

ATTENTION NETWORKS:  
THE EFFECTS OF SOCIAL AND NON-SOCIAL CUES  
ON MEASURES OF ATTENTION IN CLINICAL POPULATIONS

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ATTENTION NETWORKS:  
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Previous investigations of attention in various developmentally disabled populations have shown attention processes to operate differently than those in typically developing persons. Atypical populations exhibit deficits in the activation and alerting of attention, spatial direction of attention, and resolution of conflict requiring multiple attention mechanisms. While persons with Attention-Deficit Hyperactivity Disorder primarily exhibit deficits of conflict resolution during attention tasks, those with Autism Spectrum Disorders are shown to have impaired abilities to shift attention between locations and modalities.

The current study had three primary goals. We 1) examined components of the attention process in typical persons and in persons diagnosed with Attention-Deficit Hyperactivity Disorder to assess the differences in recruitment of attentional components between the three populations, 2) developed a social variation of the widely used Attention Network Task to determine the effects of social cues on the same attentional components in a typical and Autism Spectrum population, and 3) assessed the differences between typical persons and those along the Autism Spectrum using a standard attention paradigm and our social variant of the task.

Attention Network Task data obtained from typical persons replicates those reported in previous investigations. There was no evidence of deficits in conflict resolution in our Attention-Deficit Hyperactivity sample using standard task measurements; we thus defined additional calculations to elicit measures of these

deficits. We successfully developed a comparable social variant of the attention task. We argue that the Attention Network Task may be inappropriate to use with Autism Spectrum persons to elicit measures of primary attentional components. We also argue that cue and target features of the task do not measure attentional components in the manner currently described in the literature.

## BIOGRAPHICAL SKETCH

Born on February 14, 1975, in Stamford, Connecticut, Kathleen Linnane received her Bachelor of Arts degree with honors in Psychology from the University of Connecticut in 2003. She joined the Department of Human Development at Cornell University in September of 2003.

During her undergraduate studies at UConn, Kathleen conducted several research projects requiring extensive work with children and adolescents with various clinical diagnoses. While working on these projects, she developed an interest in developmental disabilities and specific outcomes related to the physiological, social and cognitive development in Autism Spectrum Disorders.

While at Cornell, Kathleen joined the laboratories of both Dr. Elise Temple and Dr. Steven Robertson, examining different aspects of psychobiology, neuroscience, attention and development. Kathleen also spent time at the University of Cambridge in the United Kingdom assisting with several projects under the direction of Dr. Simon Baron-Cohen, and acted as an adjunct professor in the Psychology Department at the University of Connecticut at Stamford.

For the Linnanes.

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## CHAPTER ONE

### Introduction

Attention is a cognitive process which has been of interest to researchers within various disciplines for several years. Recent decades find research initiatives into the different aspects and pathologies of attention increasing rapidly (Raz, 2004), and concepts of attention have evolved from James' (1890) philosophical accounts of the 'taking possession of the mind' to more physiologically-based concepts of brain networks involving mechanisms such as shifting, problem-solving, filtering, detecting and focusing. A current theory widely accepted among attention researchers is that attention is an organ system (Posner & Fan, 2004), involving specialized networks each responsible for specific components of the attention process.

Attention processes, and what may be considered attention organ systems, are believed to operate differently in typically and atypically developing populations. Evidence exists of attention dysfunctions in individuals with Attention-Deficit Hyperactivity (ADHD; Barkley, 1997) and Autism Spectrum Disorders (ASD; Belmonte & Yurgelun-Todd, 2003). However, varying reports of these dysfunctions make it hard to understand precisely which components of the attention organ systems in either of the disorders are factors in observable symptoms and behaviors. Likewise, it is not well understood how different sorts of environmental cues affect attentional components and play a role in the attention process. Herein we discuss a currently accepted model of the attention process and the relationship between components of the attention organ system. We review what is known about these components in ADHD and ASD in addition to a discussion about the effects of both social and non-social cues upon attention processes. We then discuss a series of experiments designed to illustrate (a) differences in the components of attention in different clinical

populations and the (b) the success of a new task in the recruitment of these components with the use of various sorts of cues.

### *Attention Networks*

There are three primary components of attention most often discussed in current attention research models (Berger & Posner, 2000). Posner and Petersen (1990) first defined these three functional networks as the alerting, orienting, and executive attention networks, all functionally and anatomically distinct. Recent investigations of attention in healthy, typically developing individuals have shown that these functional attention networks can be localized to specific and separate neuroanatomical areas (Fan, McCandliss, Sommer, Raz, & Posner, 2002; Konrad, Neufang, Hanisch, Fink & Herpetz-Dahlman, 2005), and are each associated with activity of particular neuromodulators (Raz, 2004). Thus, while each of the three carries out its respective function, each recruits its own distinct regions and chemicals of the brain during cognitive tasks.

The alerting network as described by Posner and Petersen (1990) involves the activation of attention in preparation for a stimulus presentation and the maintenance of this vigilant state. An alert state is necessary not only for successful performance on cognitive tasks, but also for environmental adaptation and survival. Neuroimaging investigations of attention have associated the alerting network with the brain's right hemisphere, primarily the right prefrontal cortex (PFC), the fronto-parietal cortex (Fan, McCandliss, Fossella, Flombaum & Posner, 2005) and the locus coeruleus (Berger & Posner, 2000). Data from patients with lesions to the right frontal cortex give evidence of these patients' inability to maintain a vigilant or alert state (Raz, 2004). Mediation of an alert state has been associated with norepinephrine systems in

the locus coeruleus (Oberlin, Alford & Marrocco, 2005; Witte, Davidson & Marrocco, 1997), which have thus been associated with the alerting attention network.

The orienting network involves selecting and attending to the location of a stimulus from within a sensory environment, requiring covert attention shifts as attention is drawn to various locations (Posner, 1980). In addition to the midbrain regions required for the integration of visual perception (Raz, 2004), the primary areas associated with the orienting network are both the left and right parietal lobes of the brain (Fan et al., 2005; Posner & Petersen, 1990). The orienting network has also been associated with the action of the brain's cholinergic system (Oberlin et al., 2005).

The executive attention, or conflict resolution network, requires greater mental effort (Bush, Luu & Posner, 2000; Raz, 2004) than either alerting or orienting as executive attention involves various processes such as monitoring, decision-making and error detection. Neuroimaging data during conflict resolution tasks indicate involvement of regions of the lateral prefrontal cortex, the dorsal region of the anterior cingulate cortex (ACC) and parts of the basal ganglia. Patients with lesions of the ACC typically exhibit deficits in conflict resolution. Further, the executive attention network has been associated with dopaminergic systems within the brain (Raz, 2004).

### *Attention-Deficit Hyperactivity Disorder*

Attention-Deficit Hyperactivity Disorder is an attention disorder characterized by inattention, hyperactivity and impulsivity (APA, 2000). Although it is currently the most commonly diagnosed psychiatric disorder (NIMH, 2006), recent research concerning the physiological factors underlying ADHD is inconsistent and inconclusive (Bush, Valera & Seidman, 2005; Shallice et al., 2002), and thus these factors are not well understood. Investigations with healthy individuals have established that various neuroanatomical regions are responsible for the different

elements of behavior that comprise the diagnostic criteria for ADHD (APA, 2000), and thus many specific structures have been implicated in the literature as putative causes of the disorder. Impairments of attention have also been researched in several clinical populations outside of those with ADHD; yet the extent to which these impairments are related to the same dysfunctions presenting in ADHD remains unknown.

Neuropsychological investigations of ADHD have revealed patterns of dysfunction similar to those exhibited in individuals who have sustained damage to their frontal lobes (Barkley, 1997; Daffner et al., 2000; Durston et al., 2003; Konrad et al., 2005; Shallice et al., 2002). Frontal lobe patients, primarily those with lesions of the dorsolateral prefrontal cortex (DLPFC), have difficulties maintaining attention during the presentation of novel events as well as with directing attention to the novel stimuli presented (Daffner et al., 2000). Investigations of humans and primates with frontal lesions have demonstrated that damage to the lateral prefrontal cortex leads to disinhibition in attentional selection (Dias, Robbins & Roberts, 1996; Deouell & Knight, 2004). The prefrontal areas have also been implicated in tasks requiring resolution of both spatial and nonspatial conflict (Fan et al., 2003). Research with nonclinical subjects indicates similar prefrontal involvement in various attention and conflict tasks (Fan, Flombaum, McCandliss, Thomas & Posner, 2003; Fan et al., 2005; Stuss et al., 2005). These types of deficits in maintenance of attention, selection and conflict resolution are among the primary diagnostic criteria for ADHD.

In addition to lesion data, recent imaging data show atypical activations of the DLPFC and ventrolateral prefrontal cortex (VLPFC) in ADHD patients during tasks requiring cognitive control and inhibition (Durston et al., 2003), vigilance, selective attention and attention shifting (see Bush et al., 2005 for review). It is thus strongly

suggested that frontal lobe dysfunction plays a key role in the symptoms associated with ADHD.

Furthermore, the relevant literature suggests the anterior cingulate cortex (ACC) influences regulation of attention and has a principal role in the etiology of ADHD (see Bush et al., 2000 for review). Connected to numerous brain regions including the prefrontal cortex, the ACC is hypothesized to have ventral-rostral affective and dorsal cognitive subdivisions (Bush et al., 2000), involved in various emotional and cognitive functions, respectively (Bush et al., 2005; Casey et al., 1997; Pardo, Pardo, Janers & Raichle, 1990). While the ventral-rostral subdivision has been shown to be important for emotional cognition, the dorsal cognitive subdivision of the ACC has been implicated in components of attention such as cognitive control, response inhibition and motivation. Investigations of healthy persons show high levels of neuronal activation in the anterior cingulate in tasks involving conflict and decision-making such as the classic Stroop (Badgaiyan & Posner, 1998; Bush et al., 1999; Fan et al., 2003a; Pardo et al., 1990) and flanker-type interference (Fan et al., 2005; Posner & Rothbart, 2000) paradigms. Recent neuroimaging studies have shown decreased ACC activation in ADHD in tasks involving alerting cues (Konrad et al., 2005) and increased activation in tasks requiring error detection (Critchley, 2005; Magno, Foxe, Molholm, Robertson & Garavan, 2006) and motivation (Bush et al., 2000).

Structural investigations of brain abnormalities in ADHD have recently become more common due to the suggested involvement of more widespread brain regions associated with the disorder's dysfunctions. Concurring with functional imaging data indicating differences in the PFC and ACC in ADHD is evidence of structural differences (Bush et al., 2005) in the same regions. However, demonstrated differences in the size of the cerebellum and of the cerebellar vermis in ADHD, as

well as basal ganglia lesion studies indicating dysfunctional attention (see Seidman, Valera & Makris, 2005 for review), are directing attention researchers toward investigations of additional brain regions for involvement with the disorder.

### *Social Attention*

Eye gaze is a naturally occurring social tool, one that is critical for the direction of attention and successful communication. The human tendency to shift the focus of attention to a location where another person is gazing is an inherent feature and reflexive behavior in social interaction (Driver et al., 1999; Langton & Bruce, 1999). Because of its very prominent role in human communication processes, the function of eye gaze and its effects on attentional processes have been widely investigated (e.g., Downing, Dodds & Bray, 2004), and it has been generally accepted that eye gaze provides a speed advantage for responses to targets presented at locations indicated by gaze (e.g., Driver et al., 1999; Quadflieg, Mason & Macrae, 2004).

It is commonly held that eye gaze is a special type of reflexive social stimulus (Downing et al., 2004; Friesen, Ristic & Kingstone, 2004). Kobayashi and Kohshima (1997) and Emery (2000) discuss the evolution of the size and coloration of the human sclera and iris as social interactions moved beyond mere reproduction and survival. The ratio of visible sclera-to-iris allows eye-gaze direction to be easily discerned so signal receivers may quickly understand social communications as emotion, threat or cooperation. In the case of a forward eye-gaze, the colored iris takes up a larger proportion of the space between the eyelids than does the white sclera, and this iris:sclera ratio changes as the eyes attend toward various stimuli in the environment.

In addition to the anatomy of the human eye, there are several other biological aspects of eye gaze of interest in the developmental, psychological, and neurological literature. Baron-Cohen (1995) suggests that gaze perception is the critical element of one's ability to infer another's mental state and focus of attention, and has proposed the existence of an innate mechanism called the Eye-Direction Detector (EDD) whose function is to determine the direction of gaze, and thus attentional focus and mental state, of another organism. There have been many reports giving evidence of an infant's ability during the first year of life to discern and follow eye gaze (e.g. D'Entremont, Hains & Muir, 1997; Scaife & Bruner, 1975), and when gazing at a face, very young infants tend to focus on the eyes more than any other part of the face (see Emery, 2000 for review). Furthermore, it has been widely agreed upon that there are brain regions which respond more strongly to eyes and eye-gaze cues (Haxby, Hoffman & Gobbini, 2002) than to non-biological types of stimuli, including the amygdala, superior temporal sulcus, and fusiform gyrus. Additionally, it has been shown that contrast polarity, the varying of light spaces (e.g. cheeks) and dark spaces (e.g. lips and eyes) in a face image, assists in the development of attention following and human communication (Tipples. 2005), and changes (light spaces to dark and dark spaces to light) in the contrast polarity create different activation patterns in the fusiform gyrus (George et al., 1999).

