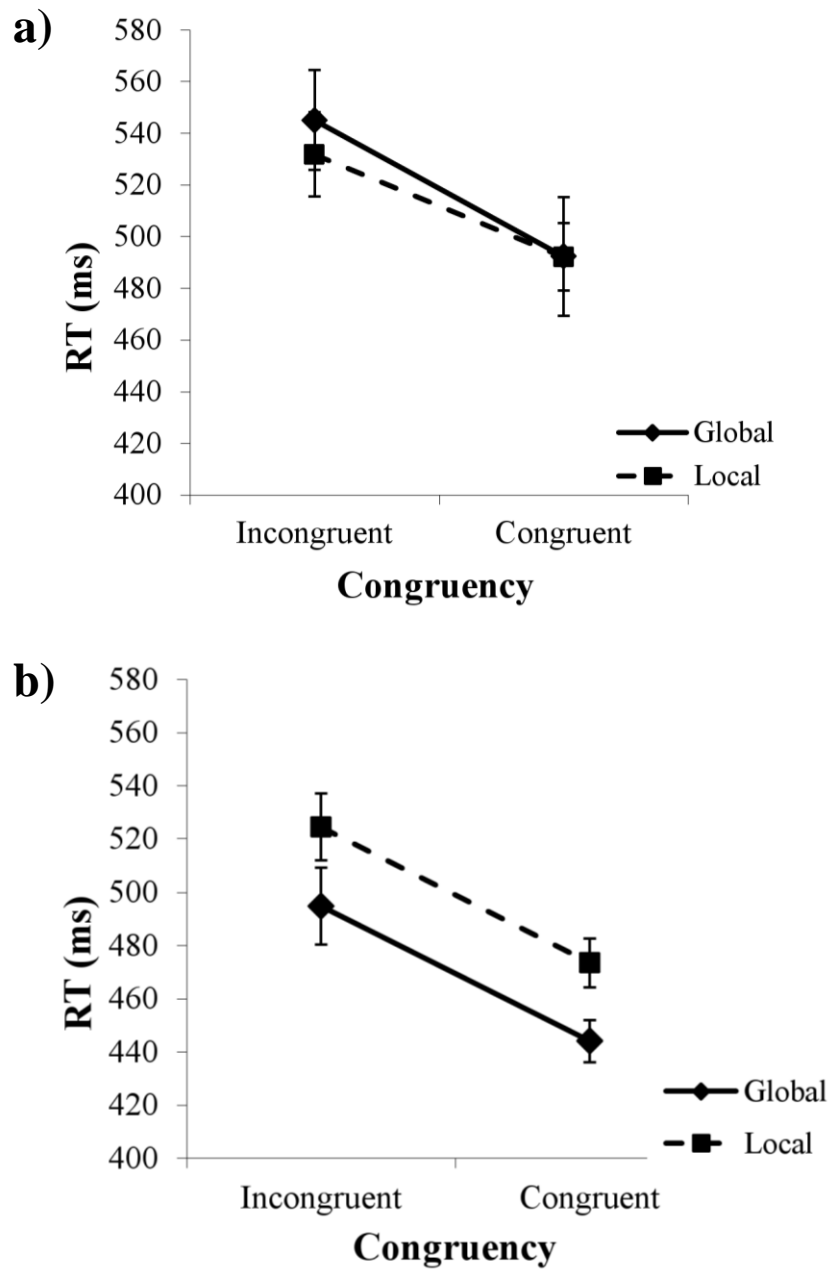


Figure 2-2. a) Mean session 1 RT on the Navon letter task, as a function of task (attend global or attend local) and target congruency. Error bars represent the standard error for each condition mean. **b)** Mean session 2 RT on the Navon letter task, as a function of task (attend global or attend local) and target congruency. Error bars represent the standard error for each condition mea

Table 2-1.

Pearson Zero-order Correlations between Test Sessions for the Three Global-Local Measures (in bold font), and the Relationships among All Measures in Study 1.

	1	2	3	4	5
1. Global Face Session 1	--				
2. Global Shape Session 1	.12	--			
3. Global Letter Interference Session 1	-.10	.11	--		
4. Global Face Session 2	.70**	-.14	-.05	--	
5. Global Shape Session 2	.17	.79**	.02	-.01	--
6. Global Letter Interference Session 2	-.19	.10	.31*	-.08	.14

Note: * indicates $p < .05$, ** indicates $p < .01$.

Bold font indicates test-retest correlations.

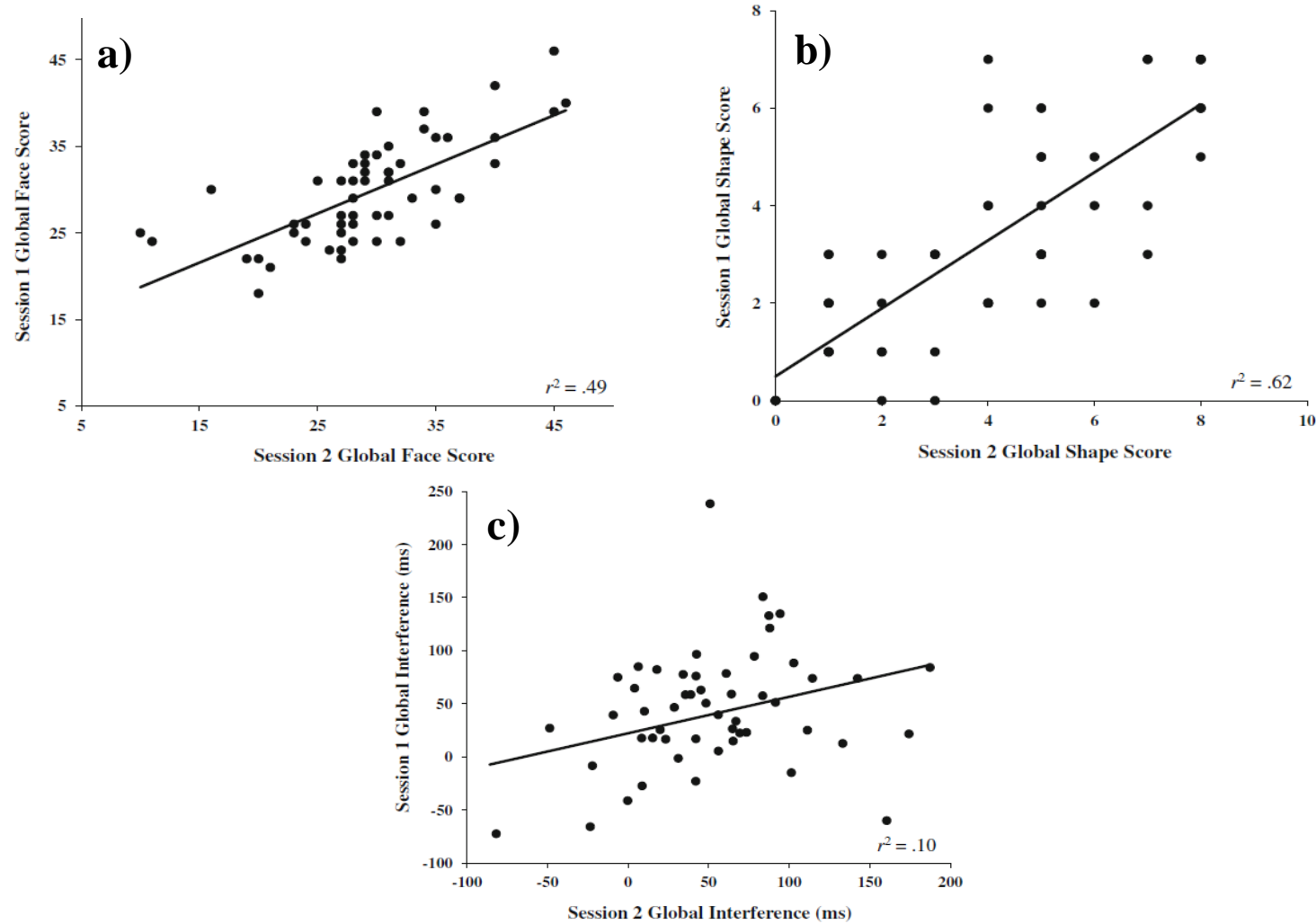


Figure 2-3. *a) Scatterplot depicting Pearson r correlation between session 1 and session 2 scores on the global/local face task. b) Scatterplot depicting Pearson r correlation between session 1 and session 2 scores on the global/local shape task. c) Scatterplot depicting Pearson r correlation between session 1 and session 2 scores on the global/local Navon letter task.*

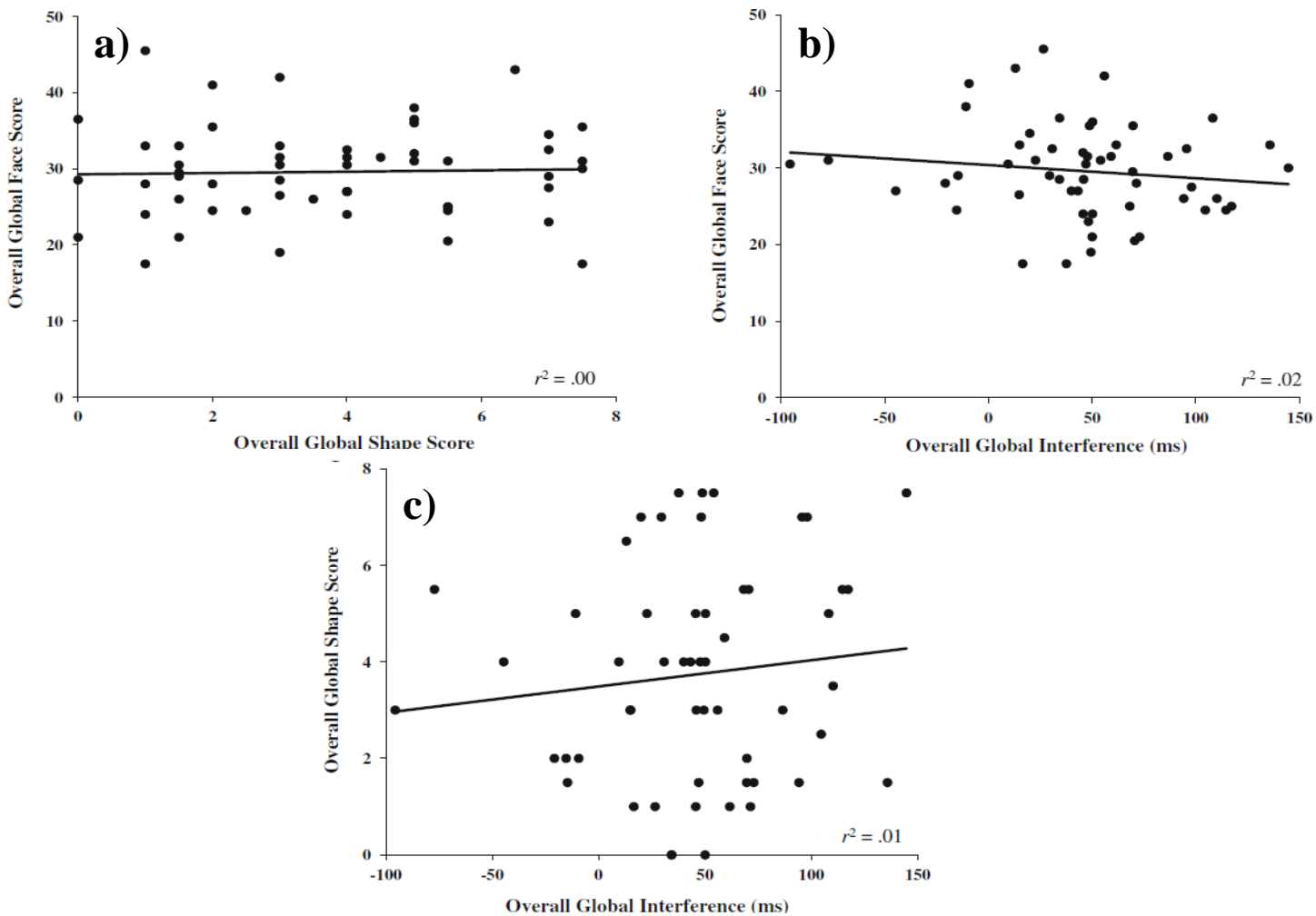


Figure 2-4. *a)* Scatterplot depicting Pearson r correlation between overall global face task score and overall global shape task score, $r = .03$. *b)* Pearson r correlation between overall global face task score and overall global interference from the Navon task, $r = -.13$. *c)* Pearson r correlation between overall global shape task score and overall global interference from the Navon task, $r = .12$.

Factor Analysis

In order to further explore the independence of the three measures, I performed a factor analysis with a varimax rotation that included the three measures of global bias for each of the two sessions (6 items). I obtained a 3-factor solution⁵, with each of the three global/local tasks loading on its own factor (see Table 2-2).

Table 2-2.

Rotated Factor Loadings for the Three Global/Local Measures, by Session, Showing Three Distinct Factors in Study 1.

	Component		
	1	2	3
Global Face Session 1	.17	.91	-.14
Global Face Session 2	-.11	.93	.01
Global Shape Session 1	.95	-.03	.07
Global Shape Session 2	.94	.07	.05
Global Letter Interference Session 1	.01	.01	.82
Global Letter Interference Session 2	.09	-.12	.79

Method: Principal Component Analysis. Varimax with Kaiser normalization.

Experiment 1: Discussion

The primary goal of Experiment 1 was to examine the stability of individual differences in global/local bias over time. The results indicate that three distinct measures of dispositional global/local bias were reliable over the period of 7-10 days, with two of the tasks showing high reliability. This suggests that individual differences in global/local

⁵ To determine the correct number of components to retain in the factor analysis, I first used the Kaiser criterion method, also called the eigenvalue-one criterion. This method retains only those factors that have eigenvalues greater than 1 (Nunnally, 1978). With this method, an obvious 3 factor solution was apparent. Additionally, when I performed a scree test, as recommended by Cattell (1966), once again an obvious 3 factor solution emerged.

bias or preference are relatively stable over time, and supports their use in studies of individual differences. However, while the face and shape tasks were highly reliable, performance on the Navon letter task had fairly low reliability over time, suggesting that this task may not be accurately measuring global/local processing. This is problematic, considering the popularity of this particular measure.

In addition to examining the reliability of these tasks, I was interested in examining how they were interrelated. Surprisingly, while the two of the three tasks were highly reliable, none of the three tasks related to each other either within, or across, session, or when data from both sessions was combined. In addition, when a factor analysis was performed it was found that the three tasks loaded onto unique factors, suggesting that they do not share an underlying construct. This indicates that while the three tasks may still be measuring global/local processing bias, they may be measuring different aspects of this construct. This finding is particularly alarming given that the letter and shape tasks are often used interchangeably as an index of global/local processing.

However, the stimuli used in each of the tasks were created in such a way as to promote neither a global nor a local bias, so as to better capture individual differences without having the stimuli themselves constrain the range of individual differences by biasing individuals in a given direction. As such, two of the three tasks (the Navon letter task and the hierarchical shape task) did not show a typical global advantage. One might be concerned that the lack of global advantage in the tasks, and the presentation conditions required to produce global/local neutral stimuli, may have changed what the tasks themselves are measuring. This could potentially have led to the lack of relationship

among the tasks, and might also have led to the low reliability of the traditional Navon letter task. As such, I conducted Experiment 2, which uses stimuli designed to promote a more typical global bias. The purpose of Experiment 2 was the same as in Experiment 1, such that I was interested in examining three distinct global/local tasks would be reliable over time, and whether performance on these tasks was related.

Experiment 2: Method

Participants

Fifty-eight Brock University undergraduate students (47 women) ranging in age from 18 to 30 years ($M = 19.7$) voluntarily participated in this study and had the same restrictions as in Experiment 1. Participants completed a 1 hour testing session, followed by a second 1 hour session 7-10 days later. All participants completed the hierarchical shape task first, followed by the global/local face task, and then the global/local Navon letter task. All tasks were the same as in Experiment 1, but with the following alterations.

Stimuli and Design

Global/Local Face Task. For the global/local face task, the duration of the hybrid face was decreased from 300 ms to 150 ms. This was done in order to make the low-spatial frequency face more salient for participants (Paquet and Merikle, 1984). Additionally, the number of faces used was decreased from 27 to 21, such that 42 hybrid pairs were now presented. This was done to remove the 6 faces that resulted in almost exclusively global or local responses in Experiment 1, and thus may have limited the variability in this measure. As such, the total global face score is now out of 42.

Hierarchical Shape Task. For Experiment 2, the pen-and-paper shape task was converted into a computerized task. This was done in order to control the viewing time

for each of the stimuli, as opposed to the virtually unlimited viewing time that participants had for the stimuli in Experiment 1. Some of the variability in this task in Experiment 1 may have resulted from individual differences in how long participants chose to examine the stimuli before responding. This new version equates participants on this measure.

Eight different hierarchical shapes were constructed such that each hierarchical shape contained both a global and a local level. Each hierarchical shape was comprised of 15-25 small (2 x 2 mm) circles, squares, triangles, or crosses (local level) that formed a larger (20 x 20 mm) square or triangle (global level). Note that these shapes are denser than those used in the previous study, as density has previously been shown to increase global saliency (e.g., Kimchi & Palmer, 1982).

These hierarchical shapes were then grouped into triads, such that each triad contained three of the hierarchical shapes. In each triad, one of the hierarchical shapes was designated the “standard” shape, and the other two were called the “comparison” shapes. For half of the triads (the “test” triads), one of the comparison shapes matched the standard shape at the global level and the other comparison shape matched the standard at the local level. For the other half of the triads (the “filler” triads), only one of the comparison shapes matched the standard at either the global or the local level. In total there were 16 test triads and 16 filler triads which were intermixed, for a total of 32 triads.

Each trial began with a 1000 ms blank screen, after which the standard hierarchical shape appeared in the center of the screen for 50 ms. This standard shape was then replaced by the two comparison hierarchical shapes. One of the shapes was

presented on the left side of the screen, and one on the right (counterbalanced).

Participants were asked to select the comparison shape that they thought best matched the standard shape by pressing the corresponding key on the keyboard. These comparison shapes remained on the screen until the participant made a response. Responses were not speeded, but participants were encouraged to go with their first instinct. Each participant performed 32 trials. For each participant, a global shape score was calculated as the total number of test trials out of 16 where the participant selected the comparison shape that matched the standard at the global level. Therefore, a high global shape score suggests a bias for global processing, whereas a low global score suggests a bias for local processing. Filler triads had only one correct response (half with global correct, and half with local correct), thus they were not used as an index of global/local bias.

Global/Local Navon Letter Task. The Navon letter task was basically the same as in Experiment 1, with the exception that density of the letters was increased by using more local letters (roughly 25 letters, as opposed to 13). Additionally, the letter stimuli now only appeared on the screen for a duration of 15 ms, after which the stimuli were replaced with a blank screen which remained until participants made a response. Increasing the density of the display typically makes the stimuli more globally salient (e.g., Kimchi & Palmer, 1982), and reducing the display time of the letter stimuli themselves was also expected to increase the saliency of the global stimuli based on a similar effect reported by Paquet and Merikle (1984).

Experiment 2: Results

Global/Local Face Task.

The mean session 1 global face score was 24.45 ($SD = 5.54$), and the mean session 2 global face score was 23.79 ($SD = 4.67$) out of 42. This indicates that just over half of the trials were classified at the global level in each session. This global advantage was significant statistically in each session (p 's $< .001$) compared to chance performance of 21. There were large individual differences in task performance with average scores across sessions ranging from 11 to 38 out of 42.

Hierarchical Shape Task.

The mean session 1 global shape score was 10.26 ($SD = 5.24$), and the mean session 2 global shape score was 11.48 ($SD = 4.43$) out of 16. This global advantage was significant statistically in each session (p 's $< .002$) compared to chance performance of 8. Scores on this task ranged greatly across sessions from 1 to 16 out of 16. Accuracy on the filler trials was .71 ($SD = .14$) and .70 ($SD = .15$) for session 1 and 2 respectively. This task was more difficult than the previous paper task version used in Experiment 1, as reflected by the lower overall accuracy scores on the filler trials, but these scores show that the participants were performing the task as instructed.

Global/Local Navon Letter Task.

Mean letter identification RTs for session 1 and session 2 of the Navon letter task are presented in Figure 2-5ab as a function of global or local task block, and congruence/incongruence of global and local levels. Mean RTs were analyzed using a 2 x 2 (task block by congruency) repeated measures ANOVA.

For both sessions 1 and 2, there was a significant main effect of congruency, with faster RTs on congruent trials than on incongruent trials, $F(1, 57) = 101.98, p < .001, \eta_p^2 = .64$ and $F(1, 57) = 108.69, p < .001, \eta_p^2 = .66$ respectively. There was also a significant main effect of task block in each session, such that global trial RTs were faster than local trial RTs, $F(1, 57) = 87.95, p < .001, \eta_p^2 = .61$ and $F(1, 57) = 228.20, p < .001, \eta_p^2 = .80$ respectively. Finally, there was a significant interaction between task block and congruency in each session, such that the congruency effect was larger on local trials as compared to global trials, $F(1, 57) = 10.78, p = .002, \eta_p^2 = .16$, and $F(1, 57) = 25.30, p < .001, \eta_p^2 = .31$ respectively. The finding that global information interfered more with local responses than local information did with global responses provides evidence for a global advantage for this task. Across sessions, average global interference scores ranged from -80 ms to 167ms.

The mean error rates in the Navon letter task were 8% and 7%, for sessions 1 and 2 respectively. A 2 x 2 (congruency by global/local task) repeated measures ANOVA on the mean error data for each session showed that errors were greater for incongruent trials than congruent trials, $F(1, 57) = 36.46, p < .001, \eta_p^2 = .39$ and $F(1, 57) = 69.77, p < .001, \eta_p^2 = .55$ for sessions 1 and 2 respectively. There was also a main effect of task block for session 2 only, $F(1, 57) = 7.55, p < .001, \eta_p^2 = .12$, and an interaction of task block and congruency for session 2 only, $F(1, 57) = 14.54, p < .001, \eta_p^2 = .20$, where the congruency effect was greater on local trials. This is consistent with the RT data, and thus does not suggest a speed-accuracy trade-off.

Test-Retest Reliability.

As an index of test-retest reliability, the Pearson correlation coefficients between scores on session 1 versus session 2 were examined individually for each of the three global/local tasks. As in Experiment 1, the face global/local task was shown to be reliable over time, as was the hierarchical shape global/local task (see bolded values in Table 2-3 and Figure 2-6abc). The test-retest reliability of the Navon letter task, however, was quite low, albeit significant. When I examined the mean Navon letter global and local RTs across session, both had high test-retest reliability ($r = .66$ and $.83$ respectively), suggesting that although the RTs were highly reliable, the measure of interference was less so, as in Study 1.

Relationships among the Measures.

The relationships among the three different measures of global/local processing bias were examined by correlating the scores for each test session. As in Experiment 1, none of the measures were significantly related to each other either within a session or across sessions (see non-bolded values in Table 2-3)⁶. When the scores for each of the three tasks were combined across the two sessions, once again there was no significant relationship among the three measures, such that global face and global shape scores correlated $-.008$ ($-.01$ disattenuated), global face and global interference correlated $-.08$ ($-.20$ disattenuated), and global shape and global interference correlated $.14$ ($.34$ disattenuated; all p 's $> .30$; see Figure 2-7 abc). This shows that once again, while the three global/local tasks were significantly reliable, they were unrelated to each other.

⁶ When performance on the Navon letter task was instead calculated as the difference between the mean local RTs and the mean global RTs, the same pattern of results was obtained, such that the test-retest reliability was still significant ($r = .36$), and the relationships among the three tasks, and the overall relationships, were still non-significant (all p 's $> .40$).