### *Autism*

Autism is a neurodevelopmental spectrum disorder characterized by abnormalities in social functioning and communication, often accompanied by abnormalities in attention, learning and cognitive function. Prevalence of the disorder is currently estimated to be between two and 12 per 1,000 children in the United States (Centers for Disease Control and Prevention, 2007). Behavioral manifestations

include language impairments and mutism, lack of social reciprocity and impaired understanding of nonverbal behaviors, and a restricted repertoire of interests (APA, 2000). Despite much research into the social, genetic, cognitive and neurophysiological aspects of the disorder (see Baron-Cohen & Belmonte, 2005; Bauman & Kemper, 2005 for reviews), its etiology is both widely disagreed upon and poorly understood. There is thus neither a cohesive definition of autism nor specific neurological or behavioral determinants.

Attempts to define the disorder and explain the range of dysfunctions which manifest in the autism spectrum have resulted in some prominent theories. A hypothesized deficit in theory of mind suggests that individuals with autism cannot engage in metarepresentations, and thus have an inability to understand another's intent or mental state. Baron-Cohen, Leslie and Frith (1985) gave evidence of this inability using a mental state attribution task and have suggested it is a 'mindblindness' that may explain the social and communicative deficits of the disorder. Another such theory involves a weak central coherence (see Happé & Frith, 2006 for review), a concept that autistics process information on a local rather than a global scale. Evidence in autism such as superior performance in extracting details in the Embedded Figures Task (Ring et al., 1999) or piecemeal processing on Block Design tasks (Happé, Briskman & Frith, 2001) suggests that weak central coherence may underlie deficits with sensory processing or integration of information within a social environment. The idea of executive dysfunction in autism (Ozonoff, Pennington & Rogers, 1991) posits that at the core of the disorder is an inability to shift focus, thus explaining the repetitive behaviors and obsessive interests exhibited in autism. The executive dysfunction theory of autism implicates frontal lobe abnormalities in the disorder, yet the 'executive function' concept includes such a broad range of skills and behaviors that executive dysfunctions are shown to exist in

several other disorders, including those related to memory, emotion, inhibition and motor control. Furthermore, while these three theories might address individual behavioral aspects of autism, not one can fully account for the vast neurological abnormalities present in autism.

Physiological investigations of autism have indicated abnormalities in several regions of the brain which are associated with the primary components of attention. The brain's frontal lobes have been shown to develop more slowly in autistics than in typically developing individuals (Zilbovicius et al., 1995), and imaging data has shown reduced blood flow in the autistic frontal lobes during tasks requiring conflict resolution and mental state attribution to others (Happé et al., 1996). Reduced neural activations have also been observed in regions of the temporo-parietal cortex in autistics during tasks requiring biological imitation (Williams et al., 2006), and greater activation in several parietal regions during set shifting (Schmitz et al., 2006). Similarly, imaging investigations of the anterior cingulate cortex have given evidence of reduced blood flow in autism during tasks requiring executive attention (Siegel, Nuechterlein, Abel, Wu & Buchsbaum, 1995).

In addition, data from some of the early structural and post-mortem imaging investigations with young autistic patients give evidence of cerebellar hypoplasia (Harris, Courchesne, Townsend, Carper & Lord, 1999; Courchesne, Chisum & Townsend, 1994), and there have been consistent reports of decreased numbers of Purkinje neurons in autistic cerebellar lobes (e.g., Bailey et al., 1998). Furthermore, a general overgrowth of the brain early in postnatal development has consistently been reported in autism (Courchesne, 2004; Courchesne, Carper & Akshoomoff, 2003, Piven et al., 1995).

### *Attention in Autism*

Attention in autism has been an area of interest to investigators since the disorder was first defined in 1943 (Kanner, 1943). Yet very little is known and generally accepted about the precise attentional deficits prevalent throughout the autistic population. Extended selective attention (Waterhouse, Fein & Modahl, 1996) was proposed as a neurofunctional impairment in autism caused by abnormal development in the parietal and temporal lobes; it has been suggested this functional impairment is responsible for dysfunctional attention shifting in autism. Similar research supports the primary role of attention shifting deficits in autistic disorders (Courchesne et al., 1994; Pascualvaca, Fantie, Papageorgiou & Mirsky, 1998; Schmitz et al., 2006), while others emphasize dysfunctions in attention orienting (Casey, Gordon, Mannheim, & Rumsey, 1993; Harris et al., 1999; Mottron, Dawson, Soulières, Hubert, & Burack, 2006) and arousal (Barry & James, 1988; Dawson & Levy, 1989). Belmonte and Yurgelun-Todd (2003) provide evidence of reduced activations in parietal, dorsolateral prefrontal and medial frontal regions of the brain during a visual attention task, and electrophysiological data show impaired performance in attention orienting in autism (Belmonte, 2000). It is widely suggested that the autistic brain uses atypical mechanisms during attentional processes, and although not currently a part of the diagnostic criteria for Autistic Disorder (APA, 2000), these and other data suggest dysfunctional attention is one of the disorder's core deficits.

### *The Attention Network Task*

The Attention Network Task (*ANT*, Fan et al., 2002) combines a Posner (1980) cueing paradigm with an Eriksen flanker task (Eriksen & Eriksen, 1974) to provide independent measures (Fan et al., 2002; Rueda et al., 2004) of efficiencies of the

previously discussed alerting, orienting and executive attention networks. Using temporal and spatial cues, a cue stimulus task activates the alerting and orienting networks, while the use of a flanker interference stimulus involves the executive, or conflict resolution, network. Incorporation of the two into one task requires use and allows measurement of all three networks within a single task. In typically developing, healthy individuals, the ANT has been shown to activate the separate neuroanatomical regions respective to each of the networks during the recruitment of different components of the attention system required during the task (Fan et al., 2005) and is shown to be a reliable tool to assess efficiency and independence of the three primary networks of attention (Fan et al., 2002).

### *The Current Study*

There were several overall objectives of the study discussed herein. First, as the regions of the brain purportedly recruited for the three networks of attention have all been associated with the atypicalities present in ADHD and autism, and as measures of these three attention networks have not been reported in these disorders using the ANT, we wished to explore the alerting, orienting, and executive networks of attention in both an ADHD and an autistic sample. We sought to examine how these networks function either similarly or differently than the same attention networks in a nonclinical sample. We also wished to evaluate and compare attention networks between the ADHD and autistic samples.

Our other primary goal was to develop and use a social variant of the Attention Network Task (Fan et al., 2002) to measure the effects of social cues on attention networks in three target samples. We discuss the development of this task variant which incorporates eye-gaze cues to measure the three attention networks. We also

discuss attention network efficiencies in a nonclinical sample, as well as a small autistic sample, using the social variant of the ANT.

## CHAPTER TWO

### Experiment One: Attention Networks in Attention-Deficit Hyperactivity Disorder

#### *Attention-Deficit Hyperactivity Disorder and the ANT*

As discussed in Chapter One, there is substantial evidence that differences exist between nonclinical and ADHD populations on tasks recruiting the various components of attention. Also, the ANT is shown to elicit efficiency measures of the alerting, orienting and executive attention processes which have been localized to brain regions shown to be dysfunctional in ADHD. However, there are very few published reports of these efficiency measures obtained using the original ANT (Fan et al., 2002) with ADHD individuals.

A modified version of the ANT, one including invalid cue trials and target presentation to the left and right of fixation, elicited group differences between ADHD and nonclinical groups as functions of cue type and target condition (Konrad et al., 2005). While there were no reported group differences in either of the alerting or orienting networks, the executive network in the ADHD group performed significantly less efficiently than in nonclinical, and overall stimulus reaction times were slower in ADHD participants.

A similar investigation of attention in ADHD examined orienting among inattentive and combined inattentive/hyperactive DSM subtypes of the disorder (American Psychiatric Association, 2000). Oberlin et al. (2005) administered the ANT to a nonclinical group and a group of ADHD individuals both on and off stimulant medications. While various group orienting differences were found between the testing groups while in different medicated states (see Oberlin et al, 2005, for complete results), these data include subjects with disorders comorbid to ADHD and

were obtained from adults whose most recent diagnoses were made before age eight, and thus will not be discussed in further detail herein.

*This Experiment: Objectives and Hypotheses*

The primary goal of this experiment was to use the ANT (Fan et al., 2002) to investigate attention networks in individuals theorized to have frontal lobe dysfunctions, particularly those diagnosed with Attention-Deficit Hyperactivity Disorder, and compare these to the same networks in individuals with no such diagnoses. As there currently are no published reports of efficiency effects in ADHD using a nonmodified version of the ANT (Fan et al., 2002), we specifically sought to use the original version of the task to replicate network effects reported by Fan et al. (2002) in nonclinical individuals, and to compare those effects with those we found in an ADHD sample.

We also wished to examine the effects of different types of target cues and flanker distractors in ADHD and nonclinical populations. Similar to Konrad et al. (2005), we anticipated similar alerting and orienting network effects amongst the two samples. However, because more brain regions (multiple areas of the prefrontal cortex as well as the ACC) are typically recruited in conflict, or executive attention, tasks, than for either alerting or orienting, and considering evidence of ADHD dysfunction in these brain regions, we hypothesized there would be differences in the efficiency of executive networks between ADHD and nonclinical individuals. Furthermore, we hypothesized that nonpredictive target cues would cause considerably slower responses in ADHD individuals than in individuals without reported attention deficits.

## Method

### *Subjects*

Our participant groups comprised 41 undergraduate students between the ages of 17 and 30. Data from 18 subjects with ADHD (11 female) and 23 nonclinical subjects (18 female) were collected. The mean age of the ADHD group was 21.9 years (S.D. = 2.7), while the mean age for the nonclinical group was 20.4 (S.D. = 1.9). All participants were self-selected; those in the nonclinical group were recruited through Cornell University's Psychology Experiment participation website, via advertisements posted throughout the Cornell University campus, and from within Cornell University Psychology and Human Development courses. ADHD participants were recruited from amongst a university database of students formally registered with Cornell University's Department of Student Disability Services; at the time of testing, all were registered with the university with a clinical diagnosis of Attention-Deficit Hyperactivity Disorder.

Prior to participation, subjects in both groups completed the Subject Data Form (see Appendix A), wherein each ADHD participant was asked to report respective diagnoses. No nonclinical participants reported either a current or past diagnosis of attention disorders. Data were also collected about handedness, age and gender.

Informed consent was obtained following the established guidelines of the Cornell University Committee on Human Subjects. Those subjects in the nonclinical group were compensated with extra course credit. Subjects in the ADHD group were given the option to receive either extra course credit or a ten-dollar monetary award.

### *Apparatus*

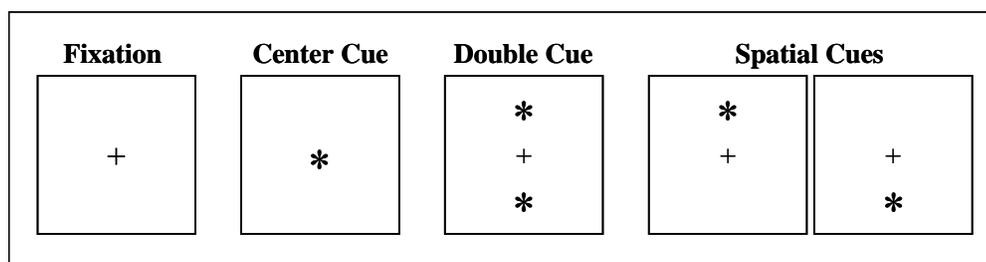
Stimuli were presented on a white background on a Dell 14-inch CRT computer monitor using E-Prime software version 1.1. Responses were collected using the left and right buttons of a standard personal computer external mouse. Each

participant's seated position was adjusted so the center of the screen was at approximately eye level at a distance of about 18 inches from the eyes.

### *Stimuli*

We used the Attention Network Task (ANT, Fan et al., 2002). This task assesses alerting (A), orienting (O) and executive (E) networks of attention by requiring subjects to indicate the status of a target stimulus when presented following one of four types of cues. Using subtractions of mean reaction times (referred to hereinafter as 'RT') under various trial conditions, the ANT provides independent measures (referred to hereinafter as '*efficiency effects*') of the three attention networks.