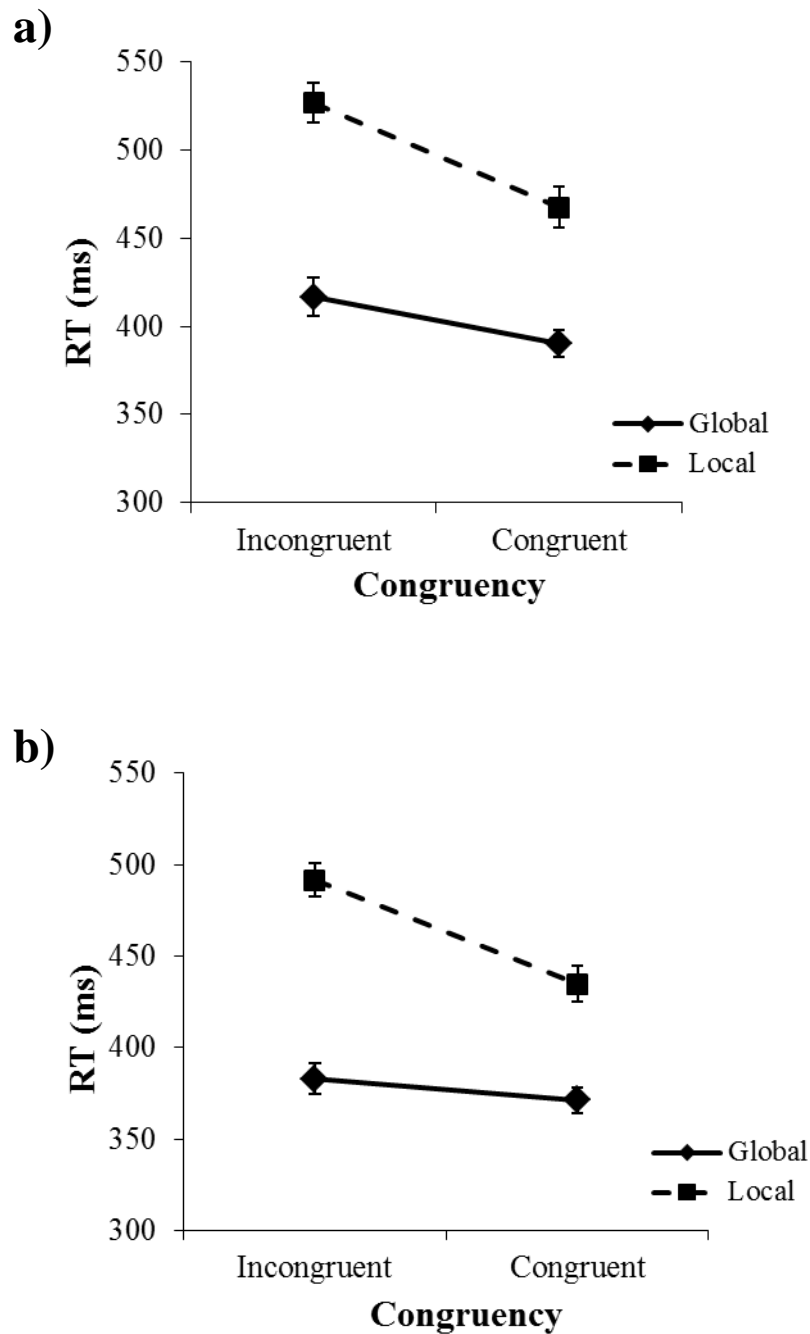


Figure 2-5. a) Mean session 1 RT on the Navon letter task, as a function of task (attend global or attend local) and target congruency. Error bars represent the standard error for each condition mean. **b)** Mean session 2 RT on the Navon letter task, as a function of task (attend global or attend local) and target congruency. Error bars represent the standard error for each condition mean.

Table 2-3.

Pearson Zero-order Correlations between Test Sessions for the Three Global-Local Measures (in bold font), and the Relationships among All Measures in Study 2.

	1	2	3	4	5
1. Global Face Session 1	--				
2. Global Shape Session 1	.01	--			
3. Global Letter Interference Session 1	-.02	.04	--		
4. Global Face Session 2	.57**	.03	-.07	--	
5. Global Shape Session 2	-.10	.64**	.04	.03	--
6. Global Letter Interference Session 2	-.06	.19	.27*	-.10	.07

Note: * indicates $p < .05$, ** indicates $p < .01$.
Bold font indicates test-retest correlations.

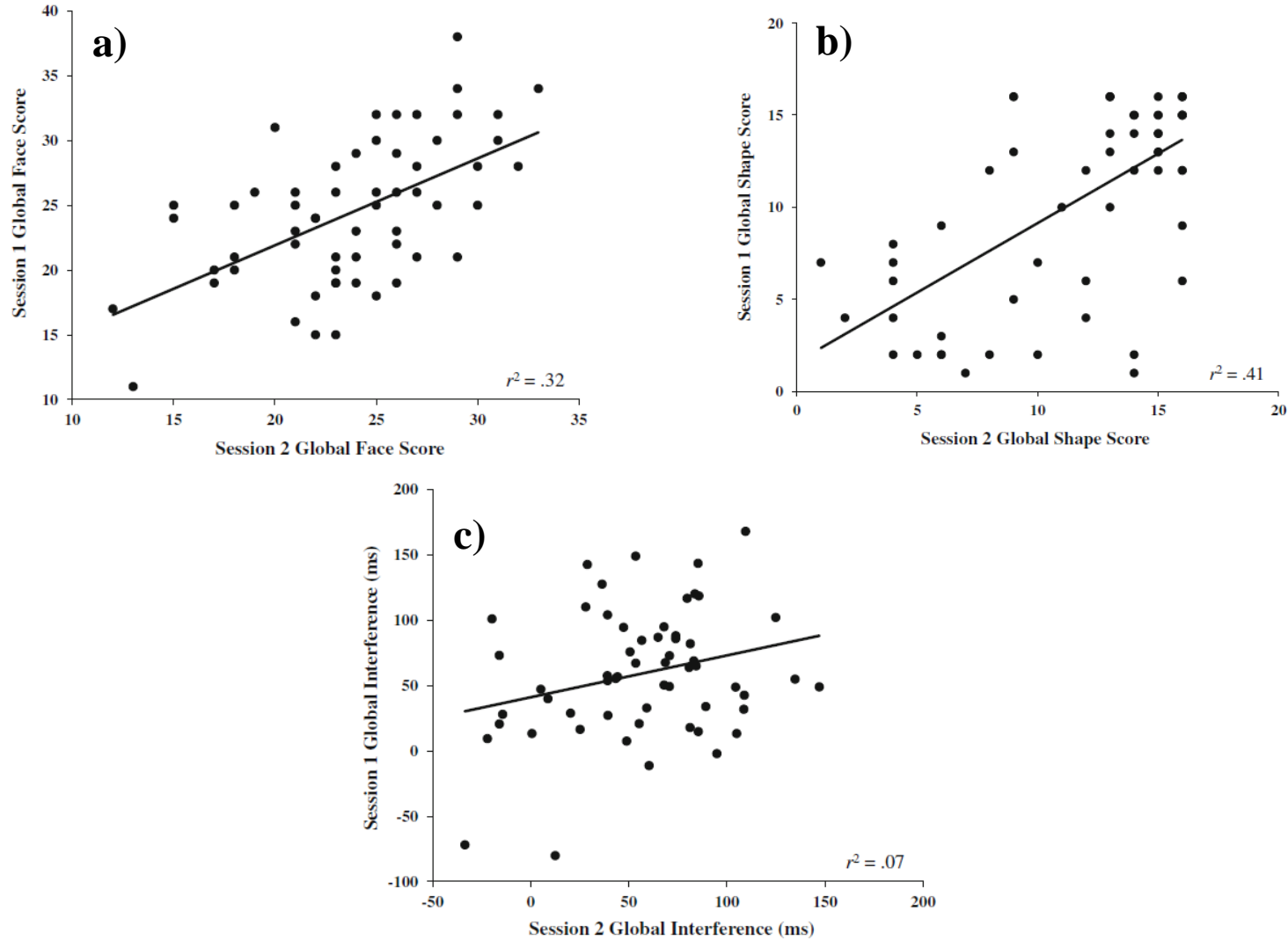


Figure 2-6. *a) Scatterplot depicting Pearson r correlation between session 1 and session 2 scores on the global/local face task. b) Scatterplot depicting Pearson r correlation between session 1 and session 2 scores on the global/local shape task. c) Scatterplot depicting Pearson r correlation between session 1 and session 2 scores on the global/local Navon letter task.*

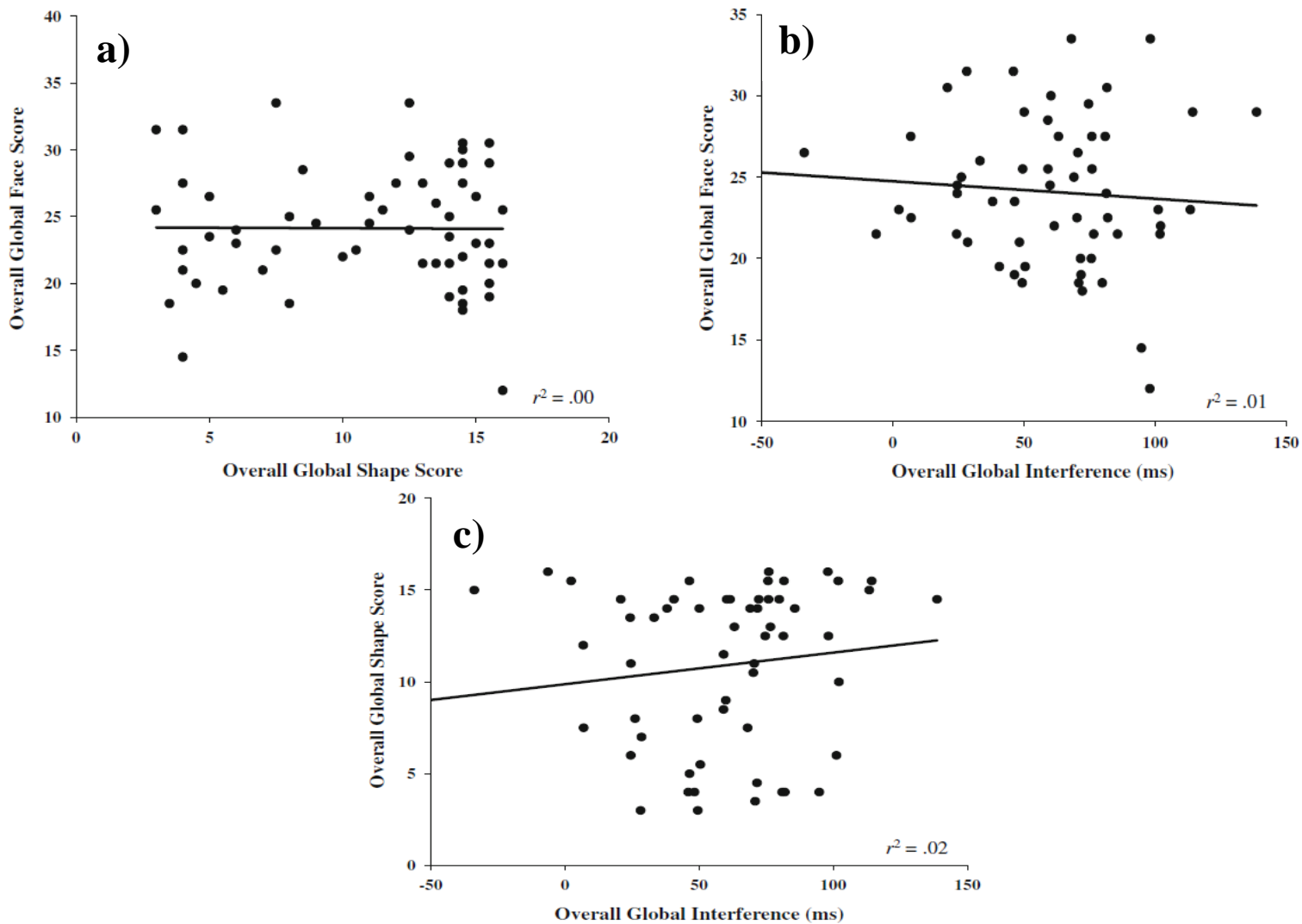


Figure 2-7. *a)* Scatterplot depicting Pearson r correlation between overall global face task score and overall global shape task score, $r = -.01$. *b)* Pearson r correlation between overall global face task score and overall global interference from the letter Navon task, $r = -.08$. *c)* Pearson r correlation between overall global shape task score and overall global interference from the letter Navon task, $r = .14$.

Factor Analysis.

As with Experiment 1, I performed a factor analysis with a varimax rotation that included the three measures of global bias for each of the two sessions (6 items). Once again, I obtained a 3-factor solution, with each of the three global/local tasks loading on its own factor (see Table 2-4). This suggests that these three tasks are each measuring some unique process.

Table 2-4.

Rotated Factor Loadings for the Three Global/Local Measures, by Session, Showing Three Distinct Factors in Study 2.

	Component		
	1	2	3
Global Face Session 1	-.06	.89	.02
Global Face Session 2	.06	.88	-.10
Global Shape Session 1	.90	.04	.09
Global Shape Session 2	.90	-.04	.04
Global Letter Interference Session 1	.01	-.01	.81
Global Letter Interference Session 2	.11	-.07	.78

Method: Principal Component Analysis. Varimax with Kaiser normalization.

Experiment 2: Discussion

The purpose of Experiment 2 was to replicate the results of the first experiment, but using presentation conditions that promote the typical global advantage effect. In Experiment 2, all three of the tasks showed a typical global advantage, such that individuals were more globally biased. Individual performance on all three tasks was again significantly reliable over time. In general, reliabilities were somewhat lower than in Experiment 1, but that would be expected given that the greater global salience of the

stimuli may have biased some individuals on at least some trials to be more globally biased than they might have been otherwise, thereby diluting the strength of the individual differences on these measures. Interestingly, the Navon letter task again had low, albeit significant, test-retest reliability, suggesting again that this task may not be a reliable measure of individual global/local preference.

Importantly, I once again found that although the tasks were reliable, none of the tasks were related to each other. Indeed, the lack of relationships was very comparable to those observed in Experiment 1, and the factor analysis again showed that each of the three tasks loaded onto their own independent factor. As such, the results from Experiment 1 cannot simply be the result of using stimuli that were too neutral or stimuli that were not measuring global/local processing in the traditional sense.

General Discussion

The primary purpose of this study was to examine the stability of individual global/local bias in two different experiments. In both experiments I found that individual global/local bias was stable over time, suggesting that individuals potentially develop a preference for processing global or local information, and that this preference persists over a period of at least several days. This, of course, does not suggest that bias is not influenced by stimulus or task demands (e.g. Kinchla & Wolfe, 1979, Kimchi & Palmer, 1982) or participant state (e.g., Fredrickson & Branigan, 2005; Gasper & Clore, 2002), as this is well documented. It does, however, indicate that individuals may have a default processing strategy that influences their perception of visual objects.

Importantly, although the face task and both versions of the hierarchical shape task showed moderate-to-high test-retest reliability, the standard Navon letter task had

fairly poor reliability in both experiments. It is unlikely that this occurred because RT was the dependent variable in the Navon letter task, as the RTs themselves were shown to be highly reliable over time, suggesting that it was the index of interference that had poor reliability. The low reliability was also not the result of using a difference score as a measure of interference.

It is possible that the Navon letter task was less reliable because the other two tasks were forced choice tasks which pitted global versus local against each other on every trial, whereas the Navon letter task required the participant to follow instructions to direct attention to the local or global level. This suggests that directing the level of attention may add noise, leading to lower task reliability. It is worth noting, however, that the Navon letter task is one of the most well-known and utilized tasks of global/local processing. The low test-retest reliability I observed for this task suggests that caution should be taken when using this task as an individual differences variable, and suggests a need for further investigation.

The secondary purpose of this paper was to examine the relationships amongst three different measures of global/local processing. Unexpectedly, in both experiments, I found that none of the three global/local measures related to each other either within or across session, and each loaded independently onto its own factor. This occurred despite the finding that all three tasks produced large individual differences and were reliable measures (with two being highly reliable).

Notably, the type of task used (level-directed speeded task or forced choice non-speeded), the presentation mode (computerized or a paper-and-pencil task in Experiment 1), the nature of the stimuli (letters, shapes, faces), and the timing of the stimulus

presentation were different for some of the tasks. Additionally, letters tend to be perceived automatically as letters (Stroop, 1935), whereas the interpretation of hierarchical shapes or faces is thought to be more influenced by an individual's goals, motivations, or beliefs (e.g. Jemel, Pisani, Calabria, Crommelinck, & Bruyer, 2003; Langley, Laird, & Rogers, 2009). Finally, it should be noted that the face task is not a common global/local task, and while spatial frequency is related to global/local processing, it is not global/local in and of itself. Therefore it is possible that any or all of these large task differences could have resulted in the dissociability of these measures. It would be interesting to isolate these factors in order to determine which, if any, factors are critical for dissociating performance on these tasks. As such, I am currently conducting a series of experiments to attempt to disentangle the critical factors responsible for the lack of differences amongst these tasks. What is clear is that if these three tasks are indeed measuring global/local processing, they are each measuring a unique aspect.

Conclusion

Global/local bias was found to be a reliable individual difference variable, especially when using the forced-choice tasks employed here. However, although reliable, individual performance on each of the global/local tasks was unrelated to performance on the other global/local tasks. Global/local tasks are often used interchangeably as an index of global/local processing. This is somewhat alarming, as it suggests that researchers may be selecting a global/local measure based on the ease of administration or the type of stimuli, without realizing that the task itself could have a large impact on their results. As such, I recommend caution when selecting a global/local

task, particularly if comparing results obtained from two different global/local processing measures, as they may be measuring unique, rather than similar, processes.

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CHAPTER 3

Study 2: How reliable is the attentional blink? Examining the relationships within and between attentional blink tasks over time¹

Abstract

When the second of two targets is presented temporally close (within 500 ms) to the first target in rapid serial visual presentation, accuracy for reporting the second target is markedly diminished – an attentional blink (AB). The AB has become a well-studied phenomenon, and multiple different versions of the AB task are currently in use. However, little is known about the stability of individual performance on the AB. The current study examined the reliability of two different versions of the AB task (a task-switch and no-task-switch version) within session, and over the period of 7-10 days, in order to examine performance stability. In addition to testing the reliability, I also examined the relationship between both versions of the AB tasks. Both versions of the AB were shown to be reliable within session, and over time, suggesting that performance is quite stable on this task. Additionally, performance on the two different AB tasks was significantly correlated within and across sessions, suggesting that the AB phenomenon is being accurately captured by versions of the AB that include a task-switch. These findings are important, particularly given the recent interest in individual differences in performance on the AB.

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Introduction

When the second of two targets (T2) is presented within approximately 500 ms of the first target (T1) in a rapid serial visual presentation (RSVP) stream, accuracy for reporting T2 is markedly diminished relative to longer target separations (Raymond, Shapiro & Arnell, 1992). This pattern is known as the attentional blink (AB; Raymond et al., 1992). There are various theories of the AB, but most agree that the attention given to T1 results in reduced and/or delayed attention to T2 (see Dux and Marois, 2009 for a recent review).

Since its inception, researchers have sought to understand the cognitive mechanisms behind the AB by manipulating the task requirements, task difficulty, or stimulus presentation conditions of distractors, T1, and T2. As such, there are now many different T1 and T2 task combinations that have been shown to produce an AB. For example, the T2 task is sometimes a detection task (e.g., ‘Was an ‘X’ present or absent?’) as in Raymond et al. (1992), and other times an n-alternative forced choice task (e.g., ‘Which letter was presented as T2?’). Some task combinations require a task switch in that one task is used for T1 and a different task for T2 (e.g., “What was the lone white letter, and was T2 an X or Y?”), whereas others do not (e.g., “Report the two digit targets from amongst the letter distractors”). Sometimes targets are defined based on stimulus features (e.g., “Report the two red letters”), and other times on the basis of category membership (e.g., “Report the two digits”). Stimuli can consist of numbers, letters, words, shapes, pictures, faces, and even sounds. As such, there is now a rich AB literature and a variety of different AB tasks in use, all of which appear to support the robustness of this phenomenon.

While the AB has been a well-studied phenomenon, and is highly robust, the actual stability of individual performance on this task over time has not been well established. Indeed, to date only one study has examined test-retest reliability of the AB over multiple testing sessions. Although not the original focus of their study, McLaughlin, Shore and Klein (2001) examined the relationship between individual performances on two different versions of the AB task completed on separate days. On the first test session, participants reported the two letter targets presented in an RSVP stream of digit distractors. They then returned four weeks later to complete the same task with the exception that only T1 and T2 and their immediate post-target distractors were presented. McLaughlin et al. (2001) observed that performance on these two different AB tasks correlated .66, providing the first evidence that individual AB performance is fairly stable over time.

Two other studies have observed reliable individual differences in the AB, but did so within a single testing session. Arnell, Howe, Joannise and Klein (2006) asked participants to perform four blocks of the same AB task in a single test session. Although a different stimulus type was used in each block (letters, digits, colors and line drawings), modest, but significant, positive correlations were obtained for AB magnitude and overall T1 and T2 accuracy across the stimulus blocks (Arnell et al., 2006).

Kelly and Dux (2011) asked participants to perform three different AB tasks twice within a single testing session. For the “featural AB” task, targets were defined by color (red). For the “categorical task”, targets were defined by category (letters). For the “probe AB” task, T1 was defined by color and T2 required an X/Y discrimination. In all three tasks the AB showed stable individual differences from the first to the second run.

Surprisingly, although individual AB magnitude on the feature task predicted AB magnitude on the categorical task, individual AB magnitude on the probe task was unrelated to the AB on the feature or categorical tasks.

While these two studies have observed decent reliability within the same testing session, and the McLaughlin et al. (2001) study observed acceptable reliability in AB performance over time (albeit with two different tasks), the stability of performance on the same AB measure over two different testing sessions is not yet established. It is necessary to properly establish the stability of the AB, particularly given the recent interest in individual differences in performance on the AB task. Researchers have recently begun to perform individual difference studies in order to investigate cognitive or dispositional factors that can predict whether an individual shows a large or small AB (e.g., Arnell & Stubitz, 2010; Colzato, Spape, Pannebakker & Hommel, 2007; Dale & Arnell, 2010; MacLean, Arnell & Busseri, 2010; Martens & Valchev, 2009). Such studies assume that individual performance on the AB is stable over time, reflecting some dispositional selective attention ability. However, this assumption has yet to receive strong empirical support. Reliability estimates provide an upper-bound on the relationships that should be expected between the AB and other predictors (i.e., one should not expect to find that performance on an AB task is more related to a dispositional measure than to a separate measure of performance on the same AB task). Thus, an examination of AB reliability is also important for interpreting the magnitude of relationships between the AB and dispositional variables.

The reliability of cognitive performance measures should not be assumed, as some other well-known cognitive paradigms have been shown to have surprisingly poor

test-retest reliability. For example, Kuntsi, Stevenson, Oosterlaan, and Sonuga-Barke (2001) observed poor test-retest reliability for a measure of response inhibition (i.e., a go-stop task), and a dual task (i.e., a memory-span task with a simultaneous tracking task) over a period of two weeks. Borgmann, Risko, Stolz and Besner (2007) observed that the reliability of the Simon effect varied from high to low across blocks depending on the proportion of compatible to incompatible trials. Similarly, Stolz, Besner and Carr (2005) showed that the reliability of semantic priming varied from modest to nil depending on the relatedness proportion within a block. Therefore, even relatively modest changes to cognitive tasks can influence reliability estimates. With this in mind, I included two versions of the AB task in the present study.

The main purpose of the current study was to assess the reliability of two different versions of the AB task both within the same testing session, and over the period of one week. Based on the previous findings of McLaughlin et al. (2001), I hypothesized that both AB task versions would have acceptable internal-consistency reliability, and that individual differences in AB magnitude and overall target accuracy would remain stable over time.

In addition to examining the reliability of the AB within session and over time, I was interested in investigating the relationships among different versions of the AB task. As noted above, multiple different AB tasks have been employed throughout the literature, and these different versions are used interchangeably as an index of the AB. However, the lack of correlations amongst switch and no-switch AB measures in the recent Kelly and Dux (2011) study suggests that switch and no-switch AB tasks may not be measuring the same dual-task cost that we call the AB. Thus, I decided to further

investigate this by examining the reliabilities for, and relationships among, two versions of the AB: one with a task switch and one without.

Method

Participants

Forty-six Brock University undergraduate students (43 women) voluntarily participated in the study for extra course credit. Participants ranged in age from 17 to 32 years ($M = 19.7$, $SD = 3.4$), reported normal or corrected-to-normal vision, and reported having learned English before the age of 8. All of the participants completed a 1-hour testing session, followed by a second 1-hour testing session approximately 7-10 days later. Participants first completed the switch AB task, and then the non-switch AB task. This task order remained constant across participants and session.

Apparatus

The tasks were controlled using E-Prime software, and were presented on a dual-core Dell desktop computer with a 17-inch CRT monitor. Participants made all responses via manual button-press on the computer keyboard.

Stimuli and Design

Switch AB Task. For the switch AB task, participants were asked to identify a single red letter (T1) from within a stream of 17 black distractor letters, and to detect the presence or absence of a black X (T2). All letters were presented in 18 point New Courier font on a white background. Each distractor and T1 was randomly drawn without replacement from all of the letters of the alphabet, except X. T1 was presented in either stream position 7 or stream position 10, and T1 and T2 were separated by a lag of 1-8

items (105 – 840 ms). T2 was present on 67% of trials (80 trials), and absent on 33% of trials (40 trials), for a total of 120 trials.

At the beginning of each trial, the participants saw a 1000 ms blank screen, followed by a 500 ms central fixation cross. The cross was then replaced by the first letter in the stimulus stream. Each letter was presented individually on the screen for 105 ms with no blank ISI. After the completion of each RSVP stream, participants were asked to enter the identity of the T1 letter on the computer keypad, and report whether or not they detected an X ('k' key for present, 'l' key for absent). To keep false alarm rates reasonably low, participants were asked to report T2 as present only if they felt it was fairly likely they had viewed it on that particular trial. Responses were not speeded.

No-Switch AB Task. The no-switch AB task was the same as the switch AB task, with the following exceptions. Participants were asked to identify two red letters (T1 and T2) presented within a stream of 17 black distractor letters. All distractors and targets were randomly drawn without replacement from all of the letters of the alphabet, except B, I, L, O, U, V, and X². Each combination of T1 position (7 or 10) and T1-T2 lag (1 – 8) was presented 5 times, for a total of 80 trials. After each RSVP stream, participants were asked to enter the identity of the T1 letter on the computer keypad, and then enter the identity of the T2 letter.

Results

AB Performance

Switch AB Task. An overall T1 accuracy score was calculated for each participant, for each AB task, averaged across lags. For the Switch AB task, session 1 mean T1

² This specific task program was adapted from a previous study where targets were digits. These letters were removed as distractors due to their physical similarity to a digit and/or their use in Roman numerals.

accuracy was .91 ($SD = .07$), and session 2 mean T1 accuracy was .90 ($SD = .07$). T1 accuracy did not differ significantly as a function of lag for either session, $F < 1$.

To obtain an estimate of each participant's overall T2 sensitivity (independent of lag), each participant's overall T2 false alarm rate was subtracted from their overall T2 hit rate. T2 performance was conditionalized on T1 report being correct³. Session 1 mean T2 sensitivity was .51 ($SD = .16$) and session 2 mean T2 sensitivity was .55 ($SD = .20$).

A large AB was observed in both sessions of the AB Switch task (see Figure 3-1a). A repeated measures ANOVA with lag and session as within-subjects factors was conducted on the T2 sensitivity scores. There was a significant main effect of lag, $F(7, 315) = 139.79$, $p < .001$, $\eta_p^2 = .76$, and a significant effect of session, $F(1, 45) = 81.44$, $p < .001$, $\eta_p^2 = .64$, where T2 sensitivity was greater in session 2 than in session 1. However, the lag by session interaction did not approach significance, $F(7, 315) = 1.04$, $p = .41$, $\eta_p^2 = .02$, indicating that the AB per se (i.e., the T2 accuracy change across lags) did not differ for the two sessions.

No-Switch AB Task. Overall T1 and overall T2 accuracy scores (averaged across lags) were calculated for each participant, and scored without concern for order errors (i.e., J and S were scored as correct if the participant reported J first and then S or S first and then J)⁴. For the no-switch AB task, session 1 mean T1 accuracy was .87 ($SD = .11$), and session 2 mean T1 accuracy was .85 ($SD = .11$). T1 accuracy did not differ significantly as a function of lag for either session, $F < 1$.

³ The same pattern of results was observed when T2 sensitivity in the switch AB task was calculated using the sensitivity measure d' , with the exception that the relationship between the switch and no-switch AB size for session 1 fell just short of significance, due in part to one outlier.

⁴ The same pattern of results was observed when the data scoring required participants to report the targets in the correct order.

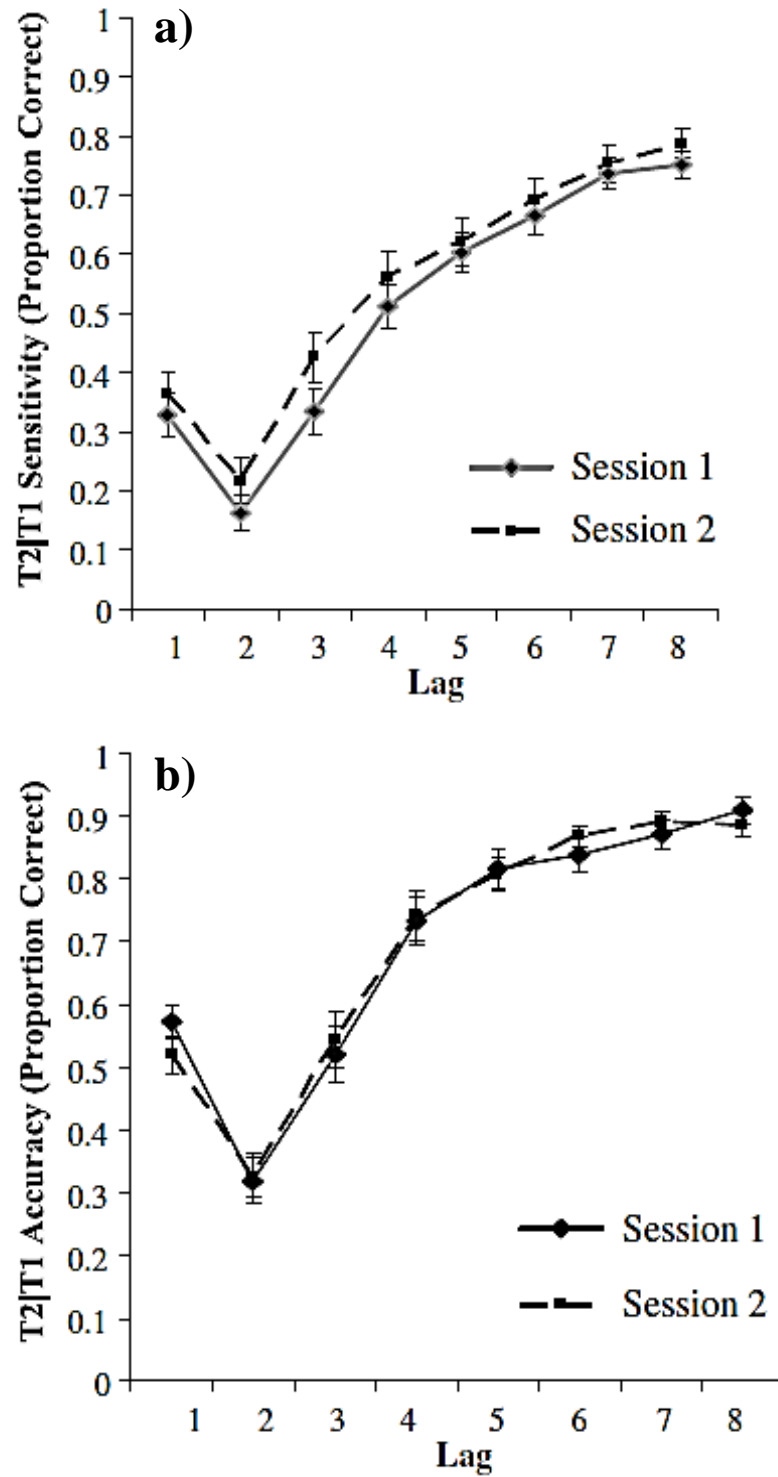


Figure 3-1. *a)* Switch AB task T2 sensitivity as a function of T1-T2 lag conditionalized on T1 correct for sessions 1 and 2. *b)* No-Switch AB task T2 accuracy as a function of T1-T2 lag conditionalized on T1 correct for sessions 1 and 2.

T2 accuracy was only calculated on trials where T1 report was correct. Mean T2 accuracy was .70 ($SD = .15$) for both session 1 and session 2. A large no-switch AB was observed in both sessions (see Figure 3-1b). A repeated measures ANOVA with session and lag as within-subjects factors was conducted on T2 accuracy rates. There was a significant main effect of lag, $F(7, 315) = 121.39, p < .001, \eta_p^2 = .73$, but no main effect of session, $F(1, 45) = .001, p = .98, \eta_p^2 < .00$, or an interaction between lag and session, $F(7, 315) = .94, p = .47, \eta_p^2 = .02$, demonstrating an equivalent AB for the two sessions.

Internal-Consistency Reliability

Each participant's AB magnitude was estimated for each combination of session (1, 2) and AB task (switch, no-switch). AB magnitude was calculated using mean T2 accuracy at the short lags (lags 2-4)⁵ controlling for mean T2 accuracy at lags 7 and 8 (i.e., using short lag accuracy with long lag accuracy partialled-out to control for individual differences in overall T2 performance that were not lag specific)⁶.

The internal-consistency reliability of both versions of the AB task was then examined. The trials for each AB task and testing session were split into odd and even numbered trials. A Pearson r correlation analysis was then performed comparing the two halves for each combination of task and test session. A Spearman-Brown correction was

⁵ Lags 2–4 were included in the short-lag estimate given that lags 2, 3, and 4 each had statistically lower T2 accuracy than the average T2 accuracy for the long lags (lags 7 and 8). Lag-1 also had lower T2 accuracy than the long lag average, but lag-1 T2 accuracy was not included in the short lag T2 accuracy estimate given that T2 accuracy at lag-1 is also influenced by the separate phenomenon of lag-1 sparing. However, the correlations with AB magnitude were also run where short lag accuracy was calculated using the average of lags 1–4 or the average of lags 2 and 3 only, and the same results were observed in each case.

⁶ AB magnitude is often calculated as the difference between long- and short-lag T2 accuracy, conditionalized on T1 correct. However, it is often difficult to assess the reliability of a difference score due to the fact that the reliability of the difference must necessarily be less than or equal to the reliability of each of the two values that are part of the subtraction. This method isolates the lag-dependent effect that is the AB while controlling for individual differences in overall T2 ability that would otherwise confound the short-lag accuracy measure. However, I also note that the pattern of results was the same when an AB difference score was used.

performed on all correlations to correct for the split-half procedure, thereby giving an estimate of the reliability of the total scale for each of the tasks (Nunnally, 1978).

For both the switch AB task and the no-switch AB task, internal consistency reliability was very high for the measures of T1 and T2 accuracy/sensitivity for both sessions (see Table 3-1). While the corrected split-half reliability was greater for switch AB magnitude (.73 and .68 for sessions 1 and 2 respectively) than for no-switch AB magnitude (.67 and .48 for sessions 1 and 2 respectively), all values are acceptably high, and suggest that both AB tasks have acceptable internal consistency reliability within a session.

Table 3-1.

Split-Half Reliability of All AB Measures

	r	Spearman-Brown Corrected r
Switch T1 Accuracy Session 1	.83	.91
Switch T1 Accuracy Session 2	.84	.91
No Switch T1 Accuracy Session 1	.84	.91
No Switch T1 Accuracy Session 2	.72	.84
Switch T2 Sensitivity Session 1	.83	.91
Switch T2 Sensitivity Session 2	.78	.88
No Switch T2 Accuracy Session 1	.80	.89
No Switch T2 Accuracy Session 2	.81	.90
Switch AB Magnitude Session 1	.57	.73
Switch AB Magnitude Session 2	.51	.68
No Switch AB Magnitude Session 1	.50	.67
No Switch AB Magnitude Session 2	.32	.48

Note: All p 's < .001.

Test-Retest Reliability

In order to examine the test-retest reliabilities for both versions of the AB task, a series of Pearson r correlational analyses were conducted on the AB magnitude for both AB tasks from session 1 to session 2. Both the switch and no-switch AB measures had at least moderate and statistically significant test-retest reliability, suggesting that an individual's relative AB magnitude is stable over at least a 1-week period (see bolded values in Table 3-2 and Figure 3-2ab).

Table 3-2.

Pearson r Correlations among All AB Magnitude Measures. Attenuation Corrected Correlations are in Brackets.

	1	2	3
1. Switch AB Session 1	-		
2. Switch AB Session 2	.62**	-	
3. No Switch AB Session 1	.36(.73)*	.38(.77)**	-
4. No Switch AB Session 2	.50(1.0)**	.43(.87)**	.39**

Note: * indicates $p < .05$; ** indicates $p < .001$

The test-retest reliability of the T1 and T2 accuracy/sensitivity measures for both versions of the AB task were also examined. Both T1 and T2 accuracy were found to be highly reliable over time across both AB task and session (see bolded values in Table 3-3).

Relationship between the Two AB Tasks

The relationships between the measures from the AB switch and the AB no-switch tasks were examined. AB magnitude on the switch AB task was a significant predictor of AB magnitude on the no-switch AB task, both within each session, and across sessions (see non-bolded values in Table 3-2). Additionally, when the scores from sessions 1 and 2

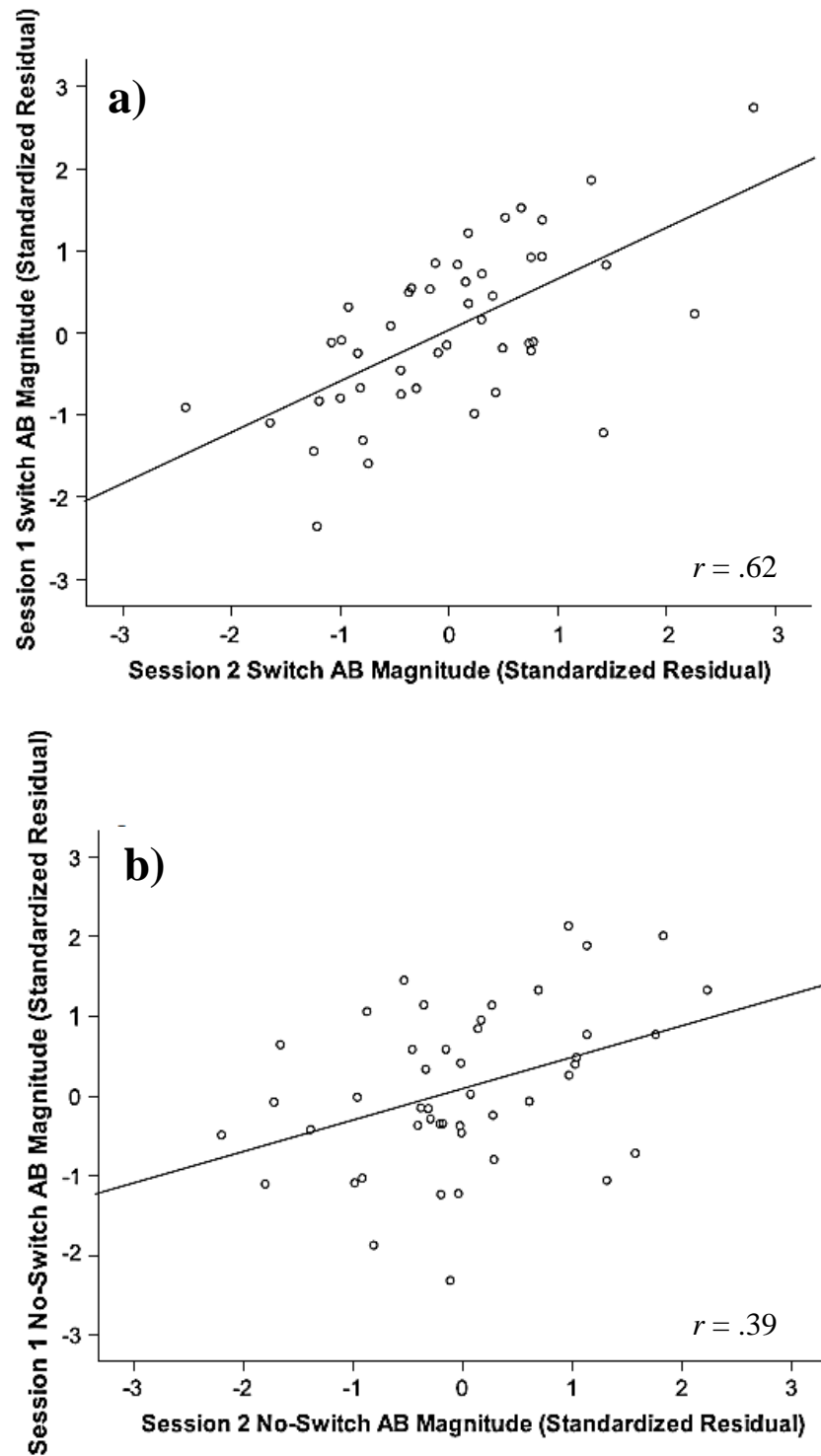


Figure 3-2. *a)* Scatterplot depicting Pearson r correlation between session 1 and session 2 AB magnitude for the Switch AB task. *b)* Scatterplot depicting Pearson r correlation between session 1 and session 2 AB magnitude for the No-Switch AB task.

Table 3-3.*Pearson r Correlations amongst all Target Accuracy Measures.*

	1	2	3	4	5	6	7
1. Switch T1 Accuracy Session 1	-						
2. Switch T2 Sensitivity Session 1	.38	-					
3. Switch T1 Accuracy Session 2	.66	.45	-				
4. Switch T2 Sensitivity Session 2	.36*	.72	.56	-			
5. No Switch T1 Accuracy Session 1	.76	.55	.72	.57	-		
6. No Switch T2 Accuracy Session 1	.74	.61	.71	.66	.83	-	
7. No Switch T1 Accuracy Session 2	.72	.36*	.85	.58	.77	.73	-
8. No Switch T2 Accuracy Session 2	.53	.57	.71	.74	.62	.79	.75

Note: * indicates $p < .05$. All other relationships in this table were significant at $p < .001$.

were combined into an overall AB magnitude score for each of the AB tasks, a significant positive relationship ($r = .56, p < .001$) was observed between switch and no-switch AB magnitudes (see Figure 3-3).

Lastly, the relationships between the two tasks were examined for the T1 and T2 accuracy measures across session (see non-bolded values in Table 3-3). T1 and T2 accuracy for both tasks were highly related to each other within and across session.

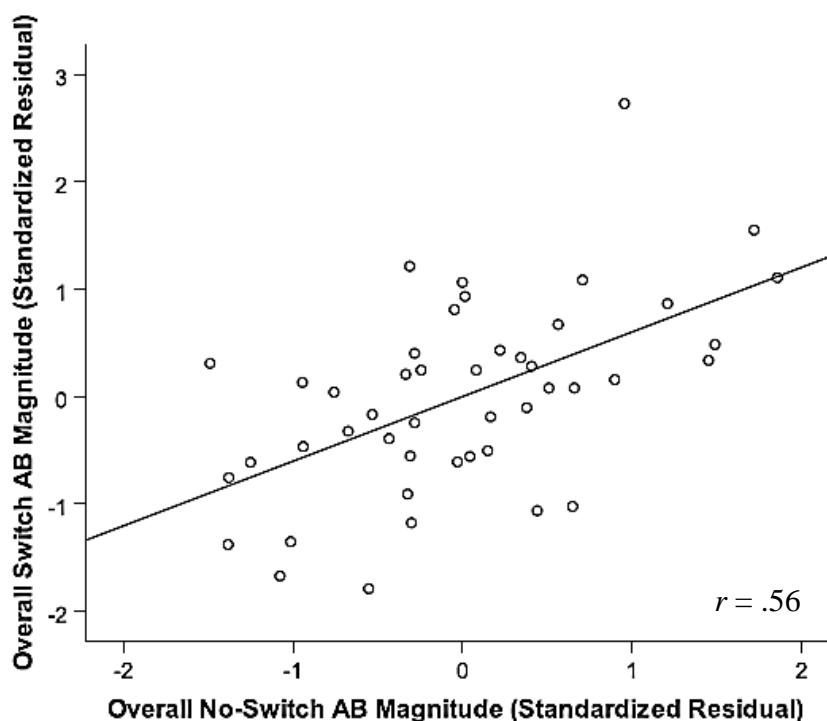


Figure 3-3. Scatterplot depicting Pearson r correlation between Switch and No-Switch AB magnitude averaged across sessions.

Discussion

Reliability

The main purpose of this study was to examine the internal-consistency and test-retest reliability of two different versions of the AB task. I hypothesized that two different AB tasks would show acceptable internal consistency reliability, and that performance on both of these tasks would remain fairly stable over the period of at least 7-10 days. The

present findings were in accordance with this hypothesis. Internal consistency reliability was very high for T1 and T2 accuracy for both AB tasks and high for AB magnitude for both sessions of the switch AB task. The no-switch AB magnitude also proved to have acceptably high reliability for both session 1 and 2, although this task was less reliable than the Switch task. The finding of reliable within session AB magnitudes for both switch and no-switch AB tasks replicates Kelly and Dux (2011).

Test-retest reliability analyses showed that both tasks demonstrated moderate stability in performance over several days. Finding reliable T2 accuracy for both AB tasks replicates Klein et al. (2011) who also showed reliable individual differences in overall T2 accuracy across sessions. The strength of the relationship between session 1 and session 2 AB magnitudes for the switch task (0.62) was very similar to the test–retest reliability of 0.66 for AB magnitude observed by McLaughlin et al. (2001) for two different versions of a switch AB task. Overall, these results suggest that AB performance remains fairly stable over the period of at least a week.

Finding stable individual differences in AB magnitude across time validates the recent interest in individual differences studies of the AB (e.g., Arnell & Stubitz, 2009; Colzato et al., 2007; Dale & Arnell, 2010; MacLean et al., 2010; Martens & Valchev, 2009). The existence of stable individual differences in AB magnitude provides an opportunity to understand the AB by asking what predicts why some individuals have a larger AB than others. Given that the relationship between the AB and any individual difference factor cannot be higher than the reliability of the AB, internal-consistency and test-retest reliability estimates such as the ones shown here also provide us with an estimate of the upper-bound that is possible for relationships between the AB and

individual differences variables. Thus, the present results provide a context in which to interpret the resulting AB variability accounted for by predictors.

One may be concerned that the present results represent a lower estimate on the reliability for these tasks given that relatively few (i.e., 10) trials were used per lag for each task in each session, thereby increasing the estimation error for each lag. This is somewhat offset, however, by averaging across lags such that 30 trials were used to estimate short lags T2 accuracy, and 20 trials were used to estimate long-lag T2 accuracy for each combination of participant, task, and session.

Relationships Across AB Tasks

The secondary purpose for this study was to examine the relationship between the two different AB task versions, both within the same testing session, and over the period of one week. There has been some concern about whether AB tasks that contain a task switch between T1 and T2 represent valid estimates of the AB (Potter, Chun, Banks & Muckenhoupt, 1998) in that task-switch costs may confound AB costs. Recent results from Kelly and Dux (2011) appeared to support such concerns given that AB estimates among two no-switch AB tasks were reliably correlated within a session, but neither was related to the ABs observed from two switch AB tasks from the same session. This led Kelly and Dux to suggest that AB tasks that include a task-switch may provide reliable estimates of task switching as opposed to reliable estimates of the AB.

The present results do not replicate those of Kelly and Dux (2011) in that my results show a statistically significant relationship between the switch and no-switch AB tasks both within, and across, testing session. In particular, the finding that AB magnitude correlated .56 between the two tasks, when averaged across session, provides evidence

that the switch and no-switch AB tasks are tapping into the same underlying process, at least in part. Thus, individual AB magnitude appears to be fairly stable, despite the type of AB task being used. This is especially important, as it provides support for the notion that the AB really is being measured by AB tasks that include a task-set switch from T1 to T2, and that cross-comparisons between studies employing different AB tasks are valid. Future research could extend this finding by examining the comparability of multiple different AB task versions, as this may yield an explanation for why I observed moderately strong relationships between switch and no-switch AB tasks, but Kelly and Dux (2011) did not. For example, in the switch task of Kelly and Dux (2011) T2 required a forced choice discrimination (e.g., X/Y), whereas in the present switch task a present/absent decision was required for T2. Future studies could determine whether a detection task, such as the one used here, is more sensitive to individual differences in AB magnitude, and as such may relate better to no-switch AB measures.

In summary, individual target accuracy and AB magnitude appears to remain fairly stable over a period of at least one week, supporting the idea that individual AB performance is influenced by dispositional ability or style, rather than state factors. In addition, AB magnitude on both a switch and a no-switch AB task was moderately correlated, providing evidence that both are valid measures of the AB.

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CHAPTER 4

Study 3: Multiple Measures of Dispositional Global/Local Bias

Predict Attentional Blink Magnitude¹

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 (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, I extended the findings of Dale and Arnell (2010) through two experiments. In Experiment 1, I examined the relationship between dispositional global/local bias and the AB by using a non-interference hierarchical shape task measure. In Experiment 2, I 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.

¹ This chapter is based on the following submitted article: Dale, G., & Arnell, K. M. (submitted). Multiple measures of dispositional global/local bias predict attentional blink magnitude. *Psychological Research*.

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 is called the “attentional blink” (AB), and is thought to reflect a limitation in selective attention (Raymond et al., 1992; see Dux & Marois, 2009 for a review). However, as opposed to reflecting a fundamental limitation, several studies have shown that the AB can be overcome by altering how participants allocate their attentional resources.

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, and 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 additional task group, as compared to controls who completed the task on its own. Arend, Johnston, and Shapiro (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.

These findings were counterintuitive because one would expect that focusing your attention would allow for more accurate target detection. Additionally, 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, irrelevant items do not cross this activation threshold, there is less competition for limited resources, and the AB is therefore 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, 2011; Colzato, Spapé, Pannebakker, & Hommel, 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. 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 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 overcome the AB.

Electrophysiological measures of performance investment have also been shown to predict the AB. Martens, Munneke, Smid, and Johnson (2006) showed that ‘non-blinkers’ (individuals who fail to show an AB) 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 breadth influences performance on the AB. However, as these studies did not directly measure breadth, but rather inferred this as the mechanism to explain the above relationships, it cannot be definitively shown that dispositional differences in breadth in and of itself influence selective attention. As such, it is also 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 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; Chapter 2). As such, it is possible that the relationship between global/local bias and the AB has been underestimated. In addition, Dale and Arnell (2013a; included here as Chapter 2) showed that three measures of global/local processing (i.e., the Navon letter task, the hierarchical shape task, and a high/low spatial frequency face task) are uncorrelated with each other. 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 in order 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; Chapter 2) 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 I 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 I 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; Chapter 2) 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 T1 accuracy

or T2 sensitivity less than 40% on the AB task, 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). 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 inch CRT monitor, and were programmed and controlled using E-Prime software. 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 Figure 4-1). The hierarchical shape at the top was called the “standard”, and 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.