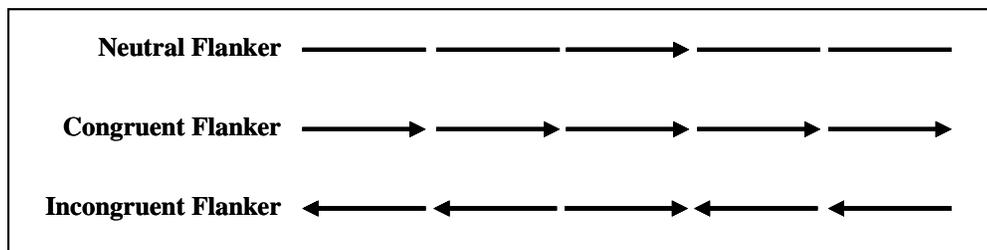
Each ANT trial begins with a fixation cross located in the center of a computer monitor for a duration randomly varied between 400 and 1600 msec. Following this fixation, one of four cue types appears on the screen for 100 msec: a single asterisk in the place of the central fixation cross (*center cue*); a single asterisk either above or below the central fixation cross (*spatial cue*); asterisks both above and below fixation presented simultaneously (*double cue*); or presentation of *no cue* (see Figure 1). The center-cue and double-cue conditions serve to alert subjects to upcoming stimulus presentation but provide no information as to the location of the upcoming target presentation. The no-cue condition provides neither alerting nor orienting information. Spatial cues, however, are locationally predictive, so provide both alerting and orienting information.



**Figure 1.** Experiment One ANT cue conditions. **NOTE:** not drawn to scale.

Immediately following cue presentation, a target stimulus is presented for 400 msec. The target stimulus is a .48cm arrow pointing to either the left or to the right in one of three flanker types.

Target flankers are arrays of arrows, two appearing on either side of the target arrow, which are the same size as the target. There are three possible flanker types: 1) *neutral*, which consists of four lines without arrowheads flanking the target arrow, two on either side of the target; 2) *congruent*, in which all four flanker arrows point to the same direction as the target arrow; and 3) *incongruent*, in which all four flanker arrows point to the direction opposite that of the target arrow (see Figure 2).



**Figure 2.** Experiment One ANT target conditions. **NOTE:** Not drawn to scale.

Each trial's response consists of a button press, input by the participant via the left or right button of the computer's external mouse, indicating the direction to which each central target arrow points. The ANT consists of one practice block of 24 trials followed by three testing blocks each of 96 trials. Combinations of four cue types and three flanker types provide twelve conditions. Each of the twelve conditions is randomly presented twice in the practice block, once with a leftward pointing target and once with a rightward pointing target, and eight times in each of the three testing blocks, four times with a leftward pointing target and four times with a rightward pointing target.

Each ANT trial has a maximum duration of 3500 msec. Fixation to target presentation time is 1600 msec, and subjects are allowed 1700 msec to indicate a response. If no response is entered during the 1700 msec allotted response time, the individual trial ends and the next begins. Trials for which no responses are indicated are recorded by the computer as “NULL”.

### *Procedure*

Each subject was seated in a quiet, closed room at a table where the subject faced a computer monitor. Following consent procedures, subject was verbally instructed to attend to the central fixation cross. Subject was told an array of arrows would appear either above or below the cross and was instructed to indicate, using either of the two buttons of the computer’s mouse, if the arrow in the center of the array was pointing to the left or to the right. Subject was informed that prior to target presentation, there may have been other symbols flashing in various locations on the screen, and reminded to focus gaze on the center of the screen. Examiner demonstrated how to hold the computer’s mouse between the two hands while using the left or the right thumb to indicate left or right responses, respectively. Examiner exited the testing room once subject indicated understanding of the task. Subject then read written instructions on the computer monitor and proceeded through the practice and testing blocks following on-screen instructions.

Total testing time was approximately 20 minutes. Breaks between testing blocks were provided, during which time subjects were permitted to move back from the computer and stand if necessary.

### *Measures*

The ANT measures RT in milliseconds between target stimulus onset and subject response via button press. Mean reaction times were calculated for each of the twelve trial conditions, and using identical cognitive subtractions as those used by the

original authors (Fan et al., 2002), we determined efficiency effects of the alerting, orienting and executive attention networks for each subject. Alerting efficiency effect  $A$  was obtained by collapsing the three flanker types and subtracting mean RT of all double cue conditions from mean RT of all no cue conditions. Orienting efficiency effect  $O$  was obtained by collapsing the three flanker types and subtracting mean RT of all spatial cue conditions from mean RT of all center cue conditions. Executive efficiency effect  $E$  was obtained by subtracting mean RT of congruent flanker conditions across all cue types from mean RT of incongruent flanker conditions across all cue types. We calculated an additional executive effect,  $E2$ , to analyze the effect of conflicting interference in all flanker trials. This was obtained by subtracting mean RT of neutral flanker conditions across all cue types from the mean RT of incongruent flanker conditions across all cue types. To examine the effect of non-conflicting interference in flanker conditions, we calculated a flanker control effect  $C$  by subtracting mean RT of neutral flanker conditions across all cue types from mean RT of congruent flanker conditions across all cue types. All efficiency effects are measured in milliseconds.

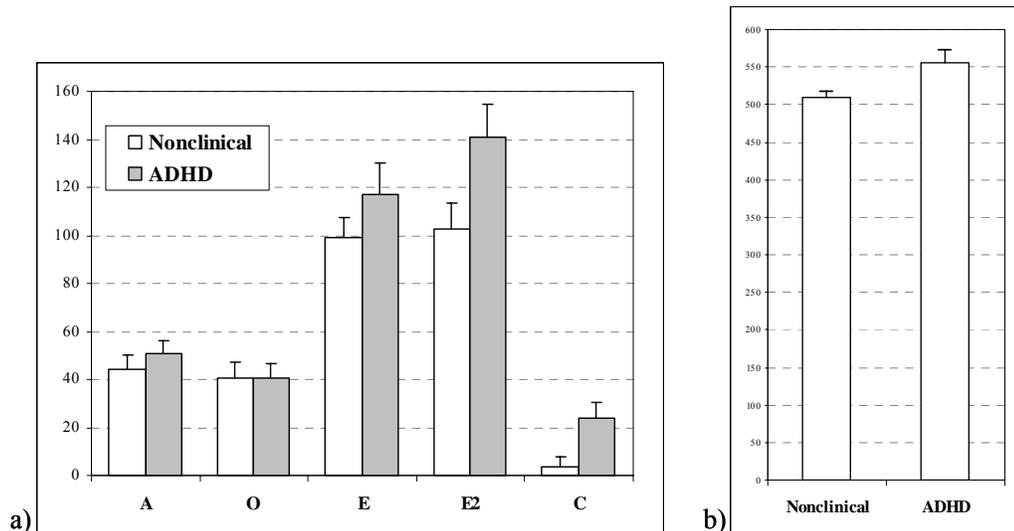
### *Analyses*

We analyzed RT for all correct responses. Due to high rates of consecutive ‘NULL’ responses, data from four participants of the nonclinical group were not included in the analyses reported herein.

We performed ANOVAs to examine various differences in performances between the ADHD and nonclinical groups. We also performed correlation analyses to measure within-group independence of the three efficiency effects.

## Results

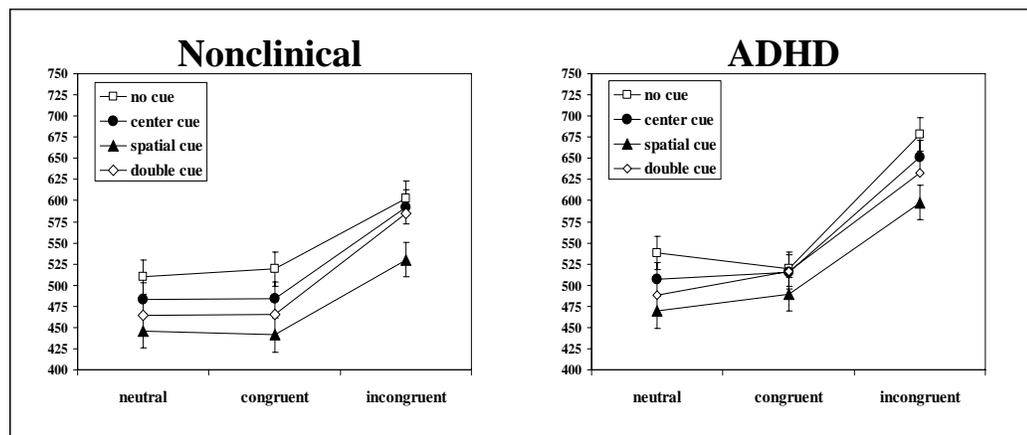
The network efficiency effects we found in our nonclinical subjects were similar to those found in previous investigations using the ANT (Fan et al., 2002, Callejas, Lupiáñez & Tudela, 2004). Our mean *A* efficiency effect was 44 (S.D. = 27) for nonclinical and 51 (S.D. = 22) for ADHD subjects; the mean *O* efficiency effect was 41 (S.D. = 31) for nonclinical and 40 (S.D. = 25) for ADHD participants; and the mean *E* efficiency effect *E* was 99 (S.D. = 41) for nonclinical and 117 (S.D. = 54) for the ADHD group. There were no significant differences in these effects between groups [ $F_{\text{alerting}}(1,39) = .75$ , ns;  $F_{\text{orienting}}(1,39) = .001$ , ns;  $F_{\text{executive}}(1,39) = 1.48$ , ns]. Group network efficiency effects are shown in Figure 3a, and group differences in overall RT shown in Figure 3b.



**Figure 3.** Experiment One group mean (SEM) efficiency effects and overall mean (SEM) RT.

Our analyses of executive effect *E2* [ $F(1,39) = 6.88$ ;  $p < .05$ ] and flanker control measure *C* [ $F(1,39) = 5.21$ ,  $p < .05$ ], yielded significant group differences, indicating the ADHD group performed more slowly than nonclinical on all trials with

arrowhead target flankers. Further analyses of RT data indicated that neutral flanker conditions yielded nonsignificant yet faster RT in the nonclinical group [ $F(1,39) = 2.26$ , ns]. The ADHD group performed more slowly in congruent flanker conditions [ $F(1,39) = 5.48$ ,  $p < .05$ ], and in incongruent flanker conditions [ $F(1,39) = 6.53$ ,  $p < .05$ ] than did the nonclinical group (see figure 4).



**Figure 4.** Experiment One group mean (SEM) RT by cue and flanker types.

Within-group analyses of neutral flanker conditions yielded significantly faster mean RT in both the ADHD group [ $t(17) = -10.46$ ,  $p < .001$ ] and the nonclinical group [ $t(22) = -9.91$ ,  $p < .001$ ] than incongruent flanker conditions. The ADHD group performed more quickly in neutral flanker conditions [ $t(17) = -3.47$ ,  $p < .01$ ] than in congruent conditions. There was no difference in the nonclinical group's RT between neutral and congruent [ $t(22) = -0.89$ , ns].

We collapsed incongruent and congruent flanker types across all cue conditions. Within-group RT analyses indicate that in the presence of a flanker across all cue types there is a significantly slowed RT in both the nonclinical group,  $t(22) = -8.01$ ,  $p < .001$ , and in the ADHD group  $t(17) = -9.62$ ,  $p < .001$ . Overall mean RT were slower in the ADHD group [ $F(1,39) = 5.45$ ,  $p < .05$ ].

Cue type analyses resulted in slower mean RT by the ADHD group in predictive spatial cue [ $F(1,39) = 4.33; p < .05$ ], nonpredictive double-cue [ $F(1,39) = 5.77; p < .03$ ], and no-cue conditions [ $F(1,39) = 6.04; p < .02$ ] than by the nonclinicals. Center-cue conditions yielded a nearly significantly slower RT in the ADHD group [ $F(1,39) = 4.05; p = .051$ ].

Despite being a nonsignificant difference, the mean error rate [ $F(1,39) = 2.11; ns$ ] was higher in the nonclinical group (13.6; S.D. = 22.0) than in the ADHD group (5.9; S.D. = 4.4). There were no effects of gender or handedness in any condition in either of the two groups.

Correlation analyses within individual subjects indicated no correlations between the *A*, *O* or *E* effects in either the ADHD or the nonclinical group. In the nonclinical group, executive effects *E* and *E2* were correlated [ $r(23) = .90, p < .001$ ] as were *E2* and *C* [ $r(23) = .48, p < .05$ ]. The ADHD group's *E* and *E2* effects were also correlated [ $r(16) = .87, p < .001$ ].

## Discussion

Our goals in this investigation were to use the original Attention Network Task (Fan et al., 2002) to measure efficiency effects of the three attention networks outlined by Posner and Petersen (1990) in typical subjects, and to compare those effects to the same in individuals diagnosed with ADHD. Our RT and efficiency effect calculations replicate those reported in previous investigations using the ANT with typical persons. Results from our correlation analyses indicate the network effect calculations used in the ANT (Fan et al., 2002) measure independent efficiency effects of the alerting, orienting and executive networks of attention in typical healthy persons. We interpret these data to indicate that the ANT is a reliable tool for the measurement of three independent components of the attention process in typically developing individuals.

Although using the ANT's original RT subtraction does not yield the expected *E* executive attention network differences between our ADHD and nonclinical groups, we provide two additional subtractions, *E2* using flanked (both congruent and incongruent) target conditions and *C*, neutral, unflanked target conditions, indicating a significantly slower overall reaction time in the ADHD group in the presence of a flanker distractor. Within both participant groups, *E* and *E2* were correlated, indicating the consistence within subjects of the two executive effects, and showing that *E2* is a valid calculation with which to measure the effect of arrowhead flanker interference in the ANT task (Fan et al., 2002).