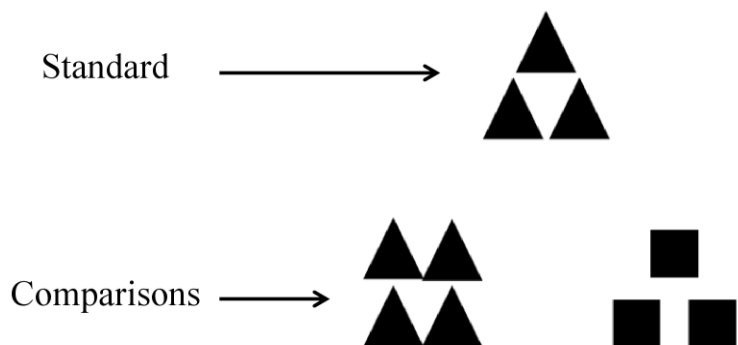


Figure 4-1. Sample hierarchical shape triad from the from the global/local shape task.

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

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, I 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.

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 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 Y². T1 was always presented as the 7th 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 a series of questionnaires/other tasks). There were no differences in mean performance from the first to the second block, $F < 1$, thus the means were collapsed across the two blocks, for a total of 240 AB trials³.

At the beginning of each trial, there was a 1000 ms blank screen, followed by a 500 ms central fixation cross, then a second 1000 ms blank, after which the first letter in the stimulus stream appeared in the centre 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

² These letters were excluded either because they were the same as T2 (X), resembled T2 (K,Y), or were the same as the replacement letter that was used on T2 absent trials (B).

³ 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 minute Navon letter task interspersed. The Navon task had no effect on the AB trials, and there were no significant differences among these mini-blocks, $F < 1$, thus the data were ultimately collapsed both within block and across block.

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. Participants completed the second block of AB trials roughly 10 minutes after finishing the first. After completion of the study, participants were debriefed and compensated for their time. In total, this Experiment took approximately 1 hour 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 ($t(38) = -.42, p = .68, d = -.07$), 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 .94 ($SD = .07$), indicating that participants were performing the task as instructed.

AB Performance

For the AB task, overall T1 accuracy was high ($M = .88$; $SD = .07$), 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, $F(7, 266) = 69.98$, $p < .001$, $\eta^2 = .65$, indicating the presence of an AB.

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, $r = -.28$, $p = .07$, such that individuals with higher global scores had smaller ABs (see Figure 4-2). Although not statistically significant, the pattern of results was in accordance with my hypothesis and suggests that global/local bias on a forced-choice global/local task can predict AB size.

A median split was then performed to further examine this finding. 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 ($n = 17$). 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, $t(36) = 2.71$, $p = .01$, $d = .89$, 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-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 Figure 4-3). There was a significant main effect of lag, $F(7, 252) = 67.46, p < .001, \eta_p^2 = .65$, and the main effect of high/low global score approached significance ($p = .07$). Importantly, there was a significant interaction between lag and high/low global score, $F(7, 252) = 3.29, p = .002, \eta_p^2 = .08$, indicating that the AB differed depending on whether the participant had a high or a low global score. As is shown in Figure 4-3, individuals with a high global score showed a smaller AB effect than did individuals with a low global score.

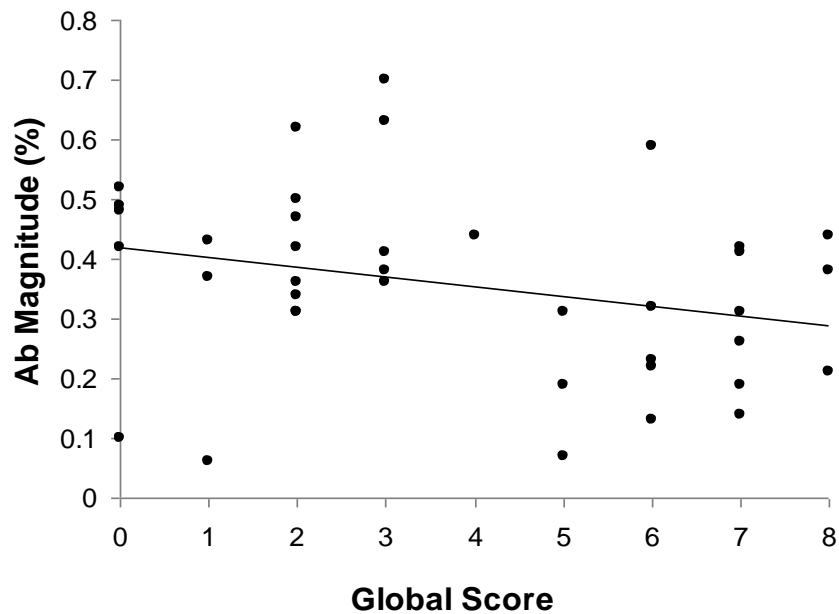


Figure 4-2. Scatterplot depicting a significant negative Pearson r correlation between overall global shape task score and AB magnitude.

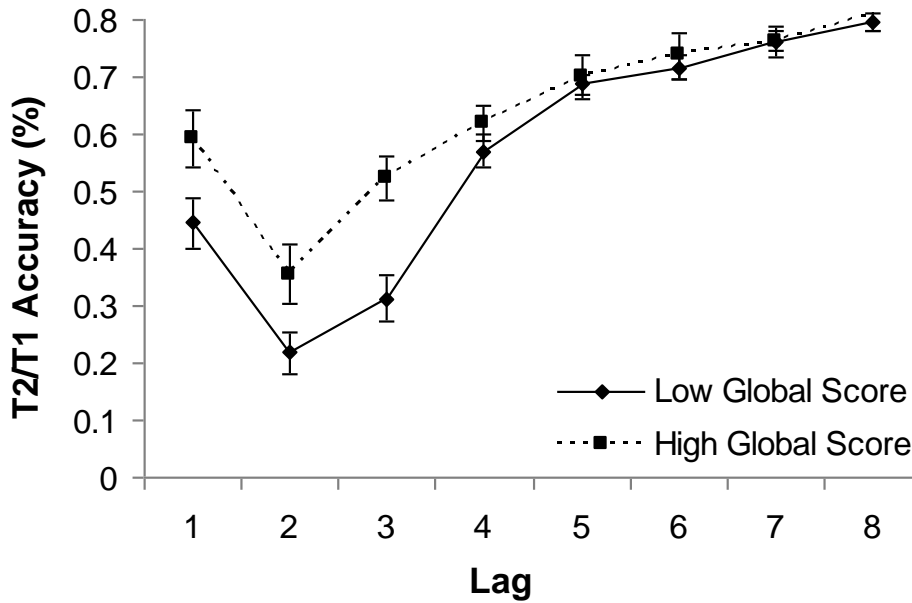


Figure 4-3. Mean T2 accuracy given T1 correct as a function of lag in the AB task for high and low global score groups. Error bars represent the standard error for each condition mean.

A post-hoc examination of the pattern of AB data for the two groups shows that the two groups showed 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, I recalculated AB magnitude to exclude lag 4. With this new estimate of AB size, the correlation between global score and AB magnitude is now statistically significant, $r = -.33$, $p = .04$, demonstrating that global score predicts AB size.

Discussion: Experiment 1

The results conformed to my hypothesis, such that greater global biases were associated with smaller ABs. This finding is also consistent with my 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, I 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 I was able to replicate my previous finding using a different measure of dispositional global/local bias, as noted above, a recent study (Dale & Arnell, 2013a; Chapter 2 here) has shown that individual performance on the Navon letter task used in the Dale and Arnell (2010), and the global/local shape task used here are uncorrelated with 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-Colleminche, 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 I 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-two 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 ($M = 19.6$, $SD = 3.3$). As with Experiment 1, 13 participants (1 male) were ultimately removed from the final analysis for having T1 and/or T2 performance of less than 40%. Thus, the number of participants included in the final analysis was 49 (3 males).

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, I 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 grayscale, 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 ensured 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). I 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 Figure 4-4a).

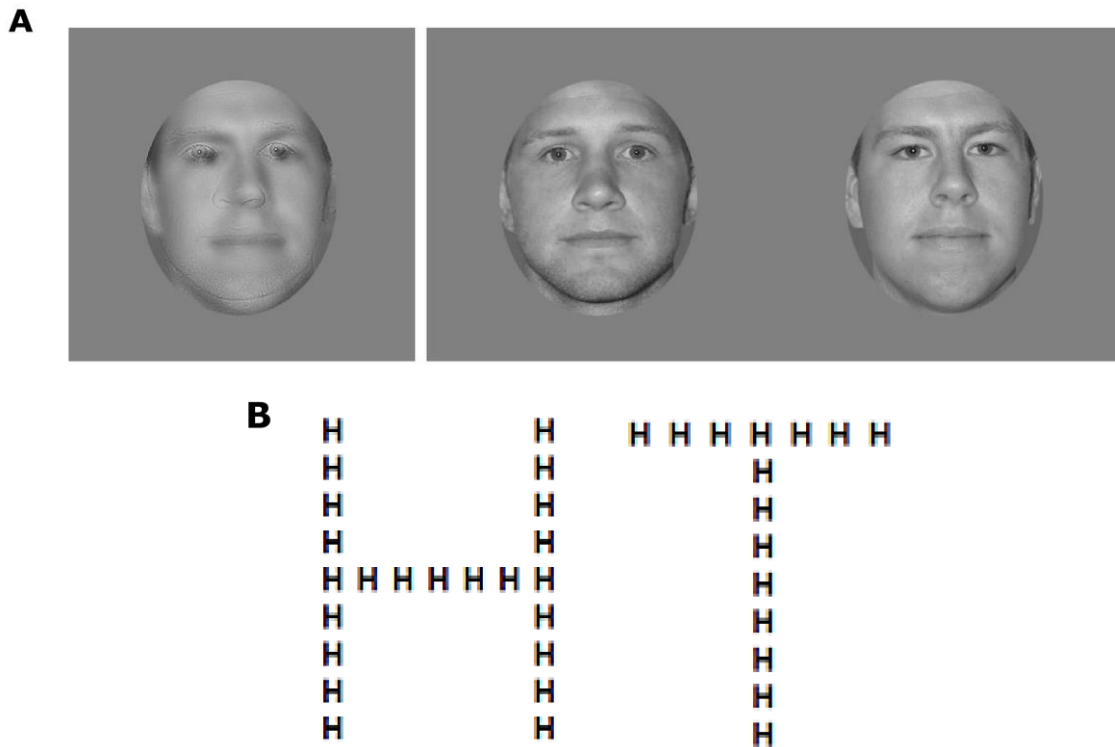


Figure 4-4. (A) Sample stimuli from the global/local face task, with the hybrid face on the far left, and the two intact faces that comprised the hybrid on the right. (B) Sample Navon letter stimuli, with congruent letters on the left (i.e., the global and local levels match) and incongruent letters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

At the beginning of each trial, a fixation cross appeared in the center of the screen for 1000 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 (“A” for the face on the left, and “L” 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, I 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.

Navon Letter Task. The Navon letter stimuli consisted of small (7 x 5 mm) “H’s” or “T’s” (the local letters) presented in black New Courier font that formed a large (70 x 50 mm) H or T (the global letter; see Figure 4-4b). 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 centre 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 X⁴ 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.

⁴ As in Chapter 3, this program was adapted from a previous experiment where these items were removed from the distractor set due to their physical similarity to a digit and/or their use in Roman numerals.

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 minute) break, after which they completed the no-switch AB task, the global face task, and the Navon letter task. Although the 5 minute 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 hours 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, $t(48) = -1.85, p = .07, d = -.26$, 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 .96 ($SD = .06$), indicating that participants were performing the task as instructed.

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 to a chance score of 27, $t(48) = 3.19, p = .003, d = .45$. However, there was a great deal of individual variability in this task, with scores that ranged from 18 to 46.

Navon Letter Task. The mean Navon letter task RTs are presented in Figure 4-5 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, $F(1, 48) = 78.07, p < .001, \eta_p^2 = .46$, but no main effect of level, $F(1, 48) = .006, p = .94, \eta_p^2 = .003$, and no interaction between level and congruency, $F(1, 48) = 1.62, p = .21, \eta_p^2 = .005$. 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.

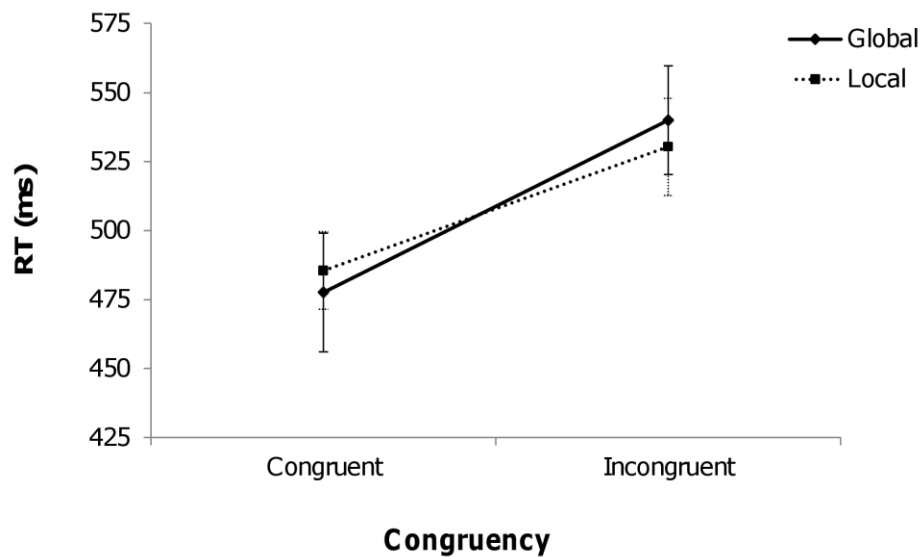


Figure 4-5. Mean RTs for the globally- and locally-directed trials of the Navon letter task as a function of congruency. Error bars represent the standard error for each condition mean.

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, $F(1, 48) = 36.42, p < .001, \eta_p^2 = .43$, 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 $> .10$.

AB Performance

Switch AB Task. For the switch AB task T1 accuracy was high overall ($M = .91$; $SD = .07$), 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 each lag, conditionalized on T1 being correct. Overall T2 sensitivity averaged across lags ranged from .25 to .89. A repeated-measures ANOVA on T2 sensitivity scores showed a significant main effect of lag, $F(7, 336) = 80.81$, $p < .001$, $\eta_p^2 = .63$, indicating the presence of an AB.

No-Switch AB Task. For the no-switch AB task, T1 accuracy was fairly high overall ($M = .78$; $SD = .12$), and did not differ as a function of lag, $F < 1$. T2 accuracy was conditionalized on T1 correct, and when averaged across all lags ranged from .27 to .94. A repeated-measures ANOVA performed on T2 accuracy showed a significant main effect of lag, $F(7, 336) = 72.52$, $p < .001$, $\eta_p^2 = .60$, indicating that an AB was present.

Combined AB Score. As previous research has shown that these switch and no-switch AB tasks share variability (see Dale & Arnell, 2013b; Dale, Dux, & Arnell, 2013), a combined AB measure was calculated to best estimate an individual's AB magnitude. To create this measure, the AB magnitude scores for each task were first converted to z -scores, 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 ($r = -.38, p = .007$), 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 ($r = -.31, p = .03$), 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 ($r = -.18, p = .21$). 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 ($r = .11$), the global shape and global precedence scores ($r = .01$), and the global face and global precedence scores ($r = -.05$) 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 ($sr = -.36, p = .007$) and the global shape score ($sr = -.26, p = .05$) each explained significant unique variance in AB magnitude (i.e., variance in the AB not explained by the other predictors). Additionally, the three global/local measures together explained a significant 25.5% of the variance in AB size, $R = .51, F(3, 45) = 5.13, p = .004$. Global precedence on its own, however, was not a significant unique predictor of AB magnitude ($sr = -.20, p = .13$).

A composite global score was created that combined the three global/local measures, thus allowing me to have a more *complete* measure of global/local bias for each individual. Each of the three global scores (shapes, faces, and global precedence) were 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, $r = -.49$, $p < .001$, such that individuals with higher global scores had smaller ABs, and vice versa (see Figure 4-6). This nicely shows that the composite global score was better able to predict AB magnitude than was each predictor on its own. Additionally, when I examined the two AB tasks individually, the composite global score was a significant predictor of both switch AB magnitude, and no-switch AB magnitude, $r = -.49$, $p < .001$ and $r = -.31$, $p = .01$ respectively.

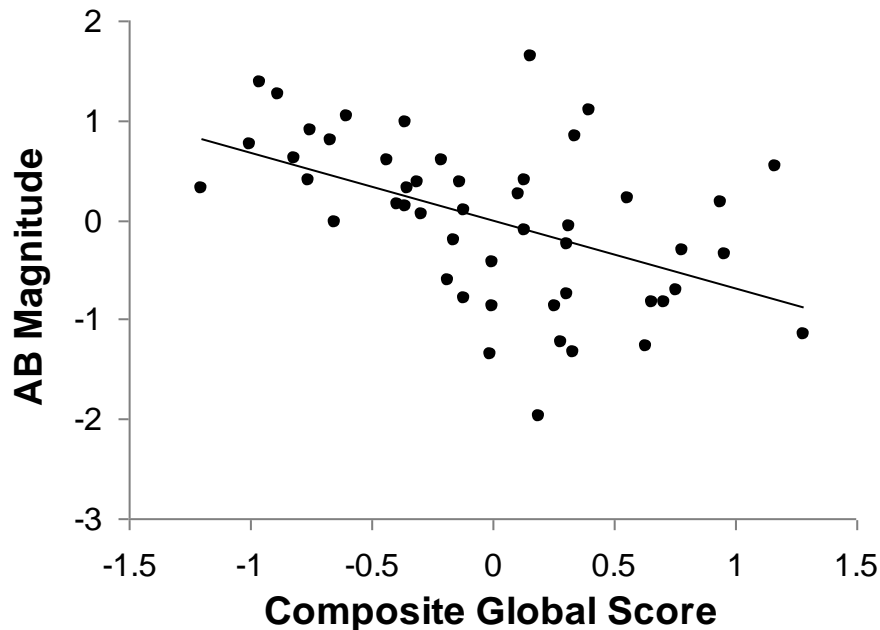


Figure 4-6. Scatterplot depicting a significant negative Pearson r correlation between the mean composite global score and combined AB magnitude.

As with Experiment 1, I then performed a median split 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, $t(47) = 3.11$, $p = .003$, $d = .89$, 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 Figure 4-7). There was a significant main effect of lag, $F(7, 329) = 132.80$, $p < .001$, $\eta_p^2 = .74$, but no main effect of high/low global score ($p = .16$). Importantly, however, there was a significant interaction between lag and high/low global score, $F(7, 329) = 2.58$, $p = .01$, $\eta_p^2 = .05$, indicating that AB magnitude differed depending on whether the participant had a high or a low global score. Indeed, Figure 4-7 shows that individuals with a high global score showed a smaller AB effect than did individuals with a low global score.

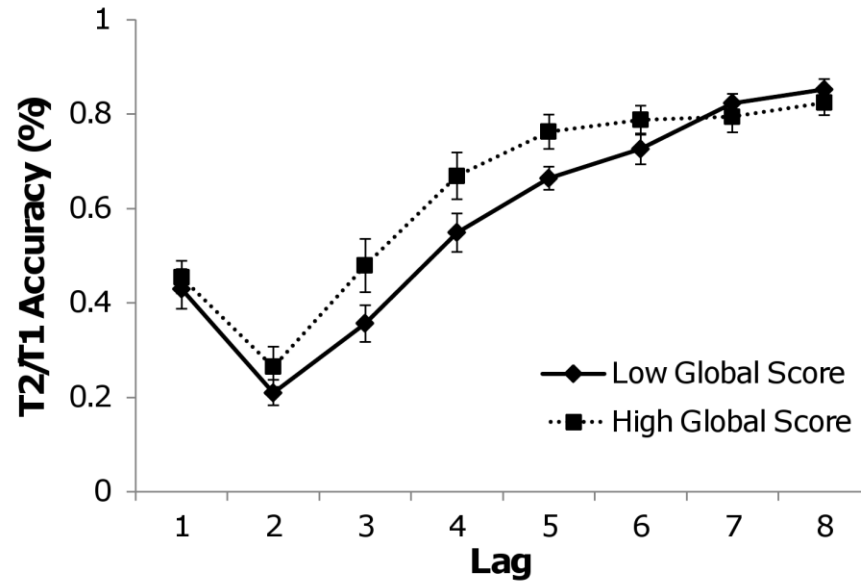


Figure 4-7. Mean T2 accuracy given T1 correct as a function of lag in the AB task for individuals with high and low composite global scores. Error bars represent the standard error for each condition mean.

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, the Navon letter task has been shown to be an unreliable measure of global/local processing (Dale & Arnell, 2013a; Chapter 3), 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. I 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 I 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 I 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 I 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, I 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, 2013; Chapter 2).

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 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 cognitive control over attentional resource deployment, (e.g., Di Lollo, Kawahara, Gorashi, & Enns, 2005; Olivers & Meeter, 2008;

Taatgen, Juvina, Schipper, Borst, & Martens, 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 distracters (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; Gaspar & 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 predict dual-task costs leads to the intriguing possibility that breadth of attention may also have implications for multi-tasking in everyday life. For example, might individuals who are dispositionally biased toward global information perform better on real-life tasks such as driving while talking on a cell phone, or attending to a lecture while monitoring for text messages? As these differences in global/local bias appear to be quite stable over time, and reliably predict performance on the AB task, it follows that these biases might influence performance on other tasks of selective attention.

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 behaviours 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 (See Chapter 5).

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.

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CHAPTER 5

Study 4: Lost in the forest, stuck in the trees: Dispositional global/local bias is resistant to exposure to high and low spatial frequencies¹

Abstract

Visual stimuli can be perceived at a broad, “global” level, or at a more focused, “local” level. While research has shown that many individuals demonstrate a preference for global information, there are large individual differences in the degree of global/local bias, such that some individuals show a large global bias, some show a large local bias, and others show no bias. The main purpose of the current study was to examine whether these dispositional differences in global/local bias could be altered through various manipulations of high/low spatial frequency. Through five experiments, I examined various measures of dispositional global/local bias and whether performance on these measures could be altered by manipulating previous exposure to high or low spatial frequency information (with high/low spatial frequency faces, gratings, and Navon letters). Ultimately, I was unable to show changes from pre-to-post manipulation on any of the dispositional measures, suggesting that individual differences in global/local bias or preference are relatively resistant to exposure to spatial frequency information.

¹ This chapter is based on the following article: Dale, G., & Arnell, K. M. (under review). Lost in the forest, stuck in the trees: Dispositional global/local bias is resistant to exposure to high and low spatial frequencies. PLOS ONE.

Introduction

Visual stimuli can be perceived at a broad, global level (e.g., “the forest”) or at a more focused, local level (e.g., “the trees”). This is referred to as “global/local processing”, and is commonly assessed through the use of compound stimuli (Navon, 1977). The most frequently used global/local stimuli involve compound letters known as “Navon letters” (Navon, 1977, 1981). Navon letters are large, single letters (representing the global perceptual level) that are comprised of smaller letters (representing the local perceptual level; see Figure 5-1a). The global and local elements can either be congruent (e.g., a large “T” comprised of smaller “T’s”), or incongruent (e.g., a large “T” comprised of small “S’s”; Navon, 1977). A typical Navon task presents a single compound Navon letter on each trial, and requires the participant to identify either the large, global letter, or the small, local letters, as quickly as possible. The response time (RT) for detecting a given target letter appearing at the global versus local level is sometimes compared (e.g., Gable & Harmon-Jones, 2008), but more often measures of global and local interference (i.e., the difference in RT from incongruent to congruent trials) are compared for local and global trials respectively. In addition to letter stimuli, variations in hierarchical stimuli have included shapes (Fredrickson & Branigan, 2005; Gasper & Clore, 2002; Kimchi & Palmer, 1982; see Figure 5-1b), digits (Evans, Shedden, Hevenor, & Hahn, 2000), and objects (Fink et al., 1997). Additionally, researchers have presented non-hierarchical hybrid high and low spatial frequency gratings (see Figure 5-1c) and faces (see Figure 5-1d; e.g., Dale & Arnell, 2013; Deruelle, Rondan, Salle-

Collemiche, Bastard-Rosset, & Da Fonséca, 2008; Hills & Lewis, 2008, 2009; Shulman, Sullivan, Gish, & Sakoda, 1986; Shulman & Wilson, 1987).

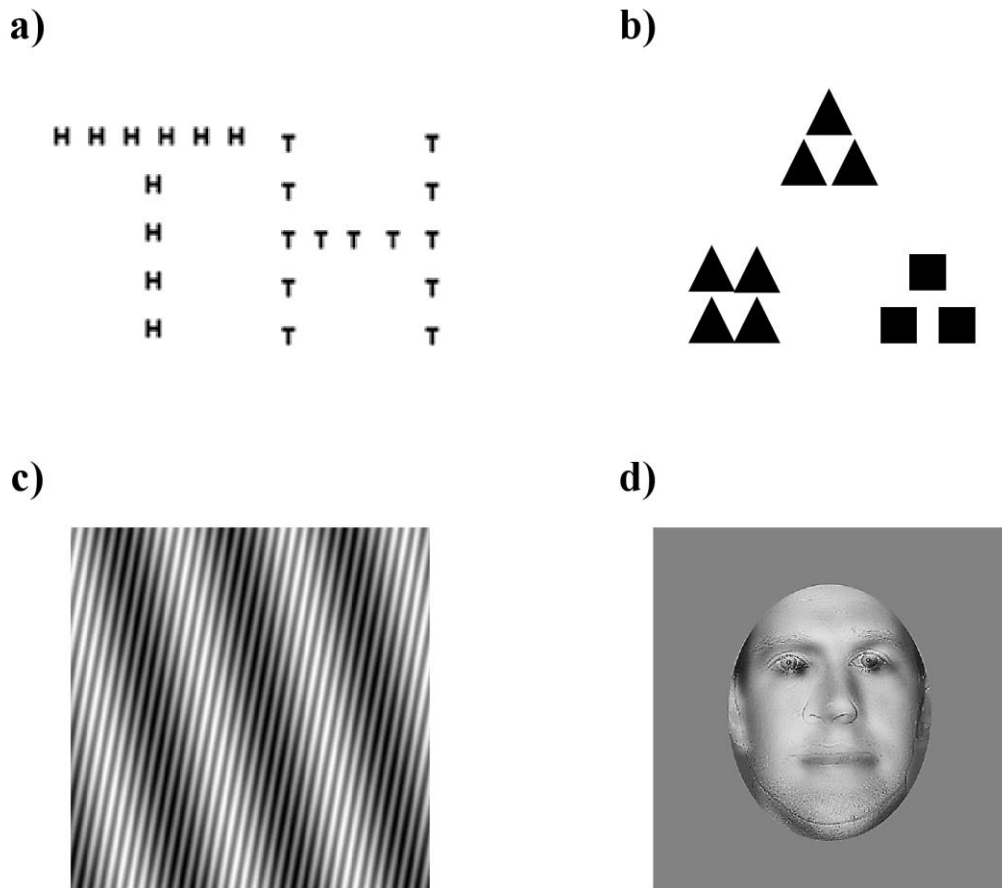


Figure 5-1. (a) *Traditional Navon letters*, (b) *hierarchical shapes*, (c) *hybrid high/low spatial frequency gratings* and (d) *hybrid high/low spatial frequency-filtered faces*

Global/local processing can also be assessed through the use of forced-choice, non-speeded tasks in which the global and local levels are pitted against each other, and the participant determines which level is attended (e.g., Kimchi & Palmer, 1982). For example, participants may be shown a square made of triangles and then asked to select either a triangle made of triangles or a square made of squares as the best representation of what they have just seen. Global or local preference is then assessed as the number of times a participant chooses the shape consistent with the global or local form.

Interestingly, some of the early studies of global/local processing have suggested that, although stimuli can be viewed at either level, there is an overall global processing advantage. That is, the global information tends to be processed faster, earlier, and there is typically more interference from the global level when focusing on the local level, as compared to the reverse (Navon, 1977). Additionally, when using a non-speeded forced-choice task, individuals as a whole are more likely to select or attend to the global figure, as compared to the local. This suggests that the processing of the coarse, global form of a stimulus takes precedence over the processing of the detailed, local parts (Navon, 1981). This phenomenon is referred to as the “global advantage” or the “global precedence effect”, and suggests that visual processing occurs in a coarse-to-fine manner. However, this global advantage is neither universal nor absolute, and can be altered in a myriad of ways.

One of the most commonly known ways of altering the global advantage is by changing the stimulus or task parameters in such a way as to make the global form less salient. For example, changes to the overall visual angle (Kinchla & Wolfe, 1979), the aspect ratio of the local to global items (Kimchi, 1992; Yovel, Yovel, & Levy, 2001), or the exposure duration (Paquet & Merikle, 1984) can reduce, or even eliminate, the global advantage. Additionally, there is clear evidence for level-repetition effects, such that individuals are faster to respond to a globally- or locally-directed trial if they were directed to the same level on the preceding trial (Hübner, 2000; Lamb & Yund, 1996; Lamb, London, Pond, & Whitt, 1998; Robertson, 1996; Ward, 1982; see also Shedden, Marsman, Paul, & Nelson, 2003). As such, global/local biases can clearly be manipulated or altered by simple task and stimulus changes.

Influencing Global/Local Bias

The degree of global or local bias within an individual can be influenced not only by the stimulus or task parameters, but also by individual characteristics and behaviours that are related to a broadened or narrowed attentional focus. For example, studies have suggested that positive affect may have a broadening effect on attention (Fredrickson, 2001) and negative affect a narrowing effect (Ashby & Isen, 1999). To examine the effect of negative affect on attentional breadth, Gasper and Clore (2002) induced one of three mood states (sad, happy, or neutral) by having participants recall a life event that corresponded to the assigned mood, prior to completing a forced-choice global/local preference task. Participants induced into a sad mood state had lower global scores than did the participants in the happy or neutral groups, and were also more likely to report making their choices in this task based on the local information, rather than the global. Conversely, Fredrickson and Branigan (2005) explored whether positive affect could influence attentional focus by using film clips to manipulate affective state. They found that induced positive mood states resulted in larger global scores on the same global/local preference task as used in Gasper and Clore (2002). These results taken together provide support for the idea that inducing positive and negative affective states can influence the degree of global or local bias. However, Gable and Harmon-Jones (2008, 2010) used a global/local task with compound stimuli and observed that, regardless of valence, induced affective states that were low in approach motivation (e.g., amusement, sadness) led to diffusion or broadening of attention, whereas induced states that were high in approach motivation (e.g., desire, disgust) led to a narrowing of attention (see Harmon-Jones, Price, & Gable, 2012 for a review).

In addition to broadening and narrowing attention through affect, global/local performance has been influenced using other tasks that are designed to broaden attentional scope. For example, Liberman and Förster (2009a) showed in three studies that participants who had been primed to think of the distant future, distant spatial locations, and distant social relationships were faster at responding to global Navon letters than individuals who had either not been primed, or who had been primed to imagine proximal distances, locations, and relationships. Another recent study showed that when individuals are asked to perform a task (such as solving anagrams or navigating a maze), and they are presented with “obstacles” (such as distracting background noises framed as obstacles to be overcome, or physical obstacles in the maze), they tend to broaden their attentional scope in order to discover a new path around the obstacle, and later show faster responses to global stimuli (Marguc, Förster, & Van Kleef, 2011).

Global/Local Bias Influencing Performance on Face Perception

While much of the research on global/local processing has focused on how global/local biases can be altered through changing task or stimulus parameters, or by inducing a positive or negative affective state, researchers have also focused on how an induced global or local state can influence performance on other tasks. One of the areas in which global/local processing has been shown to play a prominent role is in the study of face processing. Macrae and Lewis (2002) had participants watch a 30 sec. video of a simulated robbery, after which they viewed hierarchical Navon letters and reported the identity of the letter at either the global or local level for 10 minutes (control participants completed an unrelated filler task). After this induction task, participants viewed a lineup of 8 faces, which included the robber’s face, and were asked to identify the robber from

the initial video clip. Interestingly, the locally focused group showed impairments in face recognition, whereas the globally focused group showed enhancements in face recognition, relative to controls.

Perfect (2003) later replicated this effect, but had half of the participants perform first a global, and then a local, task, whereas the other group performed a local task first, followed by a global task. Whichever global/local level the participants attended to last influenced their face identification accuracy, such that participants who performed the global task last had enhanced face identification accuracy, whereas those who performed the local task last showed diminished face identification accuracy (relative to controls). Similarly, Hills and Lewis (2008) showed a reduction in face identification accuracy following the processing of the local elements of Navon letters, and also when biasing participants into a locally focused state using global/local shapes, such as diamonds and squares.

Weston and Perfect (2005) showed that inducing participants into a globally or locally focused state using a Navon letter task can influence performance on the composite face task. In the composite face task participants are presented with faces that consist of the top half of one identity and the bottom half of another identity, which are then combined into a single face (Young, Hellawell, & Hay, 1987). On some of the trials the face halves are aligned, and on some they are misaligned. Participants are instructed to identify whether or not the top or bottom face matches a previously studied face, as quickly as possible. Individuals are generally slower to make old/new identifications when the two face halves are aligned as compared to when they are misaligned. This is called the *composite face effect*, and is thought to occur because intact faces are

processed holistically. Specifically, aligning the face halves of two identities creates the impression of a novel face, rather than two individual face parts, which in turn slows recognition accuracy.

In the Weston and Perfect (2005) study, participants were given a global/local task in which they were either instructed to respond to only the local information (i.e., the local group), or the global information (i.e., the global group), and then complete a composite face task. Control participants performed a separate non-global/local task before the composite face task. Interestingly, the individuals who were in the local manipulation group were significantly faster at identifying whether a top or bottom face half was old or new on aligned trials as compared to both the global and control groups (who did not differ from each other), thus demonstrating that the local induction reduced the composite face effect. This suggests that a local processing style is useful for featural identification, whereas a global processing style is better for holistic identification (as with normal, intact faces). Gao, Flevaris, Robertson and Bentin (2011) showed a similar effect with the composite face task using a trial-by-trial manipulation, such that participants reported either the local or global level of a Navon stimulus immediately before completing a face trial.

Global stimuli contain mainly low spatial frequency information, whereas local stimuli carry mainly high spatial frequency information (see Shulman & Wilson, 1987). Some researchers also hypothesize that the spatial frequencies of the global/local stimuli, rather than the “globalness” or “localness” itself, might be contributing to effects such as those reported above. Indeed, Hills and Lewis (2009) showed that there was a large decrement in face recognition accuracy when faces were presented with only the high

spatial frequency information intact. In a similar study, Costen, Parker, and Craw (1996) showed a reduction in face identification accuracy and speed of detection when only spatial frequencies below 8 cycles/degree (low), or above 16 cycles/degree (high) were presented in the face image.

Global/Local Bias Influencing Performance on Other Tasks/Behaviours

In addition to face perception, studies have also examined the influence that global/local manipulations can have on a variety of other tasks. For example, individuals who have been induced into a globally biased state using Navon stimuli are better at detecting sarcasm (Wolfin, Corneille, & Yzerbyt, 2012), detecting similarities between dissimilar television shows (Experiment 1) and objects (Experiment 3b; Förster, 2009), self-regulating (Hanif et al., 2012), and at making basic and subordinate-level object discriminations from within similar distractors (Large & McMullen, 2006). They are also more likely to perceive atypical objects as normative (Förster & Denzler, 2012), make larger psychological distance estimates (Lieberman & Förster, 2009b), and are more accurate at judging the quality of paintings (Dijkstra, van der Pligt, van Kleef, & Kerstholt, 2012; Experiment 3), although they are also less empathetic (Wolfin, Corneille, Yzerbyt, & Förster, 2011; see Förster & Dannenberg, 2010 for a more exhaustive list). In general, a variety of cognitive processes can be influenced by global and local processing exposure.

Individual Differences in Global/Local Preference

The finding that global/local performance can be altered in a myriad of ways, and in turn can influence performance on other cognitive tasks, implies that global/local biases are dependent upon the tasks themselves, or the state of the participant during

testing. However, individuals also vary naturally in their degree of global/local bias. For example, individuals from remote cultures (Davidoff, Fonteneau, & Fagot, 2008) and musicians (Stoesz, Jakobson, Kilgour, & Lewycky, 2007) tend to show a local bias, and individuals who follow a religion that emphasizes individualism (i.e., Calvinism) show a smaller global precedence effect than do atheists or Catholics (Colzato et al., 2010). Similarly, individuals with disorders such as obsessive-compulsive disorder (Moritz & Wendt, 2006) and autism (Scherf, Luna, Kimchi, Minshew, & Behrmann, 2008) also tend to show larger local than global biases. There are also reported effects of age (Scherf, Behrmann, Kimchi, & Luna, 2009), and race (McKone et al., 2010) on global/local preference.

A recent study directly examined these individual differences in order to determine how stable dispositional global/local biases were over time (Dale & Arnell, 2013). Over two experiments, Dale and Arnell (2013) showed the dispositional global/local biases, as assessed by a traditional Navon letter interference task, the Kimchi and Palmer (1982) forced-choice shape task, and a forced-choice task with high/low spatial frequency hybrid faces (see Figure 5-1d; Deruelle et al., 2008), remained stable over a period of 7-10 days, suggesting that these individual differences are trait-like, and may reflect some default processing strategy. As such, it is clear that although global/local processing biases can be altered, or even manufactured, by altering stimulus and task parameters, individuals also show a large degree of variation person to person, and that this variation remains relatively stable over time. Additionally, these dispositional differences in global/local bias have been shown to relate to individual differences on other cognitive tasks, such as the attentional blink (see Chapter 4), which

suggests that not only do individuals vary in their preference for global or local information, but that this variation influences performance on other cognitive tasks.

The Current Study

It is clear that global/local processing biases can be altered by a variety of stimulus and task manipulations, as well as by manipulating the state of the participant. Additionally, global and local processing have been shown to influence performance on a variety of other non-global/local tasks, particularly tasks of face processing, presumably by biasing an individual's global/local disposition in the direction of the attended global or local level. Global/local processing has also been linked to spatial frequency, such that low spatial frequencies are linked to global processing and high spatial frequencies to local processing. To my knowledge, however, no study has yet examined whether exposure to global/local or high/low spatial frequency stimuli can temporarily alter an individual's dispositional global/local response bias (i.e., can viewing low spatial frequency information make one temporarily more global, or can viewing high spatial frequency information make one more local?). As such, the central purpose of the current study was to examine, through five different experiments, whether individual differences in dispositional global/local bias can also be temporarily altered through exposing participants to high/low spatial frequency information, and Navon letters. If dispositional biases cannot be altered, then it reinforces the idea that these biases are fixed and trait-like. However, if these biases *can* be altered, then that raises the interesting possibility that changing an individual's global/local bias, even temporarily, could also affect performance on other cognitive tasks and day-to-day behaviours. Therefore, it is worthwhile to examine whether these biases can be altered.

In order to manipulate spatial frequency in Experiments 1 and 2, I used two types of stimuli that, when attended, have previously been shown to influence performance on non-global/local tasks; presumably via changes in global/local processing bias. These stimuli are high/low spatial frequency faces (Experiments 1a and b) and high/low spatial frequency gratings (Experiments 1a and b). Dispositional biases were measured using the hierarchical shape task (Experiments 1a and 2a), and the Navon letter task (Experiments 1b and 2b) presented in Chapters 2 and 4. In addition, I used classic Navon stimuli (Experiment 3) to manipulate dispositional global/local biases as measured by the hierarchical shape task, and the dispositional high/low spatial frequency face task used in Chapters 2 and 4 (see Table 5-1 for a breakdown).

Introduction: Experiment 1a and 1b

Experiment 1a and 1b were designed to examine whether high/low spatial frequency faces can alter dispositional global/local biases as measured by a hierarchical shape task (Experiment 1a) and a Navon letter task (Experiment 1b). Spatial frequency faces were chosen for the manipulation task because, unlike traditional global/local measures, the high/low SF faces allow me to present participants with either the global or the local level in isolation. This ability is unique to these SF faces, which makes them an appropriate tool for biasing perceptual breadth. In particular, as no one has yet attempted to manipulate dispositional global/local biases, it seems prudent to use a manipulation task that does not expose participants to both global/local levels at once. Two different dispositional measures were used in order to examine pre/post manipulation biases both for a well-established measure of global/local processing bias (i.e., Navon letters in Experiment 1b) as well as a highly reliable measure of global/local bias (i.e., hierarchical

shapes in Experiment 1a). To examine the flexibility of dispositional global/local biases, participants were induced into both a global and a local state in two different blocks (counterbalanced). The dispositional measures were administered before and after the manipulation task in both blocks in order to examine post-manipulation differences in global/local bias.

Methods: Experiment 1a and 1b

Participants

A total of 74 Brock University undergraduate student volunteers participated in Experiment 1 for extra course credit: 46 participants (5 males) for Experiment 1a and 28 participants (3 males) for Experiment 1b. The participants ranged in age from 18 to 26 years ($M = 19.4$, $SD = 1.7$). All of the participants in this experiment, and in the following experiments, reported normal or corrected-to-normal vision and having learned English before the age of 8. All experiments were conducted one-on-one with each participant, and took approximately one hour to complete.

Apparatus

The computerized tasks in all of the experiments reported herein were presented using a Dell dual core desktop computer with a 17 inch CRT monitor, and were programmed and controlled using E-Prime software. The participants made responses via manual button-press on the computer keyboard.

Stimuli and Design

Dispositional Task for Experiment 1a: Global/Local Shapes. Participants in Experiment 1a completed this dispositional task, which was used to assess participants' degree of global or local bias, before and after each manipulation. For this paper-and-

pencil task, participants were presented with a booklet that contained global/local shape triads adapted from Kimchi and Palmer (1982) and Fredrickson and Branigan (2005).

The shape triads were composed of three different hierarchical shapes that were arranged with a standard shape on top, and two comparison shapes on the bottom (see Figure 5-2a). The participants were instructed to quickly circle the comparison shape that they felt best matched the standard shape for each of the triads. The participants were asked to complete this task as quickly as possible, and were told to use their first instinct when selecting the comparison shape.

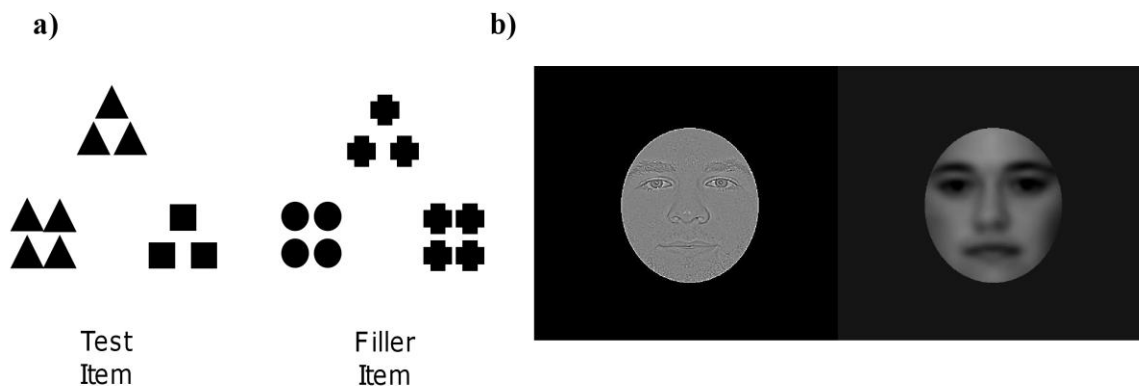


Figure 5-2. (a) Sample stimuli from the dispositional global/local shape task. (b) Sample stimuli from the global/local face manipulation task. A HSF (local) face on the left side and a LSF (global) face on the right.

The task contained 8 test triads and 16 filler triads that were intermixed, for a total of 24 triads. The hierarchical shapes in each test triad consisted of 3-4 small (5 x 5 mm) square or triangle shapes (local level) that formed a larger (15 x 15 mm) square or triangle (global level). For the test triads both comparison figures matched the standard figure, but one matched at the global level (i.e., the overall shape outline matched the standard), and one matched at the local level (i.e., the smaller, detailed shape matched the standard), counterbalanced for presentation location. The hierarchical shapes in each

filler triad were comprised of 3-4 small (5 x 5 mm) circles, squares, triangles, or crosses (local level) that formed a larger (15 x 15 mm) square or triangle (global level). For the filler triads, one of the comparison figures matched the standard shape at the global or local level, and the other did not match either level of the standard (location counterbalanced).

In order to obtain an index of global bias, the total number of test triads in which the global comparison shape was selected was calculated for each participant. This yielded a global score out of 8, where scores above 4 indicated a global bias, a score of 4 indicated a lack of preference for either the global or the local level, and scores below 4 indicated a local bias. Filler triads had only one correct response; therefore they were not used as an index of global/local bias.

Dispositional Task for Experiment 1b: Navon Letter Task. Participants in Experiment 1b completed this dispositional measure of global/local bias before and after each manipulation. Navon stimuli were created in Adobe Photoshop, and consisted of large, global letters constructed of smaller letters (e.g., an “H” made out of “T”s; see Figure 5-1a). The global letters (60 x 45 mm) were 10 times as large as the smaller local letters (6 x 4.5 mm), and it took roughly 10 local letters to make up a single global letter. A total of four different Navon letters were created, half of which were congruent (i.e., global T’s made of local T’s and global H’s made of local H’s), and half of which were incongruent (global T’s made of local H’s and global H’s made of local T’s). All of the letters were presented in black New Courier font on a white background, and the viewing distance was approximately 55 cm unrestrained.

Each trial began with a 500 ms central fixation cross, after which a single Navon stimulus was presented in the center of the computer screen for 15 ms. After the letter was presented, a blank response screen was displayed. Global and local trials were presented in alternating blocks, with 24 trials in each of 4 blocks for a total of 96 trials. 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. Participants were urged to respond as quickly and as accurately as possible. Response time (RT) was recorded. The letter combinations were randomly presented within each block, and each letter was presented 6 times within each block. All participants began with the global block.

RTs for incorrect trials and RTs that fell outside three standard deviations from the mean per condition per participant were removed. Global interference scores were then calculated for each participant by examining the degree to which global features on the local incongruent trials interfered with RT (local incongruent RT – local congruent RT)². High, positive global interference scores suggest a global processing bias, whereas low or negative global interference scores suggest either no global bias, or a local processing bias.

Manipulation Task: High/Low Spatial Frequency Faces. Whereas the participants from Experiments 1a and 1b completed different dispositional global/local tasks, both groups of participants completed the same manipulation task. In this task,

² While global interference was used here as the dependent measure, measures of global precedence (i.e., the difference between global and local interference) were also obtained and examined. In each of the experiments the same pattern of results was found whether using global interference scores or global precedence scores. The same findings for both measures provide further evidence that it is not simply the ability to overcome interference that cannot be manipulated, but actual global bias. However, as global precedence is calculated as the difference score of two difference scores, and is thus less reliable, it is not as clear whether the inability to manipulate these scores is because they are stable, or if it is simply because there is too much measurement error. Therefore, only global interference scores were presented here.

participants were presented with high spatial frequency (HSF) and low spatial frequency (LSF) filtered faces. Twenty-one male and 21 female normed young adult faces with neutral expressions were obtained from The Center for Vital Longevity Face Database (Minear & Park, 2004). The faces were cropped, converted to grayscale, and were pasted onto a 480 x 480 pixel dark grey background so that they subtended approximately 16° of visual angle with an unrestrained viewing distance of approximately 55 cm. A 215 x 275 pixel dark grey frame occluder was placed over each face to obscure the hair and ears. High and low spatial frequency faces were then constructed in Adobe Photoshop using these faces. High spatial frequency faces were constructed by using a high-pass filter in Photoshop, and contained only spatial frequencies higher than 6 cycles/degree of visual angle (i.e., a radius of 1.5 pixels). Low spatial frequency faces were constructed by using a Gaussian blur in Photoshop, and contained only spatial frequencies lower than 2 cycles/degree of visual angle (i.e., a radius of 4.5 pixels; see Figure 5-2b). As each face was made into both a high and a low spatial frequency face, a total of 42 HSF and 42 LSF faces were created.

Each trial began with a 500 ms blank grey screen, after which either a high or a low spatial frequency face (depending on the experimental block) appeared in the center of the screen. Participants were asked to indicate whether the face was male or female by pressing the corresponding key on the keyboard (“F” for female; “H” for male). The faces remained on the screen until the participant made a response, and participants were encouraged to respond as quickly as possible. Each participant performed a block of 496 randomized high spatial frequency trials, and a separate block of 496 randomized low spatial frequency trials, and each block took approximately 15 minutes to complete. An

equal number of male and female faces was shown for each spatial frequency block.

Accuracy was recorded to ensure that participants were performing the task appropriately.

Procedure

Both Experiment 1a and 1b consisted of two experimental blocks: a high spatial frequency (local) manipulation block and a low spatial frequency (global) manipulation block, the order of which was counterbalanced across participants. Each block began with the administration of either the global/local shape task (Experiment 1a) or the Navon letter task (Experiment 1b) in order to obtain a pre-manipulation measure of each participant's dispositional global/local bias. Participants from both experiments then completed the faces manipulation task with either the high or low spatial frequency stimuli. After completion of the first manipulation task, participants completed a second version of the dispositional global/local task, in order for me to examine any post-manipulation changes in global/local bias. Participants were then required to take a 5-minute break, during which they completed a maze task which was designed to reduce carryover effects from one block to the next (Finger, 2002). After the break, they completed the second experimental block which, like the first block, included a pre and post-test dispositional global/local task, and a manipulation task with the opposite spatial frequency to that used in the first block.