The most interesting finding of this investigation was the slowed reaction time in both nonclinical and ADHD participants in these target conditions flanked with arrowheads, and the very highly significant difference in the nonclinical group's mean RT between neutral and incongruent trials. Previous research shows that flanker interference affects speed of target identification (Eriksen & Eriksen, 1974; Fan et al., 2003a), and Oberlin et al. (2005) demonstrated a similar group difference between medicated ADHDs and nonclinical when comparing them with non-medicated ADHD participants. Nonetheless, our within-group differences between neutral and congruent flanker and between congruent and incongruent flanker are very interesting. While we expected significantly slowed reaction times in ADHD in incongruent flanker conditions where conflict resolution was required, we did not anticipate such a significantly slowed time in both groups in congruent flanker conditions where no conflict exists.

In addition, both nonclinical and ADHD participants show significant effects of flanker type when comparing incongruent with neutral conditions. While our analysis of executive attention network *E* did not show this effect, our analysis of effect *E2* did indicate a significantly slowed response on incongruent trials. We

propose that when using the ANT, efficiency of the executive network may be more appropriately measured by examining incongruent flankers compared with neutral flankers, rather than incongruent flankers compared with congruent flankers.

### *Limitations and Considerations*

When considering error rate differences between our two groups, as overall reaction time for the nonclinical group was significantly faster than that of the ADHD group, we surmise that nonclinical participants traded reaction speed for accuracy. The lower mean error rate in the ADHD group could also be a result of either the recruiting method or the form of compensation. Those recruited through a formal University department such as the Student Disability Services used in this study may have considered the study to be more serious than those recruited using less formal methods; the task may have thus been approached by these subjects more carefully. Similarly, although all participants were compensated for participation regardless of performance, the ADHD participants receiving monetary compensation may, again, have approached the task more carefully than those receiving extra course credit, as monetary compensation may have been a more salient reward.

Despite these interesting results, due to the small number of participants in this study, limited conclusions may be drawn from these data. The range of attention difficulties present in the ADHD population (Barkley, 1997) is not measurable using only the ANT. Our data suggest only that flanked targets are more difficult for ADHD individuals to respond to than for nonclinical persons, and our results do not address skills required for other tasks involving conflict, such as the Stroop task.

Furthermore, due to ethical restraints as the targeted population was from a student body, we were unable to request ADHD subjects to be non-medicated (if applicable) during their testing sessions. Further investigations with similar

participants are necessary to ascertain whether non-medicated ADHD subjects perform comparably to typical and medicated ADHD individuals on the ANT. Another consideration regarding diagnosis was the ADHD subtypes (APA, 2000). We neither collected information about diagnostic subtype nor differentiated amongst our ADHD subjects based on possible subtypes. As these subtypes are shown to exhibit differences on attention tasks (Oberlin et al., 2005), subtypes should be analyzed in future investigations.

## CHAPTER THREE

### Experiment Two: The Social Attention Network Task

As discussed in Chapter One, research suggests eye gaze plays a crucial role in directing another person's attention within a social engagement or interaction. Despite abundant investigations of the effects of eye-gaze cues on attention, however, none have yet used any sorts of social stimuli in combination with the Attention Network Task (ANT; Fan et al., 2002) to measure the effects of eye-gaze cues on the alerting, orienting, and executive networks of attention.

The three attention networks have all been associated with specific brain regions and neuromodulators (see Chapter One for a thorough discussion). Similarly, the brain has been shown to recruit specific regions during the processing of eye gazes or other such social stimuli. Because eye gaze has a documented effect on the direction of attention (Driver et al., 1999), and because the ANT has shown to be a reliable measure of the attention process (e.g. Callejas et al., 2004), we wished to investigate the effects of a social stimulus on attention networks using a slight modification of this widely-used attention task.

Using a shortened version of the ANT, we substituted the Posner (1980) asterisk cueing stimuli in the task with eye-gaze cues. We developed four different eye-gaze stimuli sets and ran preliminary tests of the four versions of the cue-modified ANT task. Based on these results, we then further investigated the one task version whose stimuli elicited efficiency effects most similar to, and in some cases stronger than, those obtained with the ANT using the original asterisk cues. We also tested an additional modification of the ANT to isolate variables we feel may have affected the network efficiency effects obtained by the ANT and by the social variant of the ANT.

### *This Experiment: Objectives and Hypotheses*

We had several goals for this experiment, the primary being identification of the effects on the three defined attention networks (Posner and Petersen, 1990) of a cue salient to human social interaction. By investigating the effects of four sets of eye-gaze stimuli, each set used within one version of the attention task, we aimed to develop an effective social variant of the ANT (hereinafter referred to as 'SANT'). Furthermore, we sought to examine attention processes using more realistic and isolated gaze cues than those used in previous studies of eye-gaze cueing. Drawn illustrations of human eyes have been used to study gaze-cue effects on attention (Ristic, Friesen & Kingstone, 2002; Tipples, 2005) as have full faces (Downing et al., 2004; Kylliäinen, Braeutigam, Hietanen, Swithenby & Bailey, 2006; Langton & Bruce, 1999). These eye-gaze illustrations have all failed to consider the iris:sclera proportion as eye gaze shifts to the periphery, while the full-face images used include details non-relevant to gaze orienting such as emotion or full facial features such as the mouth. We thus planned to investigate the effects of a realistic, isolated eye-gaze cue on attention.

We anticipated each SANT to provide dissimilar measures of the three attention networks. From the task versions employing gaze cues, we anticipated more efficient alerting, orienting, and executive attention networks than those observed in the original, non-social variant of the ANT. We also anticipated data to indicate a facilitating effect of the eye-gaze cues, thus causing shorter overall reaction times on all trials in SANT versions using these cues.

## Experiment 2.1: Development of the Social Attention Network Task (SANT)

### *Part One: Verifying Stimuli Effectiveness*

Before performing a complete investigation of the four SANT versions, we first confirmed the effectiveness of the four sets of eye-gaze stimuli.

#### Method

There were four versions of the SANT task (SANT1, SANT2, SANT3, SANT4) analyzed for Part One. Each of the four is a modification of the Attention Network Task (Fan et al., 2002). Each SANT was administered using identical procedures; the only differences between each version were the cueing stimuli used. The general procedures for all SANT versions are discussed below, followed by details concerning the stimuli specific to each SANT.

#### *Subjects*

20 individuals (12 females) between the ages of 18 and 25 participated in Part One. Each was administered both a shortened version of the ANT and one of four versions of the SANT, resulting in administration of all SANTs to five participants. Both task administration order (either ANT or SANT first) and SANT version administered were randomly assigned.

The overall mean age of the participants was 20.5 years (S.D. = 1.9); SANT1 mean age was 20.5 (S.D. = 1.3), 4 females; SANT2 mean age was 20.8 (S.D. = 2.5), 3 females; SANT3 mean age was 19.6 (S.D. = 1.3), 3 females; SANT4 mean age was 21.0 (S.D. = 2.5), 2 females.

For all parts of Experiment Two, all participants were self-selected. Participants were recruited through Cornell University's Psychology Experiment participation website, via advertisements posted throughout the Cornell University

campus, and from within Cornell University Psychology and Human Development courses. Prior to participation, all participants completed the Subject Data Form (see Appendix B). No participants reported either a current or past diagnosis of attention disorders or Autism Spectrum Disorders. Data were also collected about handedness, age and gender.

Informed consent was obtained following the established guidelines of the Cornell University Committee on Human Subjects. Participants were compensated with extra course credit and entry into a raffle for which a winner would be awarded either an MP3 player or music gift card.

### *Apparatus*

Stimuli were presented on a white background on a Dell 19-inch LCD flat panel computer monitor using E-Prime software version 1.1. Responses were collected using the right and left buttons of a standard personal computer external mouse. Each participant's seated position was adjusted so the center of the screen was at approximately eye level at a distance of about 18 inches from the eyes.

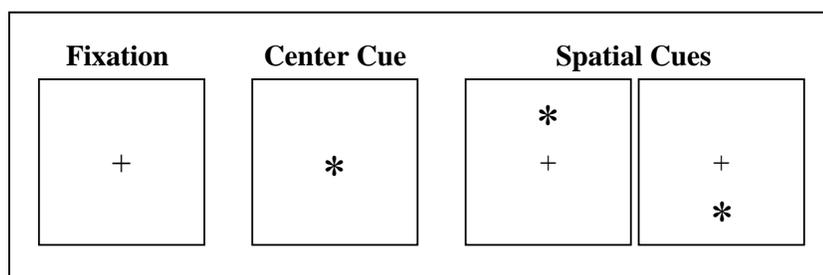
### *Stimuli*

#### ANT

We used a modified version of Attention Network Task (ANT, Fan et al., 2002). As discussed in Chapter Two, the ANT assesses alerting (A), orienting (O) and executive (E) networks of attention by requiring subjects to indicate the status of a target stimulus when presented following various types of cues. The ANT modification used in this experiment was a shortened version of the original task. As there are few data showing significant differences in alerting effects under trial conditions using a double cue as compared with those trials using a center cue, we removed all double cue trials from the ANT.

Our shortened ANT consists of one practice block of 18 trials followed by three testing blocks each of 72 trials. Combinations of three cue types and three flanker types provide nine trial conditions. Each of the nine conditions is randomly presented twice in the practice block, once with a leftward pointing target and once with a rightward pointing target, and eight times in each of the three testing blocks, four times with a leftward pointing target and four times with a rightward pointing target.

Each ANT trial begins with a fixation cross located in the center of a computer monitor for a duration randomly varied between 400 and 1600 msec. Following this fixation, one of three cue types appears on the screen for 100 msec: a single asterisk in the place of the central fixation cross (*center cue*); a single asterisk either above or below the central fixation cross (*spatial cue*); or presentation of *no cue* (see Figure 5). The center-cue condition serves to alert subjects to upcoming stimulus presentation but provides no information as to the location of the target presentation. The no-cue condition provides neither alerting nor orienting information. Spatial cues, however, are locationally predictive, so provide both alerting and orienting information.



**Figure 5.** Experiment Two ANT cue conditions. **NOTE:** not drawn to scale.

Immediately following cue presentation, a target stimulus is presented for 400 msec. We used identical target stimuli to those used in Experiment One.

## SANT

We used four versions of the SANT.

Each SANT uses a variation of a social cue in place of the asterisk cues presented as stimuli in the ANT. Each SANT consists of one practice block of 18 trials followed by three testing blocks each of 72 trials. Combinations of three cue types and three flanker types provide nine trial conditions; each of these conditions is randomly presented twice in the practice block and four times in each of the three testing blocks.

## SANT1

In SANT1, each trial begins with a central eye-gaze fixation located in the center of the monitor for a duration randomly varied between 400 and 1600 msec. Following fixation, one of three cue types appears for 100 msec in place of the center eye-gaze fixation: a central eye gaze with eyes more widely opened than fixation (*center cue*); an eye gaze with eyes averted to either the left or to the right (*spatial cue*); or no change of the central fixation gaze (*no cue*; see Figure 6).

## SANT2

SANT2 is similar to SANT1, only the spatial cues in SANT2 are eye gazes to above and below central fixation rather than to the left and the right. Each trial begins with a central eye-gaze fixation visible on the screen for a duration randomly varied between 400 and 1600 msec. Following fixation, one of three cue types appears for 100 msec in place of the center eye-gaze fixation: a central eye gaze with eyes more widely opened than fixation (*center cue*); an eye gaze with eyes averted to either above or below fixation (*spatial cue*); or no change of the central fixation gaze (*no cue*; see Figure 6).

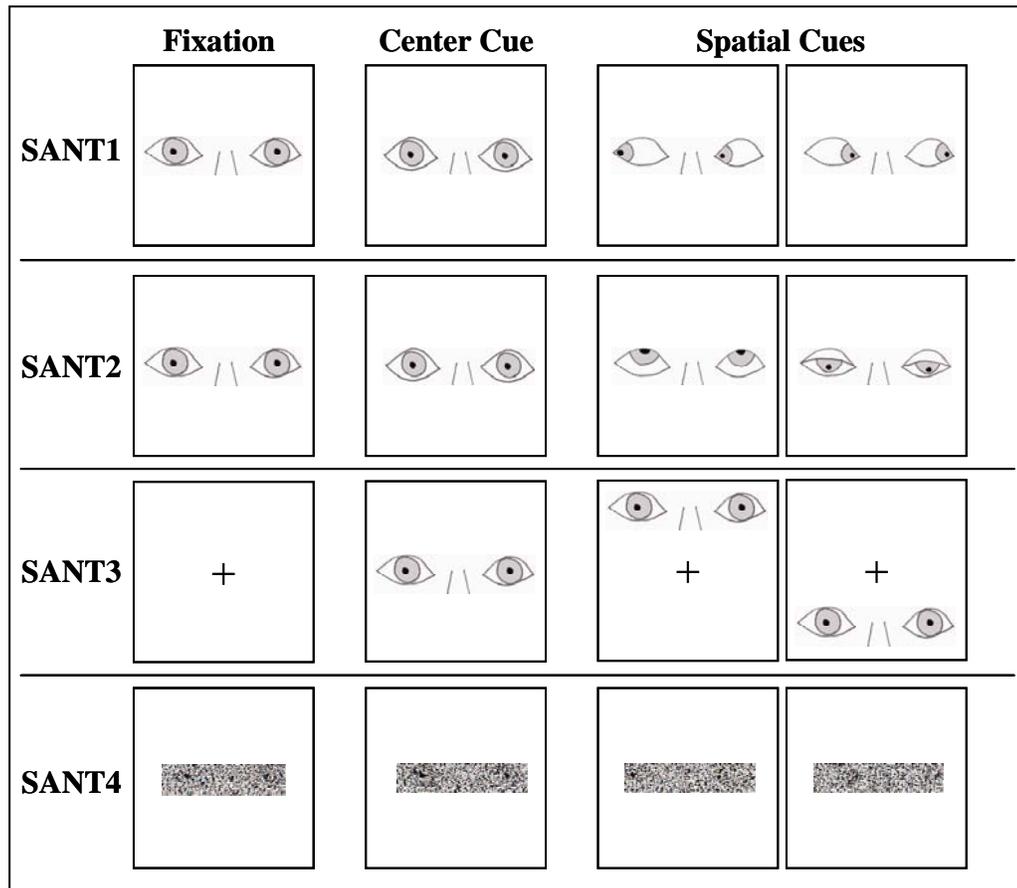
### SANT3

SANT3 uses a central eye gaze in one of three locations on the screen rather than averted eye gazes in place of central fixation. Each trial begins with a fixation cross (+) located in the center of the monitor for a duration randomly varied between 400 and 1600 msec. Following fixation, one of three cue types appears on the screen for 100 msec: a central eye gaze in the place of the central fixation cross (*center cue*); a central eye gaze located either above or below the central fixation cross (*spatial cue*); or presentation of *no cue* (see Figure 6).

### SANT4

SANT4 serves to act as a baseline and uses scrambled versions of the eye-gaze stimuli used for SANT1. In an attention-orienting investigation using eye-gaze cues, Bayliss and Tipper (2005) used scrambled faces to compare differences in response times between object and sociobiological stimuli. Each SANT4 trial begins with a scrambled central eye-gaze fixation located in the center of the monitor for a duration randomly varied between 400 and 1600 msec. Following fixation, one of three cue types appears for 100 msec in place of the scrambled center eye-gaze fixation: a scrambled central eye gaze with eyes more widely opened than fixation (*center cue*); a scrambled eye gaze with eyes averted to either the left or to the right (*spatial cue*); or no change of the central fixation (*no cue*; see Figure 6).

In all SANTs, the center-cue conditions serve to alert subjects to a forthcoming stimulus presentation but provide no information as to the location of the target presentation. All spatial cues are locationally predictive and provide both alerting and orienting information about the forthcoming stimulus. The no-cue conditions provide neither alerting nor orienting information.



**Figure 6.** Experiment Two eye-gaze cue conditions for each SANT. **NOTE:** not drawn to scale.

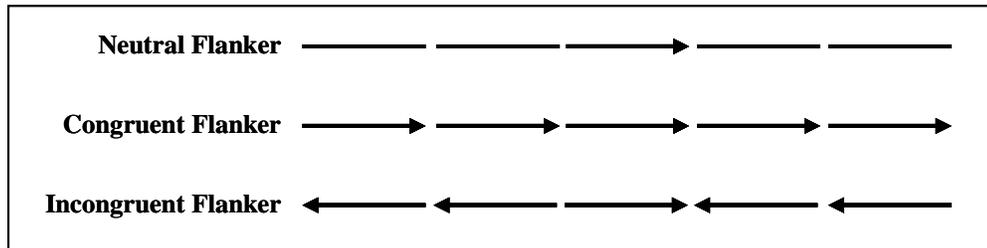
### *The SANT Task*

Immediately following cue presentation, the target stimulus is presented for 400 msec. The target stimulus is a .48cm arrow pointing to either the left or to the right in one of three flanker types.

Target flankers are arrays of arrows, two appearing on either side of the target arrow, which are the same size as the target. There are three possible flanker types:

- 1) *neutral*, which consists of four lines without arrowheads flanking the target arrow, two on either side of the target;
- 2) *congruent*, in which all four flanker arrows point to

the same direction as the target arrow; and 3) *incongruent*, in which all four flanker arrows point to the direction opposite that of the target arrow (see Figure 7)



**Figure 7.** Experiment Two SANT target conditions. **NOTE:** Not drawn to scale.

In SANT1 and SANT4, the flanked target arrow appears to either the left or to the right of the central fixation. In SANT2 and SANT3, the flanked target arrow appears either above or below central fixation.

Each trial's response consists of a button press, input by the participant via the left or right button of the computer's external mouse, indicating the direction to which each central target arrow points. Each trial has a maximum duration of 3500 msec. Fixation-to-target presentation time is 1600 msec and subjects are allowed 1700 msec to indicate a response. If no response is given during the 1700 msec allotted response time, that single trial ends and the next begins. Trials in which no response is indicated are recorded by the computer as "NULL".

### *Procedure*

Each subject was seated in a quiet, closed room at a table where the subject faced a computer monitor. Following consent procedures, subject was given verbal instructions for the first of the two tasks. Subject was asked to attend to the central fixation specific to either the ANT or the version of the SANT administered. Subject was told an array of arrows would appear and was instructed to indicate, using one of the two buttons of the computer's mouse, if the arrow in the center of the array was

pointing to the right or to the left. Subject was informed that prior to target presentation, there may have been other symbols flashing in various locations on the screen, and reminded to focus gaze on the center of the screen. Examiner demonstrated to each participant how to hold the computer's mouse between the two hands while using the right or the left thumb to indicate right or left responses, respectively. Subjects then read written instructions on the computer monitor and proceeded through the practice and testing blocks following on-screen instructions. Upon completion of the first task, examiner loaded the second task and, in the same manner as for the first task, gave verbal instructions for the second task. Subjects read written instructions on the computer monitor and proceeded through the practice and testing blocks following on-screen instructions.

Total testing time was approximately 35 minutes. Breaks between testing blocks and tasks were provided, at which times subjects were permitted to move back from the computer or stand if necessary.

### *Measures*

For the shortened version of the ANT, we calculated the same orienting and executive efficiency effects discussed in Chapter One. Alerting effect *A* for the shortened ANT was obtained by collapsing the three flanker types and subtracting mean RT of all center cue conditions from mean RT of all no cue conditions.

Similar to the ANT, the SANT measures reaction times (RT) in milliseconds between target stimulus onset and subject response via button press. Mean reaction times were calculated for each of the nine trial conditions, and using similar cognitive subtractions as those used by the original authors of the ANT (Fan et al., 2002), we determined efficiency effects of the alerting, orienting and executive attention networks for each subject. Social alerting effect *SA* was obtained by collapsing the three flanker types and subtracting mean RT of all center cue conditions from mean

RT of all no cue conditions. Social orienting effect *SO* was obtained by collapsing all three flanker types and subtracting mean RT of all spatial cue conditions from mean RT of all center cue conditions. Social executive effect *SE* was obtained by subtracting mean RT of congruent flanker conditions across all cue types from mean RT of incongruent flanker conditions across all cue types. We calculated an additional social executive effect, *SE2*, to analyze the effect of conflicting interference in all flanker trials. This was obtained by subtracting mean RT of neutral flanker conditions across all cue types from the mean RT of incongruent flanker conditions across all cue types. To examine the effect of non-conflicting interference in flanker conditions, we calculated a flanker social control effect *SC* by subtracting mean RT of neutral flanker conditions across all cue types from mean RT of congruent flanker conditions across all cue types. All efficiency effects are measured in milliseconds

### *Analyses*

We analyzed RT for all correct responses. We conducted t-tests to examine differences in participants' ANT and SANT efficiency effects and RT scores, and to verify that the new stimuli sets used in the SANTs effectively elicit attention networks in the same manner as the ANT. Data from one participant has been excluded from these analyses due to a high error rate on the SANT.

### Results

Pairwise comparisons indicated no differences in the alerting network efficiency effects between the ANT and any of the SANTs.

Orienting network efficiency effects differed significantly between the ANT and SANT4 [ $t(4) = -7.04, p < .005$ ], the ANT eliciting a far more efficient measure. Orienting differences between the two tasks neared significance in SANT3 [ $t(4) = -2.62, p = .059$ ], with the SANT eliciting the more efficient measure.

Executive network efficiency effects differed significantly between the ANT and two of the SANTS. SANT1 E [ $t(3) = 3.93, p < .05$ ] and E2 [ $t(3) = 6.10, p < .01$ ] were both less efficient than the respective measures in the ANT. SANT3 E [ $t(4) = -3.05; p < .05$ ] was a more efficient measure than that obtained with the ANT. ANT-SANT differences neared significance in SANT4 E [ $t(4) = 2.50, p = .067$ ].

Mean efficiency effects and overall RT for the ANT and each SANT are listed in Table 1. Overall RT were significantly slower in both SANT1 [ $t(4) = 5.34, p < .05$ ] and SANT4 [ $t(4) = 9.72, p < .001$ ] than in the ANT.

**Table 1.** Experiment 2.1 Part One mean (SD) efficiency effects for ANT and for each SANT version.

ANT	A	O	E	E2	C	Overall RT
	34 (22)	40 (30)	139 (63)	115 (56)	9 (16)	498.22 (51.04)
SANT	SA	SO	SE	SE2	SC	Overall RT
1	51 (35)	55 (24)	168(33)	169 (24)	2 (10)	623.20 (60.04)
2	25 (12)	26 (26)	121 (38)	127 (54)	5 (17)	535.66 (56.36)
3	35 (25)	27 (23)	85 (16)	105 (28)	20 (28)	512.51 (53.61)
4	27 (20)	-6 (16)	218 (120)	228 (129)	10 (43)	654.20 (58.70)

### Discussion: Experiment 2.1 Part One

Our analyses of the network efficiency effects and RT in each SANT indicate the sets of stimuli used in SANTS 1, 2 and 3 do elicit measures of the three attention networks and thus recruit each of the three attention networks in a fashion comparable to the ANT (Fan et al., 2002), while SANT4 does not elicit a comparable measure of the orienting network. Preliminary results indicate that of the four versions of the task, SANT1 provides the most efficient measures of the alerting (51) and orienting (55) effects while SANT3 provides the most efficient measure of the executive (85) effect. A larger sample is required to draw any conclusions about these data. Part Two of this experiment is a more in-depth analysis of the SANT versions.

### *Part Two: SANT-SANT Analysis*

Data from Part One of this experiment indicate that the four sets of SANT stimuli do elicit various measures of the three attention networks. As one of our goals herein was to measure the strength of an eye-gaze cue to direct attention, our objective for Part Two of this experiment was to determine which of the SANTs provides the strongest orienting effect while still measuring the alerting and executive networks. We thus administered all four task versions to a larger participant group.

We anticipated strong alerting efficiency effects in SANTs 1, 2 and 3. Due to the similar types of cueing stimuli used, we expected similar alerting effects in SANTs 1 and 2. We also expected to obtain a stronger alerting effect in the earlier blocks within SANT3 as compared with later blocks due to a surprise effect caused by the size of eye-gaze stimulus used in the task. We anticipated the strongest orienting effect in SANT1 and the weakest in SANT4. We expected SANTs 2 and 3 to have similar orienting effects as cueing stimuli were designed to direct attention to the same location. We anticipated SANT1 to elicit the strongest executive efficiency effect and SANT4 the weakest. We also expected SANT3 would give a more efficient executive effect than SANT2 as the cueing stimuli in SANT3 were presented in the location of the upcoming target.

### Method

For Part Two, we used the same four versions of the SANT task (SANT1, SANT2, SANT3 and SANT4) used in Part One. As data from Part One indicate SANT4 fails to elicit a robust measure of the orienting network, and one goal herein was to determine which task provided a strong orienting effect, all data collected from SANT4 in this part of the experiment were excluded from these analyses. Each

participant was administered two variants of the SANT task. Each SANT was administered to equal numbers of participants with versions randomly selected and administration order counterbalanced across subjects.

### *Subjects*

40 typically developing individuals (26 female) between the ages of 18 and 25 participated in Part Two. Data from three participants were excluded from these analyses, two for high error rates and one due to procedural errors. The analyses discussed here include SANT data collected from the 19 participants in Part One of this experiment. The mean age of the participants was 19.8 years (S.D. = 1.6). SANT1 (n=22, 14 females) mean age was 19.9 (S.D. = 1.6); SANT2 (n=23, 15 females) mean age was 20.2 (S.D. = 1.7); SANT3 (n=25, 18 females) mean age was 19.5 (S.D. = 1.4).

### *Apparatus*

We used the same testing apparatus used for Part One of this experiment.

### *Stimuli*

We used the same four SANT tasks used for Part One of this experiment.

### *Procedure*

We followed identical testing procedures as those followed for Part One of this experiment. However, we did not administer the ANT; we administered two randomly selected SANT tasks to each participant.

### *Measures*

For each SANT, we calculated identical measures as those calculated for Part One of this experiment.