Analyses

For Experiments 1ab and 2ab, data for each of the dispositional tasks were first analyzed using a mixed-model ANOVA where high/low spatial frequency block and pre/post manipulation were within participants factors, and block order was a between

participant factor. In all cases, there were no main effects or interactions with block order, and the data were collapsed across this factor. In order to examine whether repeated exposure to high and low spatial frequency faces or gratings could influence dispositional global/local bias scores, these scores were entered into a 2 X 2 repeated measures ANOVA with high/low spatial frequency and pre/post manipulation as factors. Note that successful biasing of dispositional global/local bias scores in the direction of the manipulation would result in an interaction where post-manipulation global scores would become more global after the low spatial frequency exposure, and less global after the high spatial frequency exposure. The results of these ANOVAs are summarized in Table 5-1 for each experiment.

Results: Experiment 1a and 1b

Experiment 1a

For the face manipulation task, mean gender discrimination accuracy was .80 ($SD = .06$) for the high spatial frequency condition and .85 ($SD = .07$) for the low spatial frequency condition, indicating that participants were performing the task as instructed.

The mean global scores on the hierarchical shape task are shown in Figure 5-3a as a function of high/low spatial frequency and pre/post manipulation. A repeated measures ANOVA showed that there was no main effect of pre/post or manipulation frequency, and no significant interaction between frequency and pre/post, indicating that the global shape scores were not influenced by the manipulation tasks (see Table 5-1). Indeed, planned comparisons showed no significant pre- to post-change in global shape scores when using high or low spatial frequency faces as a manipulation, $t(45) = -0.84$, $p = .41$, $d = -.06$ and $t(45) = -1.31$, $p = .20$, $d = -.14$ respectively.

Experiment 1b

For the face manipulation task, mean gender discrimination accuracy was .80 ($SD = .06$) for the high spatial frequency condition and .84 ($SD = .08$) for the low spatial frequency condition, indicating that participants were performing the task as instructed. The means for the Navon letter task are presented in Figure 5-3bc. A 2 (high/low spatial frequency) X 2 (pre/post) ANOVA was performed on the global interference scores (see Figure 5-3d). The results showed no significant main effect of pre/post or manipulation frequency, and no interaction between these two variables (see Table 5-1). Additionally, planned comparison showed no significant difference between pre- and post-manipulation scores for either the high spatial frequency block, $t(27) = .89$, $p = .38$, $d = .22$, or for the low spatial frequency block, $t(27) = .13$, $p = .90$, $d = .03$. Importantly, if I examine local, rather than global, interference, I find no significant main effect of either manipulation frequency or pre/post (all p 's $> .36$), and no interaction between frequency and pre/post ($p = .99$). Additionally, if I instead examine overall global and local RT, rather than the interference measure used here, I find no significant interactions among manipulation frequency, stimulus level (global/local), and pre/post manipulation RT (all p 's $> .10$). Therefore, these findings are not due to using an interference measure, rather than an overall RT measure.

Table 5-1.*Manipulation tasks, dispositional tasks, and ANOVA results for each experiment.*

Experiment	Manipulation	Dispositional	Main Effect Pre/Post	Main Effect SF	Interaction
1a	High/Low Faces	Paper Shape	$F(1, 44) = 2.66$ $p = .11$ $\eta_p^2 = .06$	$F(1, 44) = 0.26$ $p = .61$ $\eta_p^2 < .01$	$F(1, 44) = 0.15$ $p = .70$ $\eta_p^2 < .01$
1b	High/Low Faces	Navon Letters	$F(1, 26) = 0.92$ $p = .35$ $\eta_p^2 = .03$	$F(1, 26) = 0.46$ $p = .50$ $\eta_p^2 = .02$	$F(1, 26) = 0.28$ $p = .61$ $\eta_p^2 = .01$
2a	Hi/Low Gratings	Paper Shape	$F(1, 43) = 0.43$ $p = .52$ $\eta_p^2 = .01$	$F(1, 43) = 0.65$ $p = .42$ $\eta_p^2 = .01$	$F(1, 43) = 0.30$ $p = .58$ $\eta_p^2 = .01$
2b	Hi/Low Gratings	Navon Letters	$F(1, 22) = 1.01$ $p = .33$ $\eta_p^2 = .04$	$F(1, 22) = 0.14$ $p = .72$ $\eta_p^2 = .01$	$F(1, 22) = 4.03$ $p = .06$ $\eta_p^2 = .15$
3	Navon Letters	Paper Shape	$F(1, 22) = 0.01$ $p = .92$ $\eta_p^2 < .01$	$F(1, 22) = 0.01$ $p = .97$ $\eta_p^2 < .01$	$F(1, 22) = 0.09$ $p = .76$ $\eta_p^2 < .01$
		Faces	$F(1, 22) = 0.71$ $p = .41$ $\eta_p^2 = .03$	$F(1, 22) = 0.09$ $p = .77$ $\eta_p^2 < .01$	$F(1, 22) = 2.34$ $p = .14$ $\eta_p^2 = .10$

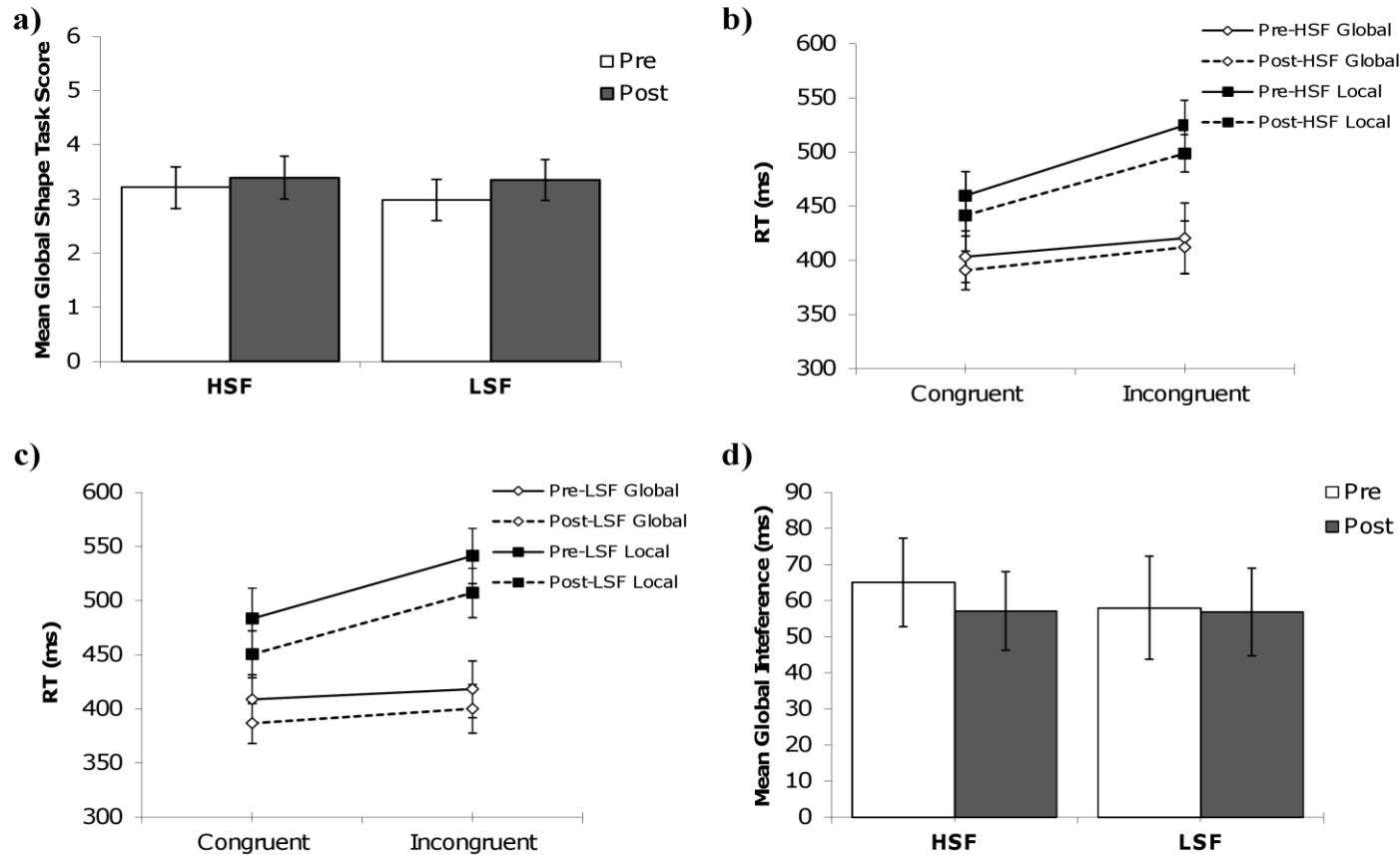


Figure 5-3. (a) Experiment 1a mean pre- and post-manipulation global shape task scores as a function of manipulation frequency (HSF or LSF faces). (b) Experiment 1b mean RTs on the Navon letter task, as a function of pre- and post-manipulation, stimulus level (global or local), and target congruency in the HSF condition and (c) in the LSF manipulation condition. (d) Experiment 1b mean pre-and post-manipulation global Navon interference scores as a function of viewing LSF or HSF faces in the manipulation task. Error bars in this and all other figures represent the standard error for each condition mean.

Pre/Post Correlations

Importantly, the global scores on the hierarchical shape task were not simply random, but appeared to be reliable measures of an individual's global bias over time. Indeed, Experiment 1a pre- and post-manipulation global shape scores correlated .86 and .72 for the high and low spatial frequency manipulation conditions respectively, indicating that the global score on the hierarchical shape task is a reliable measure of dispositional global/local bias and that individual differences are stable within a single test session. The Navon letter task scores, however, were less reliable such that pre-and post-manipulation global interference scores for the low spatial frequency condition were correlated .43, whereas the correlation between pre/post interference scores for the high spatial frequency condition were not significantly correlated ($r = .17$). This is similar to the reliability scores found by Dale & Arnell (2013) for this particular task across 1 week.

Discussion: Experiment 1a and 1b

In this experiment, I was unable to effectively manipulate individuals' global/local processing, as measured by the global shape task (Experiment 1a), and the Navon letter task (Experiment 1b), by exposing participants to high/low spatial frequency faces. This suggests that dispositional global/local biases may be resistant to very recent exposure to spatial frequency information. However, it is possible that the face manipulation task itself was not appropriate for evoking change in attentional breadth. Although participants were required to view high and low spatial frequency faces, they were not necessarily required to focus on the frequency information itself in order to make a face-gender judgment. Indeed, as face processing is done in a holistic manner, it is possible that participants used a global processing strategy for both the low and high

spatial frequency conditions in order to make their judgment. As such, this may have prevented the participants from being adapted to the high and low spatial frequencies during this task. Therefore, I conducted Experiment 2 in which participants were presented with a more “pure” spatial frequency task, in which they were required to view high/low spatial frequency gratings. In this task, participants are required to direct their attention to the gratings themselves, and make judgments about the orientation of the lines within the gratings. This requires the participants to use, and adapt to, the spatial frequency for each condition in order to actually perform the task.

Methods: Experiment 2a and 2b

Participants

A total of 69 Brock University undergraduate student volunteers participated in Experiment 2 for extra course credit: 44 participants (11 males) for Experiment 2a, and 25 participants (4 males) for Experiment 2b. The participants ranged in age from 18 to 22 years ($M = 18.7$, $SD = 1.43$).

Stimuli and Design

The participants in Experiment 2a completed the same dispositional task as in Experiment 1a (i.e., the global/local shape task), whereas the participants in Experiment 2b completed the same dispositional task as in Experiment 1b (i.e., the Navon letter task). For the manipulation task, however, participants from both Experiment 2a and 2b completed a high/low spatial frequency grating task.

Manipulation Task: High/Low Spatial Frequency Gratings. Participants in Experiment 2a and 2b completed a manipulation task in which they were presented with high and low spatial frequency gratings. The gratings were created using online software developed by Sebastiaan Mathôt (Mathôt, 2010). All of the grating stimuli were 480 x 480 pixels in size, were presented at 100% contrast, and subtended approximately 6.6° of visual angle with an unrestrained viewing distance of approximately 55 cm. The gratings were either 7.2 cycles/degree (10 pixels/cycle) for the high spatial frequency gratings, or .76 cycles/degree (1 pixel/cycle) for the low spatial frequency gratings. The gratings were tilted in 1 of 6 orientations: 10° (slight right), 45° (moderate right), 80° (extreme right), 280° (extreme left), 315° (moderate left), or 350° (slight left; see Figure 5-4). Therefore, there were 6 high spatial frequency and 6 low spatial frequency gratings generated for a total of 12 gratings.

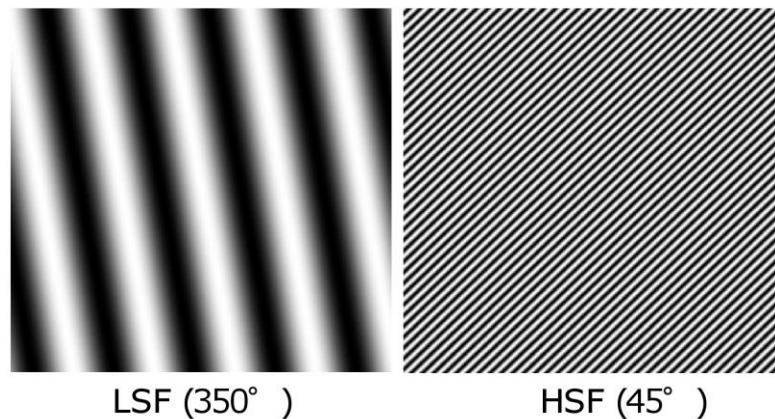


Figure 5-4. Sample stimuli from the SF grating manipulation task. The grating on the left is a LSF (global) grating with a 350° tilt, whereas the one on the right is a HSF (local) grating with a 45° tilt.

Each trial began with a 500 ms blank gray screen, after which either a high or low spatial frequency grating (depending on the experimental block) appeared in the center of the screen. Participants were required to indicate the direction in which the bars were

leaning by pressing one of 6 labeled keys on the keyboard (3 =extreme left, 4 = moderate left, 5 = slight left, 7 = slight right, 8 = moderate right, and 9 = extreme right). The gratings remained on the screen until the participant made a response, and the participants were encouraged to respond as quickly and as accurately as possible. The high and low spatial frequency grating blocks each contained 300 randomized trials, and took approximately 10 minutes to complete. Accuracy on this task was measured to ensure that participants were performing the task as instructed.

Procedure

The procedure for Experiment 2 was the same as in Experiment 1, with the exception that participants now completed the high/low spatial frequency grating manipulation task, rather than the face manipulation task used in Experiment 1a.

Results: Experiment 2a and 2b

Experiment 2a

Mean orientation discrimination accuracy for the high spatial frequency grating manipulation task was .77 ($SD = .23$), and the mean accuracy for the low spatial frequency grating manipulation task was .81 ($SD = .22$), indicating that participants were attending to the gratings during the manipulation task.

The mean global shape scores are presented in Figure 5-5a as a function of high/low spatial frequency and pre/post manipulation. As with Experiment 1a, a repeated measures ANOVA showed no main effect of manipulation frequency or pre/post, and no significant interaction between these variables (see Table 5-1). Planned comparisons showed no significant difference in global shape scores from pre- to post-manipulation

when using high or low spatial frequency gratings as a manipulation, $t(43) = -0.62$, $p = .54$, $d = -.06$, and $t(43) = 0$, $p = 1.0$, $d = 0$ respectively.

Experiment 2b

Mean orientation discrimination accuracy for the high spatial frequency grating manipulation task was .77 ($SD = .21$), and the mean accuracy for the low spatial frequency grating manipulation task was .83 ($SD = .15$), indicating that participants were attending to the gratings during the manipulation task.

The means for the Navon task are presented in Figure 5-5b and c. A 2 (HSF/LSF) X 2 (pre/post) ANOVA was performed on the global interference scores (see Figure 5-5d). The results again showed no significant main effect of either manipulation frequency or pre/post and no interactions, although the interaction did approach significance and the means did show the predicted pattern of effects (see Table 5-1). Finally, planned comparisons showed no significant difference between pre- and post-manipulation scores in the low spatial frequency block, $t(24) = 1.14$, $p = .27$, $d = -.31$, but there was a marginally significant difference between the pre- and post-manipulation scores in the high spatial frequency block, $t(23) = 2.07$, $p = .05$, $d = .56$. As with Experiment 1, if I instead examine local, rather than global, interference, I find no significant main effect of either manipulation frequency or pre/post (all p 's $> .35$), and no interaction between frequency and pre/post ($p = .72$). Additionally, if raw global and local RT scores are instead used, I find no significant interactions among manipulation frequency, stimulus level (global/local), and pre/post manipulation RT (all p 's $> .07$). Therefore, these findings are not due to using an interference measure, rather than an overall RT measure.

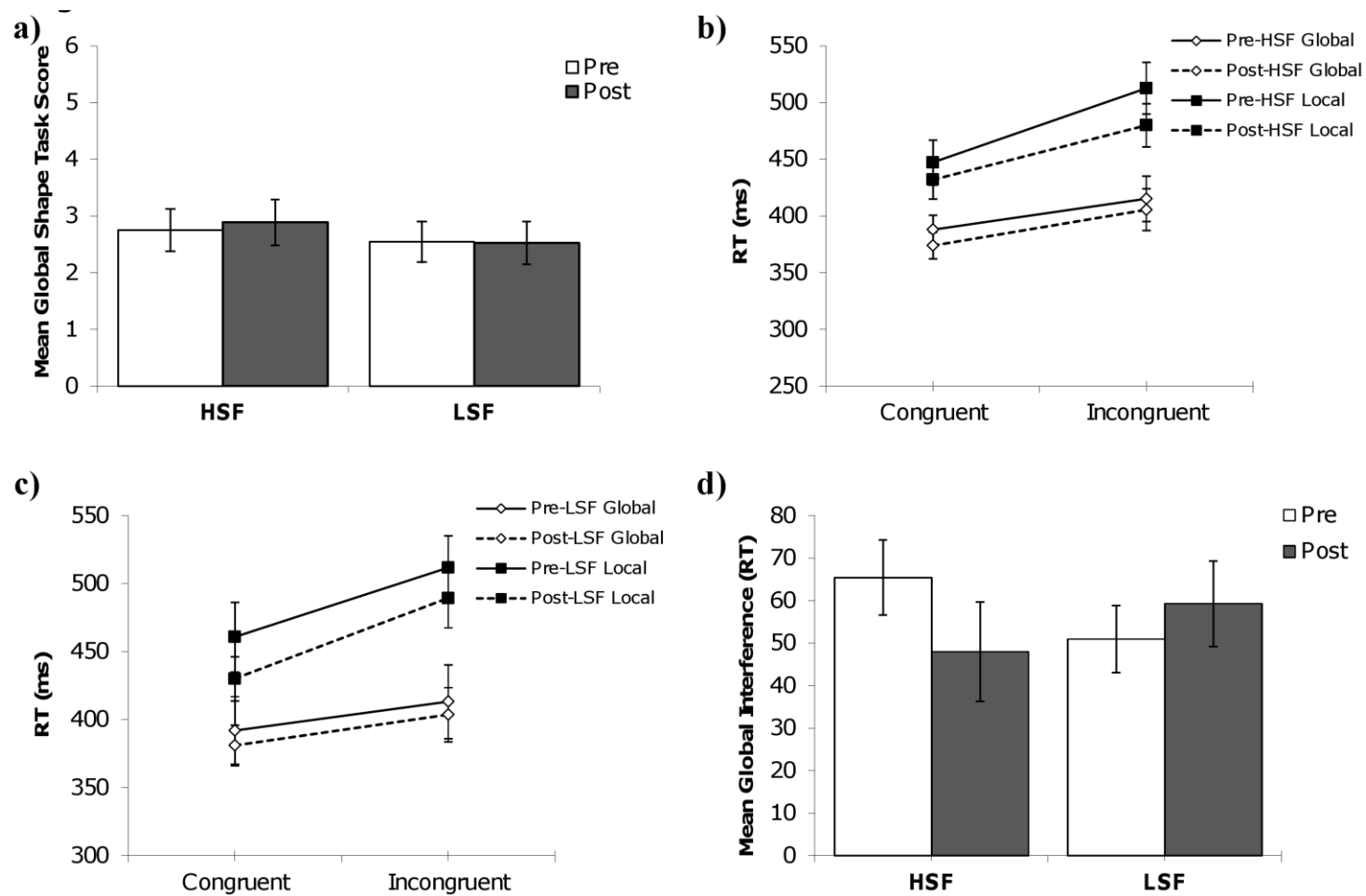


Figure 5-5. (a) Experiment 2a mean pre- and post-manipulation global shape task scores as a function of viewing LSF or HSF gratings in the manipulation task. (b) Experiment 2b mean RTs on the Navon task, as a function of pre- and post-manipulation, stimulus level (global or local), and target congruency in the HSF condition and (c) in the LSF manipulation condition. (d) Experiment 2b mean pre- and post-manipulation global Navon interference scores as a function of viewing LSF or HSF gratings in the manipulation task.

Pre/Post Correlations

Finally, I examined the correlation between the pre-and post-manipulation scores for each of the dispositional tasks, for each manipulation condition. The mean correlation between the pre-and post-manipulation global shape scores in Experiment 2a was .72 for the high spatial frequency condition, and .86 for the low spatial frequency condition. This shows a high degree of correspondence between the global shape scores before and after each manipulation, indicating that this task is a reliable measure of global bias. In Experiment 2b, however, the global interference scores were not significantly correlated for either the high ($r = .03$) or low spatial frequency ($r = .09$) conditions.

Discussion: Experiment 2a and 2b

As with Experiment 1, I was again unable to successfully alter global/local biases, as measured by the global shape task (Experiment 2a) and the Navon letter task (Experiment 2b), by exposing individuals to high/low SF gratings. Therefore, it can be concluded that, when assessed by a dispositional shape task or Navon letters, dispositional global/local bias is resistant to exposure to very recent spatial frequency information, at least when using high/low spatial frequency faces and gratings as manipulation tools.

I did, however, find a small, marginally significant, difference in the pre-post-manipulation global interference scores for the high spatial frequency manipulation condition in Experiment 2b, accompanied by the numerically opposite pattern for the low spatial frequency condition, although with no significant interaction. It is possible that it was not coincidental that this expected pattern was observed in the only experiment where the dispositional global pre and post measures were not significantly correlated

(Experiment 2b). It may be that the global/local changes induced by the manipulation simply ruin the correlation across pre/post. However, a more interesting possibility is that there is more potential to show a change in dispositional global/local processing with the Navon letter task than with the shape task, given that global interference on the Navon letter task is less of a trait variable than global scores in the shape task. Indeed, this speculation would fit with the results of Dale and Arnell (2013) who showed high correlations in individual global shape scores across more than a week ($r = .80$), but lower, albeit significant, correlations for the Navon letter task across more than a week (r 's of .27 to .31). However, in Experiment 1b, the interaction between pre/post and manipulation frequency was non-existent despite fairly low pre/post correlations for the Navon letter task.

It is clear from these findings that dispositional global/local biases are difficult to alter, at least when using high/low spatial frequency stimuli as a manipulation tool. One potential limitation of the above findings, however, is that the global/local manipulations were all completed within-subjects, such that I attempted to bias participants into both a global *and* a local state. Despite finding no consistent effects of block order, it is possible that carryover effects from the within design somewhat limited my ability to alter dispositional global/local bias. As such, I conducted a third experiment using a between-subjects design, such that some participants were biased with local stimuli and some with global.

Additionally, while the main purpose of this study was to determine whether exposure to high/low spatial frequency information could alter dispositional biases, many previous studies (e.g., Förster, 2009; Macrae & Lewis, 2002; Perfect, 2003; Weston &

Perfect, 2005) have used traditional Navon letters to bias participants, rather than the face or grating tasks previously employed in my experiments. As such, it is possible that my inability to influence dispositional global/local biases is the result of using SF manipulations, rather than being due to the fact that global/local biases are resistant to change. Therefore, I used traditional Navon letter stimuli, rather than faces or gratings, as my manipulation task for Experiment 3. Finally, I included a second measure of dispositional global/local bias, as it is possible that the lack of effect found in the previous experiments was due to the shape and Navon tasks not being sensitive enough to dispositional changes. This second measure was the high/low spatial frequency face task previously used in Dale and Arnell (2013), adapted from Deruelle et al. (2008).

Methods: Experiment 3

Participants

Twenty-four (2 male) Brock University student volunteers participated in this experiment for extra course credit. Participants were randomly assigned to either the global manipulation group ($N = 12$) or the local manipulation group ($N = 12$). Participants ranged in age from 18 to 22 years ($M = 19.9$, $SD = 1.2$).

Stimuli and Design

Dispositional Tasks: Shapes and Faces. All participants completed the same dispositional shape task used in Experiment 1a and 2a. In addition, participants completed a second dispositional task that used high/low spatial frequency face stimuli.

The high and low spatial frequency faces used in the Experiment 1 manipulation task were used to create high/low hybrid faces for the dispositional face task. These hybrid faces were created by taking the high spatial frequency version of one face and

superimposing it over the low spatial frequency version of another face (matched for gender). Each face contributed high spatial frequency information to one hybrid face, and low spatial frequency information to another hybrid face, thus a total of 42 hybrid faces were constructed (see Figure 5-1d for a sample hybrid face).

Each trial began with a 1000 ms blank screen, after which a hybrid face appeared for 300 ms in the center of the screen. The hybrid face was then replaced with the two original (unfiltered) faces that had comprised the hybrid face (i.e., the face that contributed the high spatial frequency information, and the face that contributed the low spatial frequency information). One of the unfiltered faces was presented on the left side of the screen, and one on the right (counterbalanced). Participants were instructed to indicate which unfiltered face best matched the hybrid face by pressing the corresponding key on the keyboard. The unfiltered faces remained on the screen until the participant made a response, and participants were encouraged to go with their first instinct and to not over-think their response. There were a total of 42 randomized trials, and the task took approximately 5 minutes to complete.

In order to calculate dispositional global/local bias, I totaled the number of trials out of 42 in which the participant chose the unfiltered face that had contributed low spatial frequency (global) information to the hybrid. This total represented an index of each participant's dispositional global bias, such that high global face scores indicated a global processing bias, and low global face scores indicated a local processing bias.

Manipulation Task: Global or Local Navon Letters. The Navon letter manipulation task was adapted from the traditional Navon interference task described in Study 1b and 2b. Navon stimuli were again created in Adobe Photoshop, but they were

created differently depending on whether they were to be used in the global or local manipulation condition. For the global manipulation condition, the global letters (35 x 25 mm) were 10 times as large as the local letters (3.5 x 2.5 mm), and it took roughly 20 local letters to make up a single global letter. This resulted in dense, small Navon letters that were globally salient. Conversely, the letters for the local manipulation condition consisted of global letters (65 x 45 mm) that were 10 times as large as the local letters (6.5 x 4.5 mm). Approximately 9-12 local letters were used to make up each global letter, resulting in very sparse, large stimuli that were locally salient. A total of six different Navon letters (made of H's, T's, and F's) were created for each manipulation task, all of which were incongruent. All of the letters were presented in black New Courier font on a white background, and the viewing distance was approximately 55 cm unrestrained.

For the global manipulation task, each trial began with a 1000 ms fixation cross, after which a single Navon letter appeared in the center of the screen for 15 ms. The letter then disappeared and was replaced with a blank response screen. Participants were asked to indicate what the large, global letter was as quickly as possible by pressing the corresponding key on the keyboard ("H", "T", or "F"). The letters were presented in a random order, and each letter was presented 80 times for a total of 480 trials. RT and accuracy were recorded to ensure that participants were completing the task appropriately and were following directions.

The local Navon manipulation task was very similar, with the following exceptions. First, the stimuli were presented on the screen for 175 ms, rather than 15 ms, in order to give the participants the chance to better view the local letters. Second,

participants in this group were asked to indicate what the small, local letters were, rather than the global letters.

Procedure

At the beginning of the experiment, all participants completed the shape and face dispositional tasks, in order to provide me with an estimate of their pre-manipulation dispositional bias. They then completed one 480 trial block of either the global or the local manipulation task (depending on the group to which they had been assigned). After the first manipulation block, all participants completed a post-manipulation dispositional shape task. Next, participants completed a second 480-trial block of either the global or local manipulation task (reporting the same level as in the first manipulation block). Finally, participants completed a post-test dispositional face task.

Results: Experiment 3

For the local manipulation group, mean accuracy for the first manipulation block was .96 ($SD = .04$) and accuracy for the second manipulation block was .96 ($SD = .04$). For the global manipulation group, mean accuracy for the first manipulation block was .96 ($SD = .04$) and accuracy for the second manipulation block was .96 ($SD = .03$). Therefore, the participants were performing the manipulation task as instructed, and with little difficulty.

The means from the dispositional tasks are presented in Figure 5-6a (global shape scores) and Figure 5-6b (global face scores) as a function of pre/post and the assigned Navon level during the manipulation task. For each of the dispositional tasks, a 2 X 2 mixed model ANOVA was conducted with pre/post manipulation task as a within participants factor, and local/global level as a between participants variable. For the

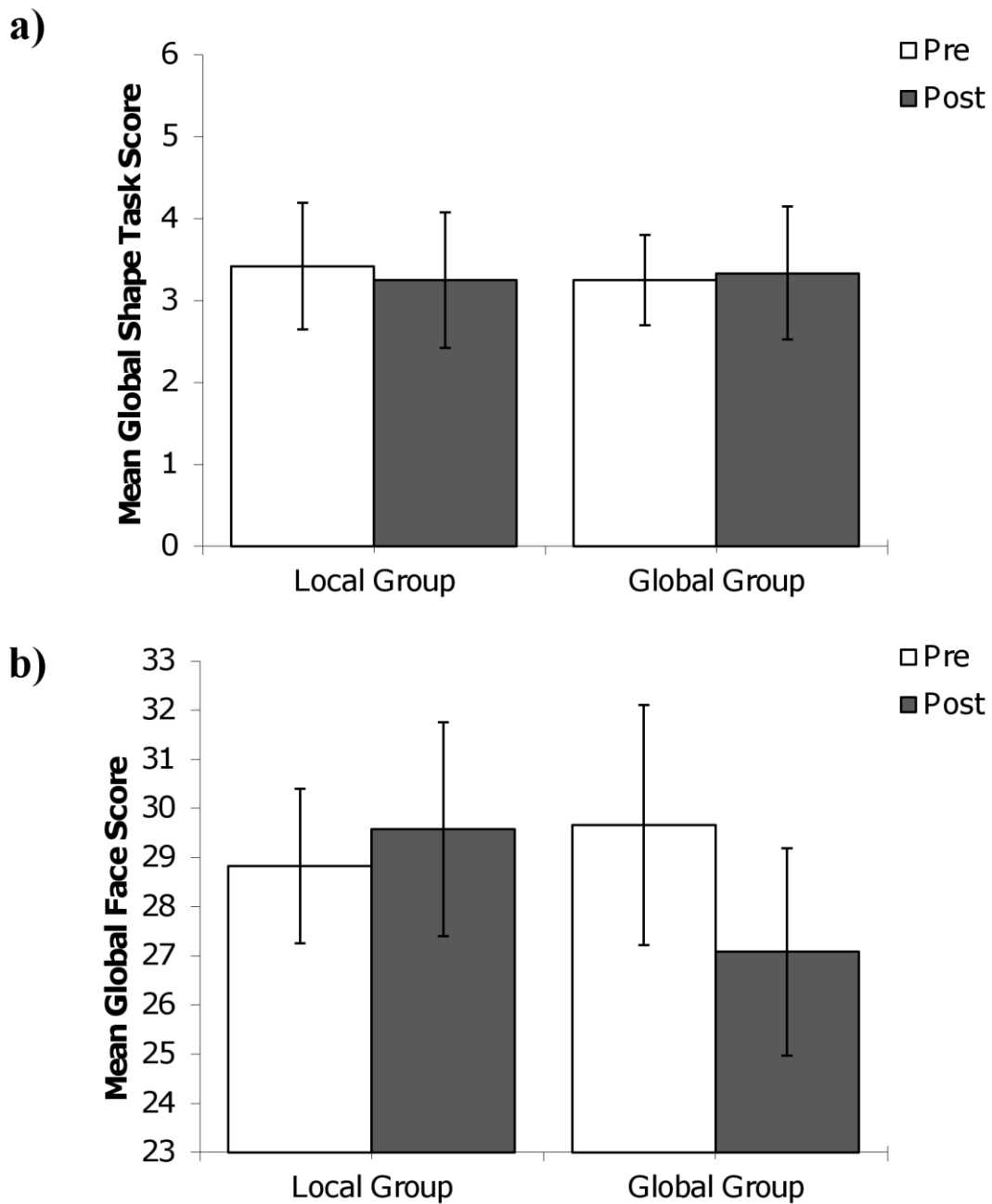


Figure 5-6. (a) Experiment 3 mean pre- and post-manipulation global shape task scores as a function of Navon task manipulation group (global or local). (b) Experiment 3 mean pre- and post-manipulation global face scores as a function of Navon task manipulation group (global or local).

global shape task, results showed no significant main effect of either pre/post manipulation or local/global level, and no interaction between pre/post and local/global (see Table 5-1). Planned comparisons using paired-samples t-tests showed no significant difference between pre- and post-manipulation global shape scores for the local level, $t(11) = .46, p = .66, d = .06$, or the global level, $t(11) = .11, p = .91, d = -.03$.

For the face task, the ANOVA results again showed no significant main effect for pre/post manipulation or local/global level, and no interaction (see Table 5-1). Indeed, although the p-value for the interaction approached significance ($p = .14$), the pattern of means was the opposite of the predicted direction. There was no significant difference between pre- and post-manipulation face scores for the local level, $t(11) = .53, p = .61, d = -.09$, or the global level, $t(11) = 1.57, p = .15, d = .39$. Overall, it is clear that the manipulation task did not significantly alter dispositional global bias as measured by the shape or face tasks.

Finally, the correlations between pre- and post-manipulation scores on the shape and face tasks were examined. For the local group, pre- and post-manipulation shape task scores were correlated .90, whereas pre and post face task scores correlated .81. The correlations between pre- and post-manipulation scores were smaller in the global group, such that the shape task scores were correlated .47, and the face task scores correlated .66.

Discussion: Experiment 3

The purpose of Experiment 3 was to rule out the possibility that the findings from the previous two experiments were simply due to the within-subjects design that I had employed. Additionally, I was also interested in seeing if the use of traditional Navon

letters could effect change in global/local bias, as the previous manipulation tasks (faces and gratings) presented the participant with high/low SF information, rather than hierarchical stimuli. However, I was still unable to find a change from pre- to post-manipulation in either the global or the local manipulation group in this experiment. I have now shown the same pattern of null results using hierarchical shapes/faces/Navon letter tasks as dispositional global/local bias measures, and when using faces/gratings/Navon letters as manipulation tasks. This shows that my non-significant results are unlikely to be due to the type of dispositional measure, or the type of manipulation. This again suggests that dispositional global/local biases are somewhat stable and resistant to change, and that the null findings were not simply due to using spatial frequency manipulations.

General Discussion

It is well documented that global/local performance can be altered through the use of task or stimulus manipulations (e.g., Kimchi, 1992; Kinchla & Wolfe, 1979; Paquet & Merikle, 1984), or through the use of an external, non-global/local task (e.g., Fredrickson & Branigan, 2005; Gable & Harmon-Jones, 2008; Gasper & Clore, 2002; Marguc et al., 2011). The purpose of the present study was to investigate whether dispositional biases could be changed by exposing individuals to high/low spatial frequencies (Experiments 1 and 2), or global/local forms (Experiment 3).

Through a series of five experiments, I measured dispositional global/local bias with a hierarchical forced-choice shape task (Experiments 1a, 2a, and 3), a traditional Navon letter task (Experiments 1b and 2b), and a high/low spatial frequency face task (Experiment 3). To manipulate global/local biases, I used high/low spatial frequency

faces (Experiment 1), high/low spatial frequency gratings (Experiment 2), and Navon stimuli (Experiment 3). In 4 of 5 experiments I was unable to show significant differences in global bias following a manipulation. In general, the results suggest that dispositional global/local biases are stable across time, and resistant to recent attention to high or low spatial frequency information.

Although I was unable to influence dispositional global/local biases in almost all of my attempts, I did find significant differences in global scores following the manipulation task in Experiment 2b. In Experiment 2b there were significant differences from pre- to post-manipulation Navon global interference scores following the high spatial frequency grating manipulation (but not the low spatial frequency), and the interaction between pre/post and manipulation frequency approached significance for the Navon task. Although Experiment 2b provides rather weak evidence that Navon interference scores can be modulated by previous viewing of high/low spatial frequency gratings, if the finding is indeed real, why did the predicted pattern appear for only this one experiment? One consideration is that in this experiment I used the traditional Navon letter task as a dispositional measure. Previous research has shown that although the dispositional face and shape global/local tasks used here are remarkably stable over time (test-retest correlations of .70 or greater from two sessions held over one week apart), and are good individual differences measures, the Navon task is a much less reliable measure with test re-test correlations approximating .30 (Dale & Arnell, 2013). As such, it is possible that the Navon task is more open to transient state influences, and therefore was better able to capture pre-to-post manipulation changes in dispositional biases, whereas the forced choice face and shape tasks may be better measures of stable trait-like biases.

Indeed, much of the work showing that global/local bias can be modulated has used Navon stimuli. For example, RTs on the Navon task can be altered by having participants perform simple tasks, such as estimating distances (Lieberman & Förster, 2009a) or navigating obstacles in a maze (Marguc et al., 2011). Navon RTs can also be altered by inducing participants into an affective state that is high in approach motivation (Gable & Harmon-Jones, 2008). As such, the Navon task may capture more flexible global/local states, and this may partially explain why I was unable to show an effect of SF manipulation in most of my experiments. However, this pattern of results was not found for Experiment 1b, which used the same dispositional Navon measure. In addition, induced positive (Fredrickson & Branigan, 2005) and negative (Gasper & Clore, 2002) affect has been shown to modulate scores on the hierarchical shape task used here, which shows that it is not just Navon performance that can be modulated.

A second consideration is that the primary purpose of the current experiment was to examine whether exposure to high and low spatial frequencies could alter dispositional global/local bias, thus two out of the three manipulation tasks used in this experiment were spatial frequency tasks. Although spatial frequencies have been linked to global/local processing (Shulman & Wilson, 1987), they are not necessarily global or local in and of themselves (Sierra-Vázquez, Serrano-Pedraza, & Luna, 2006). Indeed, Lamb and Yund (1993) showed that the removal of low SFs can *slow* global processing, but does not eliminate global biases, nor does it affect the ability to switch attention from global to local forms. As such, although the face and grating manipulations have been used to influence performance on other tasks that have been linked to global/local processing (such as face identification), and high or low spatial frequency information in

a given stimulus can facilitate global or local processing for that stimulus, consistent exposure to, or attention toward, information of high or low spatial frequency may not be sufficient to alter subsequent global/local biases. It is possible, then, that exposing participants to actual global/local stimuli could alter their global/local biases. However, I found no effect on dispositional biases when I exposed participants to global and local Navon letters in Experiment 3.

A third consideration is that, in all cases, the dispositional measures and manipulation tasks contained different global/local stimuli. A recent study showed that although the three dispositional measures used here (Navon letter interference, hierarchical shape choice, high/low SF face choice) are reliable over time, they are uncorrelated with each other, suggesting that they measure unique aspects of global/local processing (Dale & Arnell, 2013). This suggests that manipulating global/local biases with a completely different type of task may not be effective, as the dispositional and manipulation tasks are unrelated. For example, global/local biases that are measured by the hierarchical shape task may be immune to changes from the other tasks, as they are not tapping into the same aspect of global/local processing. As such, it might be more useful to examine whether dispositional biases can be manipulated by using the same stimuli for both the manipulation and to assess dispositional biases. For example, dispositional biases on the Navon letter task might be more easily manipulated by presenting participants repeatedly with global or local Navon letters.

Ultimately, more research is needed to understand the exact nature of dispositional global/local biases, but these findings suggest that they are relatively immune to changes from exposure to high/low spatial frequencies and other global/local

stimuli. These results also suggest that dispositional biases in spatial frequency use are stable over time. A few studies have shown that attention to local or global levels of Navon stimuli can influence face recognition ability, where face recognition ability is better after attending to global levels than to local levels (e.g., Macrae & Lewis, 2002; Perfect, 2003). The present results suggest that such findings are unlikely to result from attention to global levels enhancing use of low spatial frequency information or from attention to local levels enhancing use of high spatial frequency information.

Conclusion

In this paper I presented 5 different experiments that examined whether dispositional global/local biases could be altered by exposing participants to high/low spatial frequency information (Experiments 1 and 2) or global/local Navon letters (Experiment 3). I used multiple measures of dispositional global/local bias (i.e., shapes, Navon letters, and faces,), and a variety of manipulation tasks (i.e., high/low spatial frequency faces, gratings, and Navon stimuli). Ultimately, I was unable to show the predicted pattern of significant changes from pre-to-post manipulation on the dispositional measures in 4 of 5 attempts, and showed marginally significant weak effects for the other one. These findings are consistent with previous results (Dale & Arnell, 2013) showing individual differences in global/local bias are relatively stable and trait-like, and lead me to conclude that global/local processing biases are relatively resistant to recent viewing or attention toward high or low spatial frequency information.

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CHAPTER 6: GENERAL DISCUSSION

Selective attention plays a crucial role in our cognitive experience, such that it allows us to select incoming information that is relevant to existing tasks or goals, and suppress irrelevant information (Broadbent, 1958; Treisman, 1960). However, our attentional resources are limited, thus we are able to select only a few items at a time for further processing (Broadbent, 1958; Treisman, 1960). The AB effect is an excellent tool for examining this attention limitation, as it allows us to understand the time-course of information processing, and the limitations of attention, during attentional selection (Raymond, Shapiro, & Arnell, 1992). Indeed, it is one of the only cognitive behavioural tasks that can provide an indication of the time-course of attentional selection, and because it is such a robust phenomenon that occurs across a variety of task manipulations and participants, it has become an excellent task for examining temporal attention. While the AB effect is not necessarily observed outside of the lab, the AB phenomenon does inform us about why humans often have difficulty attending to multiple items at one time, thus understanding the mechanisms behind the AB itself may in turn allow us to understand the real-world dual-task difficulties that are so often observed.

Interestingly, individuals vary greatly in the magnitude of their AB, such that some individuals are particularly vulnerable to this effect, some appear immune to the effect, and others are variously susceptible. Recent studies have attempted to identify some of the key characteristics that lead to these individual differences in the AB. One promising area of investigation suggests that an individual's breadth of attention can contribute to their susceptibility to the AB. Specifically, high levels of dispositional predictors that are associated with greater attentional breadth, such as positive affect

(MacLean & Arnell, 2010; MacLean, Arnell, & Busseri, 2010; Vermeulen, 2010), extraversion and openness to experience (MacLean & Arnell, 2010), and working memory control (Arnell, Stokes, MacLean, & Gicanté, 2011; Arnell & Stubitz, 2010; Colzato, Spapé, Pannebakker, & Hommel, 2007), are associated with smaller ABs. Furthermore, individuals who report high levels of dispositional predictors that are associated with reduced attention breadth, such as negative affect (MacLean et al., 2010; MacLean & Arnell, 2010), and neuroticism (MacLean & Arnell, 2010) tend to have larger ABs.

I recently examined the relationship between attentional breadth and individual performance on the AB, and showed that individuals who were more biased toward the global characteristics of hierarchical stimuli were less susceptible to the AB effect (Dale and Arnell, 2010). This was the first direct examination of the relationship between dispositional attentional breadth and AB performance. However, that study gave rise to a number of questions with regard to the stability of these individual differences and the replicability and generalizability of our previous findings. As such, the general purpose of this dissertation was to better understand the critical role that dispositional attentional breadth plays in selective attention. Four empirical studies were conducted which were designed to clarify the role of individual differences in attentional breadth and AB performance. Collectively, they help elucidate the nature of individual differences in global/local processing and the AB, and the relationship between attentional breadth and selective attention. Each of the four studies is summarized below.

Study 1: Global/Local Stability

Study 1 was designed to establish whether individual differences in global/local bias are reliable over time. Before further examining the relationship between individual differences in global/local processing and the AB, it is beneficial to investigate whether both global/local processing and the AB are reliable individual difference variables, as estimates of reliability provide an upper-bound on the degree of relationship that can be expected between two tasks. In addition, I was interested in examining the relationships amongst different global/local tasks to see whether different global/local tasks are equally reliable, and whether they share common variability.

To examine whether dispositional global/local biases are stable over time, participants were required to complete three distinct global/local processing tasks: a hierarchical shape task, a standard Navon letter task, and a high/low spatial frequency (SF) face task. Participants then returned 7-10 days later and again completed the same three tasks. In two separate experiments, dispositional global/local biases were found to be moderately-to-highly reliable over time, depending on the measure used. Scores on the global/local shape task correlated .79 and .64 in Experiments 1 and 2 respectively, whereas scores on the global/local face task were correlated .70 in Experiment 1, and .57 in Experiment 2. Scores on the Navon letter task, however, were much less reliable (.31 in Experiment 1 and .27 in Experiment 2), albeit significant, indicating that this is a poorer measure of individual variation in global/local bias. In general, these results showed that dispositional bias in global/local processing are stable over time, and suggests that individual biases may be trait-like. Interestingly, I also found that none of the three measures of global/local bias were correlated with each other in either

experiment, which suggests that these tasks may be measuring unique aspects of global/local processing bias. This finding raises the interesting possibility that global/local is not a unitary phenomenon, but rather is a multifaceted combination of perceptual and attentional processes that give rise to what we call “global/local processing”.

Study 2: Stability of Individual AB Performance

In Study 2, I was interested in establishing the reliability of individual differences in AB performance. It does not make sense to ask what dispositional characteristics predict individual differences in AB magnitude if the AB itself is not a reliable individual differences variable. Participants completed two different AB tasks: one in which there were different tasks for T1 and T2 (i.e., a switch AB task), and one in which the T1 and T2 tasks were the same (i.e., a no-switch task). The participants then returned 7-10 days later to again complete the same two AB tasks. Target accuracy and AB magnitude were found to be moderately reliable over time, which suggests that individual differences in performance on this task are stable. Additionally, whereas previous studies have provided evidence that switch and no-switch AB tasks measure different underlying variability (see Kelly & Dux, 2011), I found that performance on these different AB tasks was correlated both within testing session, and over time, suggesting that they are measuring the same underlying variability that we call the AB. This finding has since been replicated and extended (see Dale, Dux, & Arnell, 2013), and demonstrates that not only is performance on the AB stable over time, but that the choice of AB task does not influence the results.

Study 3: Global/Local Bias and AB Revisited

Now that the reliability of the global/local and AB measures had been established, the purpose of Study 3 was to bring together the measures from both Study 1 and 2 in order to examine whether individual differences in attentional breadth could predict AB magnitude. A previous study had shown that individual differences in global precedence, as measured by the Navon letter task, predicted AB magnitude using a switch AB task, such that individuals who had higher levels of global precedence had smaller ABs (Dale & Arnell, 2010). However, the generalizability of this effect was unclear, especially given that the three global/local tasks examined in Study 1 were shown not to relate to each other, and the Navon letter task used in Dale and Arnell (2010) has since been shown to be an only modestly reliable measure of individual differences in global/local processing bias (see Chapter 2)

Through two experiments, participants completed the three global/local tasks used in Study 1 (global/local shape task, Navon letter task, and the high/low spatial frequency face task), and the two AB tasks used in Study 2 (switch and no-switch AB tasks). In both experiments, global/local performance predicted AB size, such that individuals who were globally biased had smaller ABs. Interestingly, two of the three global/local tasks explained unique variance in the AB in Experiment 2, and when combined to create a composite global score, the composite global score correlated .50 with AB size. These results replicated and extended our previous findings (Dale & Arnell, 2010), and also supported the literature suggesting that attentional breadth is related to AB performance (see below for more discussion on this point).

Study 4: Manipulating Global/Local Bias

The final study in my dissertation was designed to examine whether global/local bias can be manipulated by exposing individuals to high/low SFs and Navon letters. If dispositional biases can modulate performance on the AB task, then it follows that inducing participants into a global or local state may also influence AB performance. As such, the purpose of Study 4 was to examine whether these dispositional biases could even be altered. Through five different experiments, participants were exposed to high/low spatial frequency faces (Experiment 1ab), high/low spatial frequency gratings (Experiment 2ab), and Navon letter stimuli (Experiment 3). Dispositional global/local biases were measured before and after each manipulation with the hierarchical shape task (Experiments 1a, 2a and 3), the Navon letter task (Experiments 1b and 2b), and a high/low spatial frequency face task (Experiment 3). In all of the experiments save one (Experiment 2b), I was unable to show significant changes in dispositional bias from pre-to-post manipulation. In Experiment 2b, there were marginally significant changes from pre-to-post manipulation for the high spatial frequency manipulation condition, and the interaction between manipulation frequency and pre/post performance approached significance. However, this finding was weak, and no such findings were found throughout the other experiments, leading me to conclude that dispositional biases for global/local appear to be relatively resistant to change following exposure to high/low spatial frequency information or practice on global/local Navon levels.