### *Analyses*

We analyzed RT for all correct responses. We performed ANOVAs to examine the differences in RT and efficiency effects between the SANT versions in

addition to within-task interactions. We performed within-task correlations to assess the independence of the network measures for each task version.

## Results

There were significant effects of cue and flanker types on RT in all three versions of the SANT. SANT1 cue [ $F(2,189) = 155.35, p < .001$ ] and flanker [ $F(2,189) = 25.96, p < .001$ ]; SANT2 cue [ $F(2,198) = 125.57, p < .001$ ] and flanker [ $F(2,198) = 15.45, p < .01$ ]; SANT3 cue [ $F(2,216) = 150.44, p < .001$ ] and flanker [ $F(2,216) = 16.96, p < .001$ ]. Interactions between cue and flanker types were found to be nonsignificant in all three SANTs.

Post hoc analyses of RT data indicate significant differences between SANTs 1 and 2 on all combinations of cue and flanker type (see Table 2). SANTs 2 and 3 differed significantly only in the incongruent flanker spatial cue condition [ $t(46) = 3.44, p < .001$ ]. Overall reaction times differed between SANTs 1 and 2 [ $t(43) = 6.72, p < .001$ ] and 1 and 3 [ $t(45) = 9.60, p < .001$ ]. Mean overall reaction times and reaction times as a function of flanker and cue types can be seen in Figure 8.

**Table 2.** Experiment 2.1 Part Two SANT1-SANT2 condition means and differences.

	no cue			center cue			spatial cue		
	neutral flanker	congruent flanker	incongruent flanker	neutral flanker	congruent flanker	incongruent flanker	neutral flanker	congruent flanker	incongruent flanker
<b>SANT1</b>	599.85	618.27	776.09	571.27	576.20	738.71	523.64	530.91	700.96
<b>SANT2</b>	501.37	512.44	625.55	481.65	479.13	604.36	449.55	455.02	583.37
<b>t(43)</b>	6.298*	6.574*	6.978*	6.812*	6.740*	6.105	4.919*	4.741*	5.702*

\*significant at the .001 level

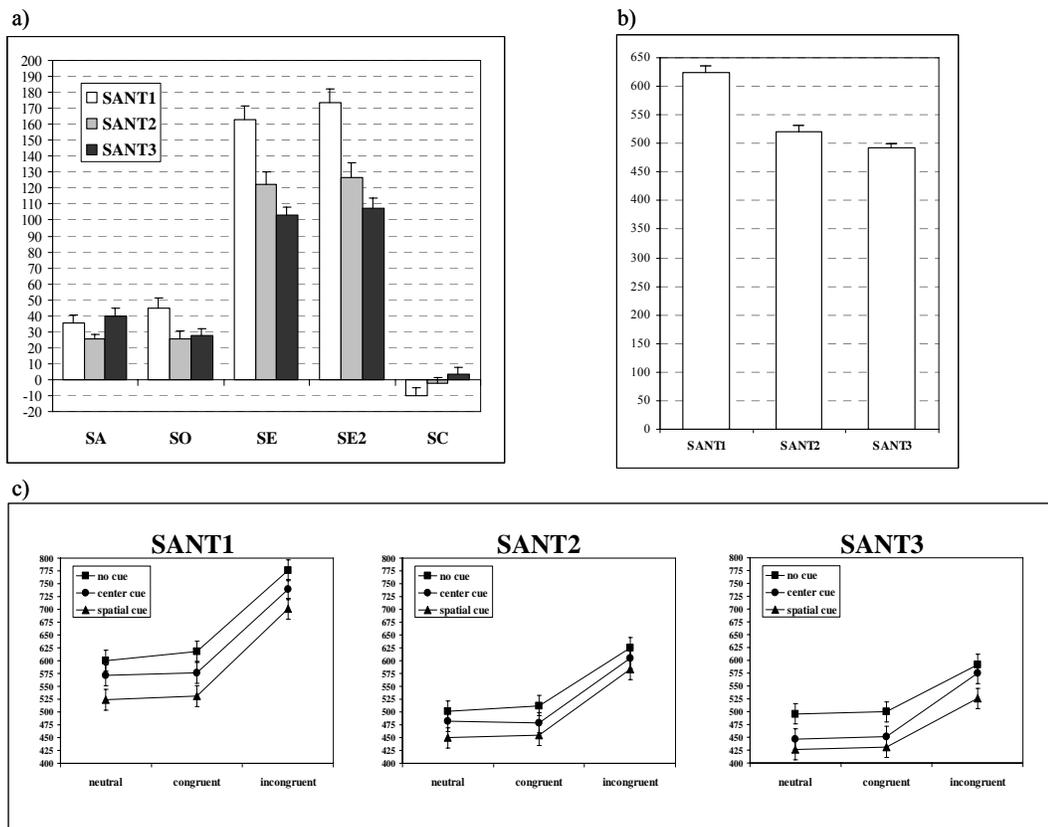
There were no alerting efficiency effect differences between any of the SANTS. Orienting efficiency effect differences were present between SANTS 1 and 2 [ $t(43) = 2.43, >.05$ ] and 1 and 3 [ $t(45) = 2.44, p<.05$ ]. Executive efficiency effects *SE* [ $t(43) = 3.67, p<.001$ ] and *SE2* [ $t(43) = 3.71, p<.001$ ] differed between SANTS 1 and 2 as well as between SANTS 1 and 3: *SE* [ $t(45) = 6.60, p<.001$ ] and *SE2* [ $t(45) = 6.51, p<.001$ ]. Control measure *SC* did not differ significantly between any of the three SANTS. Mean efficiency effects for all Experiment 2.1 SANTS 1, 2 and 3 can be seen in Table 3 and Figure 8.

**Table 3.** Experiment 2.1 mean (SD) attention network efficiency effects for SANTS 1, 2 and 3.

SANT	SA	SO	SE	SE2	SC	Overall RT
1	36 (23)	45 (29)	163 (38)	174 (40)	-9.8 (21)	623.18 (56.57)
2	25 (15)	26 (24)	122 (37)	127 (45)	-2.3 (18)	519.80 (46.31)
3	40 (26)	28 (18)	103 (24)	108 (30)	3.5 (23)	491.61 (36.34)

Correlation analyses of the efficiency effects within each task indicate that all three SANTS provide independent measures of the alerting, orienting and executive networks of attention. In SANTS 1 [ $r = .86, p<.001$ ], SANTS 2 [ $r = .93, p<.001$ ] and SANTS 3 [ $r = .65, p<.001$ ], executive effects *SE* and *SE2* are highly correlated. Additionally, in SANTS 2, overall RT correlated with executive effect *SE* [ $r = .55, p<.01$ ].

A block analysis indicated there were no within-subject differences in alerting effects between blocks in SANTS 3.



**Figure 8.** Experiment 2.1 (a) mean (SEM) attention network efficiency effects, (b) mean (SEM) overall RT, and (c) mean (SEM) RT from correct trials by cue and flanker types in SANTS 1, 2 and 3.

### Discussion: Experiment 2.1 Part Two

These data indicate that all three SANT versions provide strong alerting effects, and those obtained by SANTS 1 and 2 are of similar size. While we expected between-block alerting effect differences in SANT3, this was not the case. SANT3 did, however, obtain a nearly significantly stronger alerting effect than did SANT2. While this was an unexpected result, it is not a surprising one, as the cue stimulus used in SANT3, a flashing pair of eyes in the location of the target, was a larger and more

easily noticeable stimulus than were either of the eye-gaze shift stimuli sets used in SANTs 1 and 2.

As expected, of the SANT tasks tested, SANT1 elicits the strongest orienting effect, significantly more efficient than those measured in either SANT2 or SANT3. We anticipated this as left-right eye gaze cues are typically far more environmentally common than are up-down eye gazes devoid of head turn.

The executive *SE* and *SE2* effects in SANT1 are far less efficient than those same effects measured by SANTs 2 and 3, and SANTs 2 and 3 measured very similar executive effects. These were unexpected results and are discussed in more depth later in this chapter. Further, the significantly slower overall RT in SANT1 than in either SANT2 or 3 is quite interesting and is discussed later in this chapter.

We interpret these data to indicate that SANT1 is the social variant of the Attention Network Task (Fan et al., 2002) most comparable to the ANT. The next experiment in this chapter is an investigation of the efficiency effects obtained with both the ANT and SANT1 to further determine if eye-gaze cues play a role in the measure of attention networks.

### Experiment 2.2: A Comparison of the ANT and SANT1

Based on results from both parts of Experiment 2.1, we chose to complete a more detailed analysis of SANT1 and the effects of its eye-gaze cues within a typical adult population. For this experiment, we thus administered both SANT1 and the shortened version of the ANT discussed in Experiment 2.1 to a larger participant group to better understand the effectiveness of the SANT1 task.

We expected SANT1 to yield more efficient alerting, orienting and executive network efficiency effects than those measures obtained using the ANT. Although we

expect stronger network effects using SANTI, data from Experiment 2.1 indicate slower overall RT in SANTI than those we measured in Experiment One and than those reported in previous investigations using the ANT (Fan et al., 2002; Konrad et al., 2005). We thus expect slower overall RT in SANTI than in the ANT.

### Method

For this experiment, all participants were administered both a shortened version of the ANT (Fan et al., 2002) and SANTI. The task administration order (either ANT or SANTI first) was randomly assigned and counterbalanced across subjects.

#### *Subjects*

60 individuals (8 males) between the ages of 18 and 24 participated in this experiment. The mean age of the participants was 19.6 years (S.D. = 1.4).

#### *Apparatus*

We used the same testing apparatus used in Experiment 2.1.

#### *Stimuli*

We used both the shortened version of ANT and SANTI, both discussed in Experiment 2.1.

#### *Procedure*

We followed identical testing procedures as those followed for Part One of Experiment 2.1.

#### *Measures*

For both tasks for each subject, we calculated the same measures as those calculated for Experiment 2.1.

### *Analyses*

We analyzed RT for all correct responses. We conducted t-tests to examine within-subject RT differences and differences in efficiency effects between the ANT and SANTI. We conducted ANOVAs to analyze the effects of cue and flanker types on RT and to determine any interactions. We performed within-task correlations to assess the independence of the network measures for each task, and between-task correlations to ensure both the ANT and SANTI recruited the orienting attention network in a comparable manner.

### Results

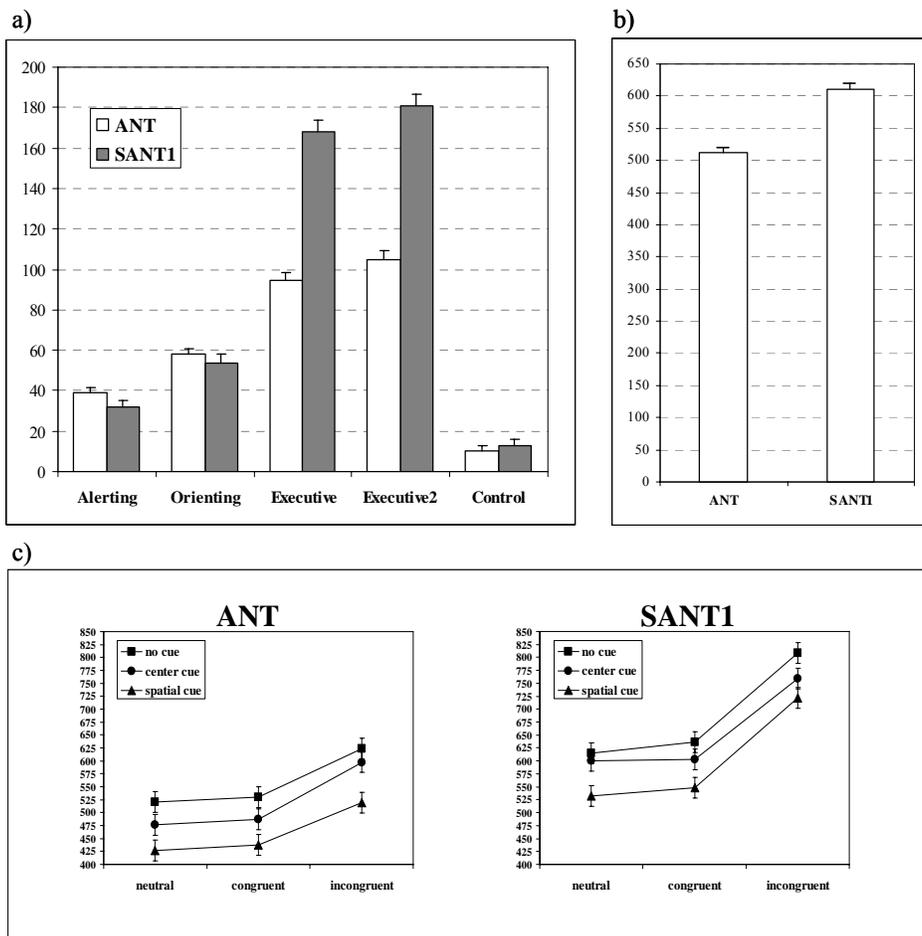
There were effects of both cue and flanker types on RT in the ANT [ $F_{\text{cue}}(2, 531) = 126.11, p < .001$ ;  $F_{\text{flanker}}(2, 531) = 89.60, p < .001$ ] and in SANTI [ $F_{\text{cue}}(2, 531) = 298.75, p < .001$ ;  $F_{\text{flanker}}(2, 531) = 55.10, p < .001$ ]. Interactions between cue and flanker types were found to be nonsignificant in both the ANT and SANTI.

Analyses of the RT data indicate there are highly significant differences within individual participants across tasks in each of the cue and flanker types. These RT, however, are each significantly correlated across tasks. Condition means and correlations values are noted in Table 4. See Figure 9 for mean RT in each of the combinations of cue and flanker types.

**Table 4.** Experiment 2.2 mean (SD) RT and correlations between ANT and SANTI cue and flanker types.

ANT	cue type			flanker type		
	no	center	spatial	neutral	congruent	incongruent
	557.14 (67.25)	518.34 (66.69)	460.51 (62.18)	474.68 (57.63)	485.09 (64.39)	579.36 (74.76)
<b>SANTI</b>						
	683.35 (73.62)	651.70 (66.88)	597.95 (79.20)	582.58 (65.75)	595.46 (65.23)	763.31 (88.12)
<b>ANT-SANTI correlations</b>						
	.843*	.811*	.837*	.854*	.850*	.761*

\*correlation significant at the .001 level



**Figure 9.** Experiment 2.2 (a) mean (SEM) attention network efficiency effects, (b) mean (SEM) overall RT, and (c) mean (SEM) RT from correct trials by cue and flanker types in ANT and SANTI.

There exists a near significant difference in the alerting efficiency effects between the ANT and SANTI1 [ $t(59) = 1.95, p=.06$ ]. Significant differences are present between executive effects *E* and *SE* [ $t(59) = -12.85, p<.001$ ] and between effects *E2* and *SE2* [ $t(59) = -12.25, p<.001$ ]. There is no significant difference between orienting effects *O* and *SO* across tasks [ $t(59) = .88, ns$ ]. Mean efficiency effects and overall RT for the ANT and SANTI1 are listed in Table 5.

**Table 5.** Experiment 2.2 mean (SD) efficiency effects for ANT and SANTI1.

<b>ANT</b>	<b>A</b>	<b>O</b>	<b>E</b>	<b>E2</b>	<b>C</b>	<b>Overall RT</b>
	39 (19)	58 (24)	94 (33)	105 (34)	10 (17)	511.82 (64.03)
<b>SANTI1</b>	<b>SA</b>	<b>SO</b>	<b>SE</b>	<b>SE2</b>	<b>SC</b>	<b>Overall RT</b>
	32 (25)	54 (35)	168 (45)	181 (46)	13 (24)	644.42 (70.57)

Correlation analyses indicate no correlations between the alerting, orienting, or executive networks of attention within either the ANT or SANTI1. *E2* shows a correlation with *E* in both the ANT [ $r = .88, p<.01$ ] and SANTI1 [ $r = .85, p<.01$ ]. Between-task analyses indicate correlations of the orienting networks [ $r = .31, p<.05$ ], the executive networks [ $r = .40, p <.01$ ] and in overall RT [ $r = .85, p<.001$ ]. Task administration order was shown to have no significant effect on any of the network effects in either the ANT or SANTI1.

### Discussion: Experiment 2.2

We have successfully developed a social variant of the Attention Network Task (Fan et al, 2002), using eye-gaze cues to elicit efficiency effects in the same manner as do the asterisk cues in the ANT.

We expected SANTS to provide more efficient measures of all attention networks than the ANT. Due to both the salience of eye-gaze cues in social situations, and to previous research indicating the facilitating effect of eye-gaze on reaction time in attention tasks (e.g. Friesen et al., 2004), we anticipated rapid alerting and orienting to the target, resulting in faster conflict resolution than in ANT trials. Our data do not indicate such to be true. Significant differences are present in overall RT. Further, the eye-gaze cueing task provides a less efficient executive network of attention than the task with asterisk cues. We have, however, also determined both the SANTS executive effects and SANTS overall mean RT to be correlated across tasks, and we will look at these in greater detail in the next experiment in this chapter.

Another unexpected result were the nonsignificant interactions between cue and flanker type in each task. While the graphs in Figure 9 would seem to indicate such an interaction to exist, we feel the participant group in this experiment was too small to elicit an interaction of these effects.

### Experiment 2.3: The Sideways ANT (W-ANT)

Experiments 2.1 and 2.2 discuss the effects of various sorts of eye-gaze cues upon attention in a typical adult population. As noted in Part One of Experiment 2.1, both SANTS1 and SANTS4 show similarly high overall mean reaction times. Further, as discussed in Experiment 2.2, SANTS1 consistently elicits a higher overall mean RT than either SANTS2 or SANTS3 despite its providing the most efficient measures of the alerting, orienting and executive attention networks of the three tasks. Because the element common to both SANTS1 and 4 is the presentation of cue and target stimuli to the left and right of fixation, as compared to above or below fixation as in SANTS2

and 3, we hypothesized there was an effect of left-right cue and target presentation upon the overall slowed reaction times in SANTI1.

To isolate this effect, we developed an additional task, the W-ANT. The W-ANT presents target stimuli to the left and right of central fixation in the same manner as SANTS 1 and 4, yet uses asterisks as cues in the same manner as the ANT (Fan et al., 2002). To clarify if the slowed RT specifically in SANTI1 was due to cue and stimulus location or to the cue stimulus itself, we administered a W-ANT/SANTI1 task combination to one half of our participant group and a W-ANT/ANT task combination to the other half.

We anticipated similar overall RT in the W-ANT and SANTI1, and expected both to result in slower overall RT than those obtained using the ANT. We expected all three tasks to provide similar efficiency measures of the alerting network. We also expected SANTI1 to have a stronger orienting efficiency effect than the W-ANT due to the use of eye-gaze cues in SANTI1. In addition, we expected similar measures of the executive networks in SANTI1 and the W-ANT.

## Method

### *Subjects*

27 individuals (7 males) between the ages of 18 and 22 participated in this experiment. 12 participants were administered the W-ANT and the ANT while 15 were administered the W-ANT and SANTI1. The mean age of the participants was 19.8 years (S.D. = 1.2). Data from five female participants were excluded from these analyses, three for high error rates and two due to procedural errors.

### *Apparatus*

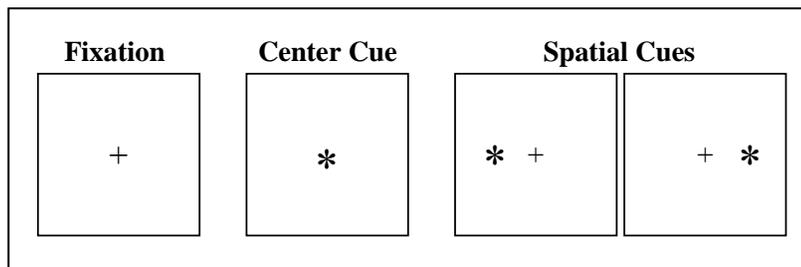
We used the same testing apparatus used in Experiment 2.1.

### *Stimuli*

We used both the shortened version of ANT (Fan et al., 2002) and SANTI, both discussed in Experiment 2.1, and the W-ANT.

The W-ANT uses the same target stimuli and target location (to the left or right of central fixation) used in SANTI. Cues are asterisks which flash prior to stimulus onset in the same manner as those cues used in the ANT (Fan et al., 2002).

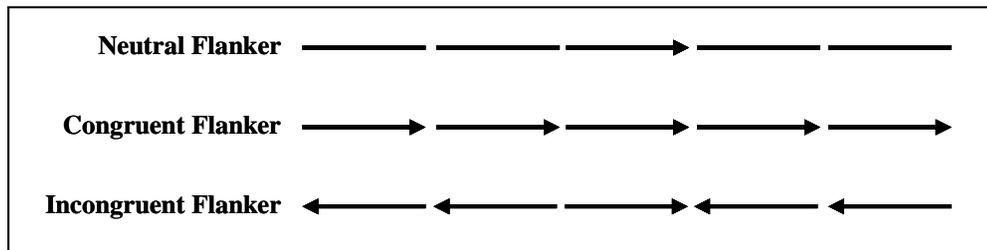
Each W-ANT trial begins with a fixation cross located in the center of a computer monitor for a duration randomly varied between 400 and 1600 msec. Following this fixation, one of four cue types appears on the screen for 100 msec: a single asterisk in the place of the central fixation cross (*center cue*); a single asterisk to either the left or right of the central fixation cross (*spatial cue*); or presentation of *no cue* (see Figure 10). The center-cue conditions serve to alert subjects to upcoming stimulus presentation but provide no information as to the location of the target presentation. The no-cue condition provides neither alerting nor orienting information. Spatial cues, however, are locationally predictive, so provide both alerting and orienting information.



**Figure 10.** Experiment 2.3 W-ANT cue conditions. **NOTE:** not drawn to scale.

Immediately following cue presentation, a target stimulus is presented for 400 msec. The target stimulus is a .48cm arrow pointing to either the left or to the right in one of three flanker types.

Target flankers are arrays of arrows, two appearing on either side of the target arrow, which are the same size as the target. There are three possible flanker types: 1) *neutral*, which consists of four lines without arrowheads flanking the target arrow, two on either side of the target; 2) *congruent*, in which all four flanker arrows point to the same direction as the target arrow; and 3) *incongruent*, in which all four flanker arrows point to the direction opposite that of the target arrow (see Figure 11). In the same manner as the ANT, the W-ANT was designed so asterisk cues flash at the precise location of the center of the target arrow.



**Figure 11.** Experiment 2.3 W-ANT target conditions. **NOTE:** Not drawn to scale.

Each trial's response consists of a button press, input by the participant via the left or right button of the computer's external mouse, indicating the direction to which each central target arrow points. The W-ANT consists of one practice block of 18 trials followed by three testing blocks each of 72 trials. Combinations of three cue types and three flanker types provide nine conditions. Each of the nine conditions is randomly presented twice in the practice block, once with a leftward pointing target and once with a rightward pointing target, and eight times in each of the three testing

blocks, four times with a leftward pointing target and four times with a rightward pointing target.

Each W-ANT trial has a maximum duration of 3500 msec. Fixation to target presentation time is 1600 msec, and subjects are allowed 1700 msec to indicate a response. If no response is entered during the 1700 msec allotted response time, the individual trial ends and the next begins. Trials for which no responses are indicated are recorded by the computer as “NULL”.

### *Procedure*

We followed identical testing procedures as those followed for Parts One and Two of Experiment 2.1. However, each participant was administered the W-ANT and either the ANT or SANT1. Both administration order and assignment of either the ANT or SANT1 was random and counterbalanced across participants.

### *Measures*

For the ANT and SANT1, we calculated the same measures as those calculated for Experiment 2.1.

The W-ANT measures RT in milliseconds between target stimulus onset and subject response via button press. Mean reaction times were calculated for each of the nine trial conditions, and using similar cognitive subtractions as those used by the original authors of the ANT (Fan et al., 2002), we determined efficiency effects of the alerting, orienting and executive attention networks for each subject. Alerting effect *WA* was obtained by collapsing the three flanker types and subtracting mean RT of all center cue conditions from mean RT of all no cue conditions. Orienting effect *WO* was obtained by collapsing all three flanker types and subtracting mean RT of all spatial cue conditions from mean RT of all center cue conditions. Executive effect *WE* was obtained by subtracting mean RT of congruent flanker conditions across all cue types from mean RT of incongruent flanker conditions across all cue types. We

calculated an additional executive effect, *WE2*, to analyze the effect of conflicting interference in all flanker trials. This was obtained by subtracting mean RT of neutral flanker conditions across all cue types from the mean RT of incongruent flanker conditions across all cue types. To examine the effect of non-conflicting interference in flanker conditions, we calculated a flanker control effect *WC* by subtracting mean RT of neutral flanker conditions across all cue types from mean RT of congruent flanker conditions across all cue types. All efficiency effects are measured in milliseconds.

### *Analyses*

We analyzed RT for all correct responses. We conducted t-tests to examine within-subject differences between the W-ANT and ANT and between the W-ANT and SANTI. We conducted ANOVAs to analyze differences between the three tasks and correlations to verify independence of the network effects within each task.