Implications for Understanding the AB

The results of this dissertation clearly show that there are large, stable individual differences in both global/local bias, and AB performance, and that these differences in

global/local bias are related to the AB, such that individuals who have a natural tendency to diffuse or broaden their attention are less susceptible to the AB effect. The collection of studies in this dissertation are the first to examine the stability of individual differences in both global/local bias and the AB across sessions, and whether these differences can be modulated by exposure to high/low spatial frequencies or Navon stimuli. Additionally, Chapter 4 has expanded the findings of Dale and Arnell (2010) by showing that 3 unique measures of global/local processing predict individual AB size. Of particular importance, Chapter 2 has raised a multitude of questions with regard to the nature of global/local processing, such that global/local processing appears to be multifaceted, rather than a unitary concept. Alarming, Chapter 2 also demonstrated that the traditional Navon letter task measure is actually only a modestly reliable index of global/local processing bias. As such, this dissertation has not only contributed to our understanding of why individuals are variously susceptible to the AB, but also helped us to better understand the trait-like differences in attentional breadth that appear to strongly influence selective attention, as well as how to best measure these differences. These findings are not only important for our understanding of why the AB occurs, but they also raise the interesting possibility that dispositional biases in global/local processing may influence selective attention in general, and thus might explain why some individuals are better at attending to multiple items or tasks at a given time.

These results are consistent with recent individual differences studies that suggest that control over resource allocation, and attentional breadth, can modulate the AB. For example, dispositional differences in self-reported trait (MacLean, et al., 2010), and state affect (MacLean & Arnell, 2010; Vermeulen, 2010) predict individual differences in AB

magnitude, such that individuals who are higher in state and trait positive affect show smaller ABs, and individuals who are higher in state and trait negative affect show larger ABs. As higher levels of positive affect are related to attentional broadening (e.g., Rowe, Hirsch, & Anderson, 2007), this suggests that these individuals who show naturally higher levels of positive affect may also have a broadened attentional scope, which helps them overcome the AB. Higher levels of negative affect are associated with attentional narrowing and focus (e.g., Gasper & Clore, 2002), suggesting that individuals high in negative affect may experience attentional focus that exacerbates the AB. Individual differences in executive control of working memory have also been shown to predict AB size, such that individuals who are better at inhibiting irrelevant information from entering working memory are less susceptible to the AB (Arnell et al., 2011; Arnell & Stubitz, 2010; Colzato et al., 2007, Dux & Marois, 2008; Martens & Valchev, 2009). This indicates that some aspect of control over the allocation of attentional resources contributes to the AB. Research has also shown that individuals who show greater performance-related feedback negativities (indicative of greater motivational investment in performance outcomes) on the AB task and a separate time-estimation task, have larger ABs (MacLean & Arnell, 2013). Trial-to-trial performance on the AB task is also predicted by levels of pre-trial attentional investment, which is measured as event-related alpha desynchronization (alpha ERD). Pre-trial alpha ERD was shown to be significantly greater when T1 was correct versus incorrect, and when long lag T2 performance was correct versus incorrect. However, the opposite pattern was observed for T2 at short lags in that pre-trial alpha ERD was greater on incorrect T2 trials than on correct trials (MacLean & Arnell, 2011). These data suggest that attentional focus and overinvestment

appear to be good for single target performance, but bad for the AB. Together, these results suggest that attentional breadth, focus, and investment play a critical role in selective attention¹.

Although it is still uncertain how broadening the scope of attention allows for better dual-task performance, a few possibilities merit discussion. The first possibility is that attentional breadth may decrease overinvestment of attentional resources during an AB task, which reduces distractor competition for limited attentional resources, thus reducing the probability of an AB. Recall that Olivers and Nieuwenhuis's (2006) overinvestment hypothesis suggests that during a typical AB task, participants focus their attention on the stream in order to select the targets. However, this narrowing of attention results in an overinvestment of valuable attentional resources to both the first target (T1), and surrounding distractors, which allows both targets and the irrelevant distractors to cross an activation threshold where they compete for limited resources. The increased competition for resources results in interference with the T2 representation, which can lead to the occurrence of an AB. However, when participants broaden or diffuse their attention, this overinvestment is prevented. As such, only targets cross the activation threshold, and the AB is attenuated (Olivers & Nieuwenhuis, 2006).

The overinvestment hypothesis is supported by the original Olivers and Nieuwenhuis (2005; 2006) studies, which showed that forcing participants to broaden their attention by having them complete a simultaneous additional task during an AB task resulted in smaller AB magnitudes as compared to when participants completed the AB

¹ It should be noted that the studies that have shown a relationship between attentional breadth and the AB are correlational in nature, thus it is not certain whether attentional breadth per se modulates the AB, or if there is some as yet unidentified third variable that contributes to individual differences in both global/local bias and AB size.

task only. It is also supported by much of the individual differences literature, which shows that dispositional characteristics that presumably broaden attention, such as positive affect (MacLean et al., 2010) or personality traits like openness to experience and extraversion (MacLean & Arnell, 2010), are associated with smaller ABs. The finding that individuals who are dispositionally globally biased show smaller ABs may then be explained by the overinvestment hypothesis, such that their natural tendency to broaden their attention prevents them from overinvesting resources in an RSVP task, and thus attenuates the AB by reducing competition for resources.

A second possibility is that individuals who are globally biased may have a broadened attentional window during the AB task, and thus treat the two AB targets as a set, rather than individual items. If individuals are unable to open a second attentional window for T2 soon after opening one for T1, then placing both T1 and T2 in the same attentional window may overcome this limitation. Indeed, lag-1 sparing (the finding that T2 accuracy at lag-1 is typically higher than T2 accuracy at lag-2) is said to result from the lag-1 T2 item slipping into the same attentional window as T1 (Raymond et al., 1992). Having both T1 and T2 in the same attentional window causes attention to treat these individual targets as a set, allowing them to be processed together where they both receive attention, and thereby reducing the AB. Support for this possibility comes from AB studies in which the task instructions were manipulated to allow participants to treat the AB stream as a set, rather than as individual items. For example, the AB is dramatically reduced when participants are asked to report the entire 6 letter RSVP stream as compared to when they are asked to just report the two red target letters from within the same streams (Potter, Nieuwenstein, & Strohminger, 2008). Similarly, when

participants are asked to report the sum of two digit targets, as opposed to the two targets individually, the AB is significantly reduced (Ferlazzo, Lucido, Di Nocera, Fagioli, & Sdoia, 2007). It seems that T1 and T2 are also processed within an extended attentional window when T1 is gradually morphed across successive distractors, as the AB is attenuated dramatically under these conditions (Kellie & Shapiro, 2004). Di Lollo, Kawahara, Ghorashi, and Enns (2005) also noticed that the attentional window initiated for T1 could be extended if two targets appeared after T1 (i.e., three successive targets) such that now there was lag-2 sparing as opposed to the typical AB that was observed when T1 was followed by a distractor and then T2 in lag 2. Together, these results suggest that broadening the attentional span by having participants extend a temporal attentional window to encompass both T1 and T2 can reduce the AB. A similar effect might therefore occur in individuals who are naturally globally biased, such that they may be more likely to view the AB stream as a coherent whole, rather than individual parts, or the targets as a set, rather than two discrete items. One way to examine this possibility might be to examine electrophysiological markers of attention to individual items in the AB stream to examine whether there are differences in the amount of attention given to individual items in the AB stream, and whether items are treated individually or as a cohesive whole in the brain.

A third possibility is that increases in attentional breadth might decrease inhibitory control. Although earlier models suggested that the AB occurs because there are limited attentional resources, newer models suggest that an overexertion of inhibitory control, can give rise to the AB. For example, the Boost-and-Bounce model (Olivers & Meeter, 2008), and the Threaded Cognition model (Taatgen, Juvina, Schipper, Borst, &

Martens, 2009) both suggest that in an attempt to protect T1 encoding, and stem the flow of information into working memory, inhibitory control is overexerted when the distractor that follows T1 is presented, thus causing T2 to become inhibited and suppressed, rather than elaborated. Therefore, the role of attentional breadth may be to prevent overexertion of inhibitory or attentional control, thus preventing T2 from being shut out in the event that a distractor is presented before T2.

This idea is supported by research findings that show that increased attentional breadth actually reduces inhibitory control (Rowe et al., 2007). Rowe et al. (2007) showed that whereas positive affect broadens attention and allows people to creatively solve unusual word associations in the remote associates task (RAT), individuals in positive moods are also more likely to be distracted by external, irrelevant distractors (i.e., flankers) in a typical flanker task, which demonstrates that while their attentional scope has been broadened, they are more susceptible to distraction. Indeed, positive affect has been shown to increase distraction, in set-switching paradigms (Dreisbach & Goschke, 2004). This suggests that broadened attention somehow relaxes inhibitory control, and although this can cause more susceptibility to irrelevant stimuli, it can presumably also prevent an AB from occurring by preventing an overexertion of control to post-T1 distractors and T2. Given that I have just reviewed three non-mutually exclusive possibilities for how attentional breadth could influence the AB, more research is clearly needed to explore why global biases are associated with reduced ABs.

Lingering Questions and Future Directions.

Cognitive Control

Attentional breadth, as measured by global/local processing biases, appears to play an important role in modulating the AB. Control over the allocation of attentional resources also appears to play a role in the AB, such that individuals who are better at inhibiting irrelevant information from entering working memory tend to have smaller ABs (Arnell & Stubitz, 2010; Dux & Marois, 2008; Martens & Valchev, 2009). However, as discussed above it is not currently clear how attentional breadth might relate to cognitive control. According to the overinvestment hypothesis (Olivers & Nieuwenhuis, 2006), control over resources is beneficial when performing an AB task, and diffusion aids in this control. In addition, some recent models of the AB suggest that the AB occurs when individuals lose control over their attentional gating (e.g., Di Lollo et al., 2005). However, as mentioned, other research on attentional breadth and affect suggest that attentional broadening actually *reduces* inhibitory control by loosening the restraints on our attentional filtering system, such that both relevant and irrelevant information can receive processing (Rowe et al., 2007). As such, it is currently unclear whether greater attentional breadth reduces the AB because fewer attentional resources are being allocated to T1 and surrounding distractors, as in the overinvestment hypothesis, or if it results in a loosening of inhibitory control that may underlie the AB. Both possibilities suggest that the AB results from an overinvestment, either of limited resources, or of inhibitory control, and both suggest that broadening one's attention can reduce this overinvestment. However, it is unclear which type of overinvestment results in the AB, thus it is difficult to determine the precise role of attentional breadth or

diffusion. To begin to understand the role of overinvestment, it would be useful to first examine the relationships between inhibitory control and global/local processing. If individuals with naturally occurring global biases also demonstrate a loosening of inhibitory control on other cognitive tasks, such as the Stroop task, it may indicate that this disinhibition leads to their better performance on the AB task. Additionally, it might be interesting to examine how small doses of alcohol influence the AB, as alcohol has been shown to negatively affect inhibitory control. Alternatively, it is possible that attentional breadth plays some other unknown role in the AB, thus additional research is needed to explore the relationship between attentional breadth and cognitive control. As such, it would be beneficial to examine whether individuals who are naturally biased toward the global form of a hierarchical stimulus also show poorer inhibitory control.

Generalizability of Global/Local Biases. A second consideration is whether individuals who diffuse their attention use this strategy during the AB task because that is the optimal strategy for this task, or if these individuals use this strategy across a wide range of tasks, regardless of whether or not it is appropriate. Global/local biases are clearly quite stable over time, and obviously can influence temporal selective attention, but it would be interesting to examine whether these biases can affect other areas of cognition, such as working memory, spatial attention, and inhibitory control. It is possible that a whole range of individual differences are influenced by one's global or local strategy, thus it would be interesting to further explore this possibility. Additionally, it may be fruitful to examine why individual differences in global/local bias are resistant to change when participants are exposed to high/low spatial frequencies and Navon letter stimuli, yet a host of other research studies have shown that global/local biases can be

influenced easily with external tasks that are designed to broaden or constrict attention (e.g., Förster & Dannenburg, 2010). To begin to explore this question, it would be useful to first examine whether dispositional global/local biases can be altered with the same types of tasks used by Förster and Dannenburg, to determine whether dispositional global/local biases are truly immovable, or if the types of manipulation tasks used in Chapter 5 somehow were insufficient for affecting change in global/local bias.

Additionally, the differences among various tasks purported to measure global/local processing need to be explored, in order to better understand this construct. Indeed, I am currently completing a study that examines the differences and similarities among various global/local measures and stimuli. Finally, it may be fruitful to explore how global/local processing biases develop in the first place, by examining global/local biases across the lifespan, and environmental factors that may lead someone to develop a tendency to broaden their attention. As global/local processing appears to be important for our cognitive functioning, being able to induce an individual into a more global or local state might be beneficial for certain cognitive tasks, and especially for individuals who have difficulties dividing or focusing their attention, or individuals who perform jobs for which a globally or locally biased attentional scope would be beneficial (such as fighter pilots or athletes). Therefore, the boundaries on the flexibility of global/local attention require further investigation.

What is Global/Local? A final, but extremely important, consideration is that although the term “global bias” is used here as an indication of attentional broadening, the construct of global/local is clearly more complex and multifaceted than initially thought, as evidenced by the fact that three different measures of global/local all uniquely

predicted AB performance, but were uncorrelated with each other (see Study 1). This suggests that there are multiple different aspects that contribute to an individual's tendency to focus or diffuse their attention. One possibility is that there are different perceptual and attentional mechanisms that contribute to the experience of attending globally or locally, and that the three different global/local tasks used in this dissertation measure different aspects of these attentional and perceptual mechanisms. For example, although individuals show variation in their preference for selecting global or local information in forced-choice task, as shown in Studies 1 and 4, other studies have shown that the time course of global-to-local perception is similar across participants, such that the global information appears to be extracted first, and is perceptually dominant for almost all participants (Navon, 1991; Sanocki, 1993). As such, global/local perception may be distinct from global/local attention. Interestingly, support for this notion comes from a study that examined cultural differences in global/local bias (Caparos, Linnell, Bremner, de Fockert, and Davidoff, 2013). Individuals from a remote Himba culture had previously been shown to have a strong local bias when tested using a perceptual task. However, when they were given a global/local attention task, they had no difficulties attending to global information when directed, and showed no differences in global/local interference when compared to individuals from a Western culture (Caparos et al., 2013). This suggests that global/local perception and attention are separable mechanisms that uniquely contribute to our global/local biases. As such, more research is needed to clarify the precise mechanisms behind individual differences in global/local bias, as there are likely multiple different components that contribute to this effect.

Conclusion

In this dissertation I reported four empirical research studies which examined the stability of individual differences in global/local processing (Study 1), and in AB performance (Study 2), the relationship between dispositional global/local bias and the AB (Study 3), and whether individual differences in global/local bias can be altered by exposing individuals to high/low spatial frequencies and Navon stimuli (Study 4). The results of these studies showed that dispositional differences in global/local bias and the AB are relatively stable over time, and that global/local biases appear to be resistant to transient state influences, suggesting that these are good individual differences variables. Additionally, I was able to show that a variety of global/local measures are independent of each other, yet each predict AB performance, which supports the hypothesis that attentional breadth modulates selective attention. These results also raised a number of additional questions, particularly with regard to the precise nature of global/local processing. Although more research is necessary to elucidate the precise mechanisms behind the relationship between attentional breadth and the AB, the present results highlight the important contribution of individual differences in attentional scope to selective attention.

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Appendix A

REB Approval and Modification Letters

DATE: August 24, 2008
 FROM: Michelle McGinn, Chair
 Research Ethics Board (REB)
 TO: Karen Arnell, Psychology
 Gillian Dale
 FILE: 08-045 ARNELL/DALE
 TITLE: Visual Attention and Cognitive Abilities

The Brock University Research Ethics Board has reviewed the above research proposal.

DECISION: ACCEPTED WITH NOTES

Please Note:

- Please remove the cancellation deadline from the SONA Advertisement to avoid any misperceptions that participants cannot withdraw from the study after that point.
- Please change the term “ethical approval” on the consent form to “ethics clearance”.

This project has received ethics clearance for the period of **August 24, 2008 to August 31, 2009** subject to full REB ratification at the Research Ethics Board's next scheduled meeting. The clearance period may be extended upon request. ***The study may now proceed.***

Please note that the Research Ethics Board (REB) requires that you adhere to the protocol as last reviewed and cleared by the REB. During the course of research no deviations from, or changes to, the protocol, recruitment, or consent form may be initiated without prior written clearance from the REB. The Board must provide clearance for any modifications before they can be implemented. If you wish to modify your research project, please refer to

<http://www.brocku.ca/researchservices/forms> to complete the appropriate form
 Revision or Modification to an Ongoing Application.

Adverse or unexpected events must be reported to the REB as soon as possible with an indication of how these events affect, in the view of the Principal Investigator, the safety of the participants and the continuation of the protocol.

If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and clearance of those facilities or institutions are obtained and filed with the REB prior to the initiation of any research protocols.

MM/an

FROM: Michelle McGinn, Chair
Research Ethics Board (REB)

TO: Karen Arnell, Psychology
Gillian Dale

FILE: 08-045

DATE: September 23, 2008

END DATE: August 31, 2009

The Brock University Research Ethics Board has reviewed the research proposal:

Visual Attention and Cognitive Abilities

The Research Ethics Board finds that your ***modification request*** to an ongoing project involving human participants conforms to the Brock University guidelines set out for ethical research.

MM/a

FROM: Michelle McGinn, Chair
Research Ethics Board (REB)

TO: Karen Arnell, Psychology
Gillian Dale

RE: Continuing Review

FILE: 08-045 - ARNELL/DALE
Graduate Thesis/Project
Original clearance date: August 24, 2008
Date of completion: December 31, 2010

DATE: December 21, 2009

Thank you for completing the *Continuing Review* form. The Brock University Research Ethics Board has reviewed this report for:

Visual Attention and Cognitive Abilities

The Committee finds that your original proposal and ongoing research conforms to the Brock University guidelines set out for ethical research.

*** Continuing Review Accepted.**

MM/a



Brock University
 Research Ethics Board
 Tel: 905-688-5550 ext. 3035
 Email: reb@brocku.ca

Certificate of Ethics Clearance for Human Participant Research

DATE: August 19, 2010
 PRINCIPAL INVESTIGATOR: ARNELL/DALE, Karen - Psychology
 FILE: 08-045 - ARNELL/DALE
 TYPE: Masters Thesis/Project STUDENT: Gillian Dale
 SUPERVISOR: Karen Arnell
 TITLE: Visual Attention and Cognitive Abilities

ETHICS CLEARANCE GRANTED

Type of Clearance: RENEWAL Expiry Date: 8/31/2011

The Brock University Research Ethics Board has reviewed the above named research proposal and considers the procedures, as described by the applicant, to conform to the University's ethical standards and the Tri-Council Policy Statement. Clearance granted from 12/21/2009 to 8/31/2011.

The Tri-Council Policy Statement requires that ongoing research be monitored by, at a minimum, an annual report. Should your project extend beyond the expiry date, you are required to submit a Renewal form before 8/31/2011. Continued clearance is contingent on timely submission of reports.

To comply with the Tri-Council Policy Statement, you must also submit a final report upon completion of your project. All report forms can be found on the Research Ethics web page.

In addition, throughout your research, you must report promptly to the REB:

- a) Changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
- b) All adverse and/or unanticipated experiences or events that may have real or potential unfavourable implications for participants;
- c) New information that may adversely affect the safety of the participants or the conduct of the study;
- d) Any changes in your source of funding or new funding to a previously unfunded project.

We wish you success with your research.

Approved:

 Michelle McGinn, Chair
 Research Ethics Board (REB)

Note: Brock University is accountable for the research carried out in its own jurisdiction or under its auspices and may refuse certain research even though the REB has found it ethically acceptable.

If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and clearance of those facilities or institutions are obtained and filed with the REB prior to the initiation of research at that site.



Brock University
Research Ethics Board
Tel: 905-688-5550 ext. 3035
Email: reb@brocku.ca

Certificate of Ethics Clearance for Human Participant Research

DATE: August 19, 2010
PRINCIPAL INVESTIGATOR: ARNELL/DALE, Karen - Psychology
FILE: 08-045 - ARNELL/DALE
TYPE: Masters Thesis/Project STUDENT: Gillian Dale
SUPERVISOR: Karen Arnell
TITLE: Visual Attention and Cognitive Abilities

ETHICS CLEARANCE GRANTED

Type of Clearance: MODIFICATION Expiry Date: 8/31/2011

The Brock University Research Ethics Board has reviewed the above named research proposal and considers the procedures, as described by the applicant, to conform to the University's ethical standards and the Tri-Council Policy Statement. Clearance granted from 8/24/2008 to 8/31/2011.

The Tri-Council Policy Statement requires that ongoing research be monitored by, at a minimum, an annual report. Should your project extend beyond the expiry date, you are required to submit a Renewal form before 8/31/2011. Continued clearance is contingent on timely submission of reports.

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- c) New information that may adversely affect the safety of the participants or the conduct of the study;
- d) Any changes in your source of funding or new funding to a previously unfunded project.

We wish you success with your research.

Approved:

Michelle McGinn, Chair
Research Ethics Board (REB)

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Brock University
 Research Ethics Office
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 Email: reb@brocku.ca

Social Science Research Ethics Board

Certificate of Ethics Clearance for Human Participant Research

DATE: 9/15/2011
 PRINCIPAL INVESTIGATOR: ARNELL/DALE, Karen - Psychology
 FILE: 08-045 - ARNELL/DALE
 TYPE: Masters Thesis/Project STUDENT: Gillian Dale
 SUPERVISOR: Karen Amell
 TITLE: Visual Attention and Cognitive Abilities

ETHICS CLEARANCE GRANTED

Type of Clearance: RENEWAL Expiry Date: 9/28/2012

The Brock University Social Sciences Research Ethics Board has reviewed the above named research proposal and considers the procedures, as described by the applicant, to conform to the University's ethical standards and the Tri-Council Policy Statement. Clearance granted from **9/15/2011 to 9/28/2012**.

The Tri-Council Policy Statement requires that ongoing research be monitored by, at a minimum, an annual report. Should your project extend beyond the expiry date, you are required to submit a Renewal form before **9/28/2012**. Continued clearance is contingent on timely submission of reports.

To comply with the Tri-Council Policy Statement, you must also submit a final report upon completion of your project. All report forms can be found on the Research Ethics web page at <http://www.brocku.ca/research/policies-and-forms/research-forms>.

In addition, throughout your research, you must report promptly to the REB:

- a) Changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
- b) All adverse and/or unanticipated experiences or events that may have real or potential unfavourable implications for participants;
- c) New information that may adversely affect the safety of the participants or the conduct of the study;
- d) Any changes in your source of funding or new funding to a previously unfunded project.

We wish you success with your research.

Approved:

Jan Frijters, Chair
 Social Sciences Research Ethics Board

Note: Brock University is accountable for the research carried out in its own jurisdiction or under its auspices and may refuse certain research even though the REB has found it ethically acceptable.

If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and clearance of those facilities or institutions are obtained and filed with the REB prior to the initiation of research at that site.



Brock University
 Research Ethics Office
 Tel: 905-688-5550 ext. 3035
 Email: reb@brocku.ca

Social Science Research Ethics Board

Certificate of Ethics Clearance for Human Participant Research

DATE: 9/7/2012
 PRINCIPAL INVESTIGATOR: ARNELL/DALE, Karen - Psychology
 FILE: 08-045 - ARNELL/DALE
 TYPE: Masters Thesis/Project STUDENT: Gillian Dale
 SUPERVISOR: Karen Arnell
 TITLE: Visual Attention and Cognitive Abilities

ETHICS CLEARANCE GRANTED

Type of Clearance: RENEWAL Expiry Date: 9/30/2013

The Brock University Social Sciences Research Ethics Board has reviewed the above named research proposal and considers the procedures, as described by the applicant, to conform to the University's ethical standards and the Tri-Council Policy Statement. Clearance granted from 9/7/2012 to 9/30/2013.

The Tri-Council Policy Statement requires that ongoing research be monitored by, at a minimum, an annual report. Should your project extend beyond the expiry date, you are required to submit a Renewal form before 9/30/2013. Continued clearance is contingent on timely submission of reports.

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- c) New information that may adversely affect the safety of the participants or the conduct of the study;
- d) Any changes in your source of funding or new funding to a previously unfunded project.

We wish you success with your research.

Approved:

 Jan Frijters, Chair
 Social Sciences Research Ethics Board

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Social Science Research Ethics Board

Certificate of Ethics Clearance for Human Participant Research

DATE: 9/24/2013
 PRINCIPAL INVESTIGATOR: ARNELL, Karen - Psychology
 FILE: 08-045 - ARNELL
 TYPE: Masters Thesis/Project STUDENT: Gillian Dale
 SUPERVISOR: Karen Arnell
 TITLE: Visual Attention and Cognitive Abilities

ETHICS CLEARANCE GRANTED

Type of Clearance: RENEWAL Expiry Date: 9/30/2014

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- b) All adverse and/or unanticipated experiences or events that may have real or potential unfavourable implications for participants;
- c) New information that may adversely affect the safety of the participants or the conduct of the study;
- d) Any changes in your source of funding or new funding to a previously unfunded project.

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Approved:

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 Social Sciences Research Ethics Board

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