## Results

ANT and SANTI RT and efficiency effects were consistent with those reported in Experiment 2.2

### W-ANT – ANT

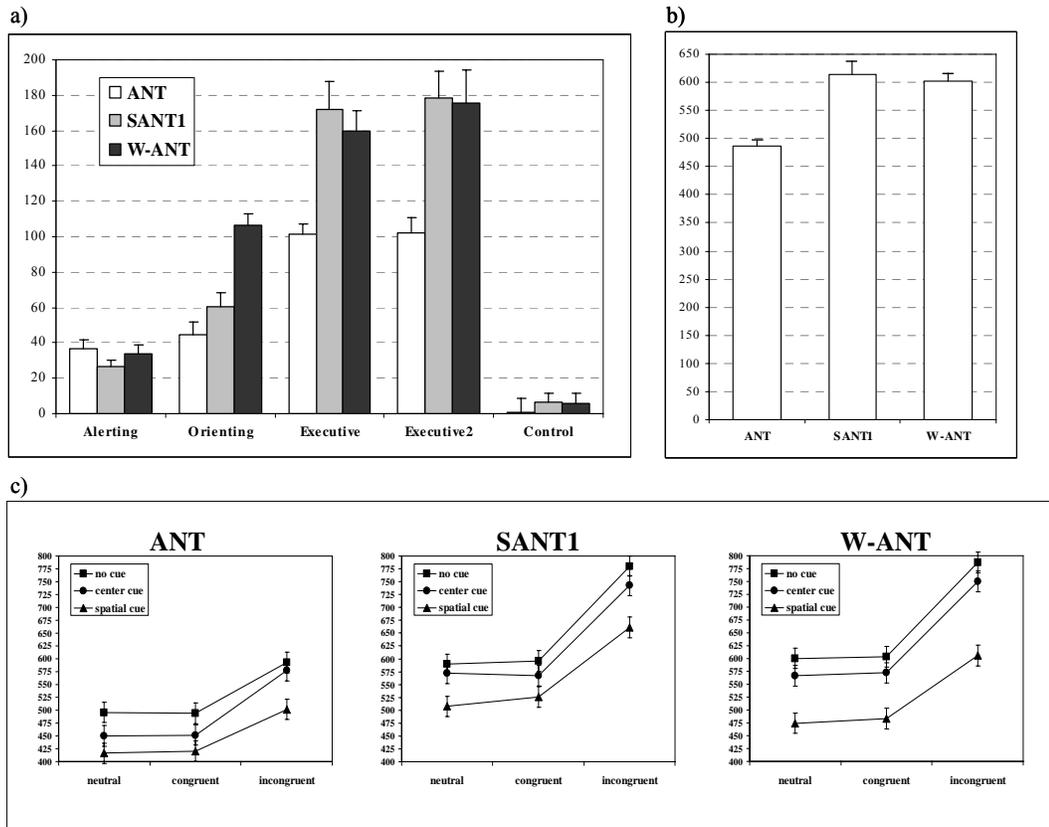
Paired comparisons indicate there were no significant differences in alerting networks between the two tasks. The W-ANT measured more efficient orienting [ $t(9) = 7.58, p < .001$ ] and executive networks *E* [ $t(9) = 3.27, p < .05$ ] and *E2* [ $t(9) = -37.36, p < .001$ ] than did the ANT. The ANT yielded significantly faster mean RT than the W-ANT in all flanker conditions [ $t_{\text{neutral}}(9) = 6.94, p < .001$ ;  $t_{\text{cong}}(9) = 9.05, p < .001$ ;  $t_{\text{incong}}(9) = 6.99, p < .001$ ] and all cue conditions [ $t_{\text{nocue}}(9) = 10.35, p < .001$ ;

$t_{\text{center}}(9) = 8.22, p < .001$ ;  $t_{\text{spatial}}(9) = 4.82, p < .001$ ], and thus in overall mean RT [ $t(9) = 8.71, p < .001$ ]. See Figure 12.

#### W-ANT – SANT1

Paired comparisons indicate no significant differences in alerting networks between the two tasks. The W-ANT orienting effect was more efficient than orienting in SANT1 [ $t(11) = 3.88, p < .01$ ]. Both the W-ANT and SANT1 provided similar measures of the executive *WE* and *WE2* networks of attention. There were no SANT1-W-ANT effects of flanker types. SANT1 no-cue condition RT were faster than in the W-ANT [ $t(11) = 2.50, p < .05$ ]. Differences in overall RT between the two tasks were highly nonsignificant [ $t(11) = .85, ns$ ].

Correlation analyses of all three tasks indicate independence of the alerting, orienting and executive networks of attention within the ANT and SANT1, with a correlation between the alerting and orienting networks in the W-ANT [ $r = -.46, p < .05$ ]. See Figure 12 for W-ANT, SANT1 and ANT data for this experiment attention network effects, mean overall RT and mean RT in each cue and flanker condition.



**Figure 12.** Experiment 2.3 (a) mean (SEM) attention network efficiency effects, (b) mean (SEM) overall RT, and (c) mean (SEM) RT from correct trials by cue and flanker types in ANT, SANTI and W-ANT.

### Discussion: Experiment 2.3

In this experiment we compared a sideways modification of the ANT task (Fan et al., 2002) with our newly developed SANTI and a shortened version of the ANT. As we anticipated, the ANT elicited faster overall RT than the sideways ANT (the W-ANT). However, although the W-ANT resulted in slower overall reaction times, attention network efficiency effects are quite comparable to, and in the case of orienting, more efficient than, those effects measured using the ANT.

Our objective in this experiment was to isolate any effect that would cause the overall slowing of RT in SANTI we observed in Experiment 2.1. Comparisons

between SANT1 and the W-ANT indicate that the slower overall RT were due not to inefficient stimuli in SANT1, but rather to the lateral design of the task itself. It is quite apparent in Figure 12 that there is a significant interaction between cue and flanker conditions, yet due to our small data set, there was not enough statistical power for this interaction to reach significance. In the following discussion we address implications of the W-ANT when taken into consideration with the rest of the data in Experiment Two.

Data collected using our sideways modification of the ANT (Fan et al., 2002) are quite suggestive of what may cause the overall slowing effect observed in our SANT1 task. However, regardless of the observations in this experiment, due to the very small amount of data collected this sideways version of the task, results discussed for this experiment are inconclusive.

### General Discussion: Experiment Two

Our goals in Experiment Two were to design a social variant of the Attention Network Task (Fan et al, 2002) and to identify the effects of the social cue used in this social variant on the alerting, orienting and executive networks of attention. By creating four sets of stimuli which cue attention in different ways, we developed a social ANT (SANT) which uses an eye-gaze cue to elicit measures of the three attention networks in a similar fashion to the ANT.

When considering data obtained using the various task modifications discussed in this experiment, we suggest that in a combination cueing-flanker paradigm such as those discussed herein, left-right cue and target presentation locations, as compared to above-below fixation presentation locations, have a slowing effect on overall RT under identical cueing conditions. Overall RT in SANT1,

SANT4 and the W-ANT are both significantly longer than overall RT in the ANT or SANT2. We interpret this to mean that response times are affected by an attention shift to either side of fixation more strongly than an attention shift to above or below fixation, and as previously mentioned, due to the lateral designs of the three tasks.

The effects of flankers must also be taken into consideration. There were no significant differences found in flanker conditions between SANT1 and the W-ANT. Yet all were significantly different between SANT1 and the ANT, and between the ANT and W-ANT. An argument can be made that the slowed overall RT in SANT1 and the W-ANT are due to flanker effects, rather than left-right presentation, because target location in both tasks requires attention to cross over two interfering flankers to arrive at the target stimulus arrow. However, data from neutral flanker conditions shows this to not be the case. Data patterns from typical flanker tasks reports slowed responses on trials with incongruent flankers, enhanced responses on trials with congruent flankers, and no effect of flankers on trials with neutral flankers (Diedrichsen, Ivry, Cohen & Danziger, 2000). Our incongruent flanker data are consistent with these patterns. However, if crossing over a flanker were the cause of the slowed RT in the W-ANT, then our neutral flanker condition RT would be the same as that in the ANT, as neutral flankers have little or no effects on response speed. Yet, these two measures are very significantly different. While our flanker conditions did slow reaction times considerably in incongruent trials, data from neutral flanker conditions support our belief that our overall RT are primarily affected by the locations of cue and target.

The W-ANT measured a more efficient orienting effect than did SANT1, and spatial cue conditions had a nonsignificantly faster RT in the W-ANT than in SANT1. These are surprising results given that eye-gaze cues have been shown to facilitate both reaction times and speed of conflict resolution in attention tasks (Driver et al.,

1999, Quadflieg, et al., 2004). We believe the slower reaction times on SANTI spatial trials are not due to the failure of the eye-gaze stimuli to orient attention toward the upcoming target stimulus. Rather, when considering the orienting effect of a flashing cue in the W-ANT versus a gaze cue in SANTI, one should understand that a flash in the precise location of an upcoming target will facilitate attentional location of the target more efficiently than a gaze toward the direction of the target.

In the case of this type of paradigm, the ANT and W-ANT spatial cue flashes occur in the precise location of the upcoming target arrow, thus in the center of the array of flankers. Moreover, in both tasks, the flashes occur where the exact center of the target arrow will be located. SANTI spatial cues, on the other hand, indicate the direction toward which an attention shift must occur, but as they do not indicate the precise location of the upcoming target, do not facilitate rapid extraction of the target arrow from the array of flankers as do the ANT and W-ANT spatial cues. In experiment 2.2, we reported a slower RT on SANTI spatial trials than on ANT spatial trials. We believe spatial cue RT will consistently be faster in spatial conditions cued by flashing asterisks rather than by eye-gaze cues because asterisk cues indicate location while the eye-gaze cues merely indicate direction.

Both W-ANT executive effects *WE* and *WE2* were less efficient than in the ANT. A similar difference was reported in experiment 2.2 between the ANT and SANTI. Further, executive *SE* and *SE2* effects in SANTI were far less efficient than those same effects measured by SANTS 2 and 3 in Experiment 2.1, while SANTS 2 and 3 measured very similar executive effects. We believe these executive effect differences are due to the slow RT in incongruent conditions in SANTI and the W-ANT due again to the lateral design of the task. Alerting *WA* and orienting *WO* do not prove to be independent network measures in the W-ANT. Interestingly, alerting *SA*

and orienting *SO* in SANTI neared significance in a correlation analyses. These effects involve interactions we were unable to analyze due to the small data set.

## CHAPTER FOUR

### Experiment Three: Attention Networks in Autism: ANT and SANT

As previously discussed, it is well documented that those diagnosed with Autism Spectrum Disorders (ASD) have dysfunctional attention processes (see Chapter One for a detailed discussion). Attention to various sorts of social stimuli is widely investigated in autism due to the social nature of the disorder (Baron-Cohen et al., 1999; Bayliss & Tipper, 2005). Biosocial cues such as eye gaze are shown to reflexively direct attention and facilitate conflict resolution in typical populations. Yet this not the case in ASD, as social cues within the environment seem to have little salience, and as opposed to typical persons, autistics lack a preference for social over non-social cues (Senju, Tojo, Dairuko & Hasegawa, 2004).

Despite widespread interest in the different aspects of attention in ASD, nowhere in the literature have the efficiencies of the alerting, orienting and executive attention networks of attention in the ASD population been measured by the Attention Network Task (*ANT*, Fan et al., 2002). In this experiment, we administered the *ANT* and the Social Attention Network Task to individuals with ASD to investigate attention network patterns in the disorder using both social and non-social cues.

The Social Attention Network Task (*SANT*) is a modified version of the *ANT*, a combined Posner (1980) cueing and Eriksen flanker task (Eriksen & Eriksen, 1974). In typically-developing persons, both the *ANT* and *SANT* provide comparable, independent measures of the three primary networks of attention, each task using a different set of cueing conditions. The *ANT* has proven to be a reliable measure of attention networks within typical populations (Rueda et al, 2004). Using social cues, the *SANT* measures these same attention networks as effectively as the *ANT* (refer to Experiment 2.2 for a detailed discussion of the *SANT*).

### *This Experiment: Objectives and Hypotheses*

We had several goals for this experiment. We first sought to examine attention network efficiency effects using the ANT (Fan et al., 2002) in an ASD population. Our second goal was to use the SANT to examine how a biosocial cue such as eye gaze might play a role in attention in autism, how an eye-gaze cue might affect the three individual attention networks, and how SANT efficiency effects might compare with attention network effects measured using non-social cues. We also sought to understand how these measures in ASD might compare to the same in nonclinical individuals.

Based on evidence of neuroanatomical differences (e.g. Schmitz et al., 2006) and attention shifting differences (e.g. Courchesne et al., 1994) shown to exist among the autistic population, we anticipated slower reaction times in both tasks by ASD participants on trials requiring attention orienting. We also expected slower overall reaction times in both the ANT and SANT by ASD participants. We anticipated that those ASD participants with more autistic traits measured using the Autism Quotient (AQ; Baron-Cohen et al., 2001) would perform less efficiently on all measures in both tasks than either nonclinicals or ASD participants with lower AQ scores.

#### ANT

As previous investigations have shown similar reaction times to cues between typical and ASD participants (Senju et al., 2004), we expected the ANT to measure similar alerting efficiency effects in both our ASD and nonclinical groups. We expected a slightly less efficient orienting network of attention in our ASD group due to the autistic's inability to orient to relevant environmental stimuli (Swettenham et al., 2003). Further, due to evidence of structural and functional abnormalities in brain regions typically recruited during conflict tasks (Seigel et al, 1995; Schmitz et al.,

2006), we anticipated less efficient executive network measures in our ASD participants.

### SANT

In our ASD group, we expected the SANT to result in a slightly smaller alerting effect than the ANT. We expected there to be a very poor orienting effect due to the well-documented inability for those with ASD to follow gaze in social situations (e.g. Klin, Jones, Schultz, Volkmar, & Cohen, 2002). We anticipated our eye-gaze cues would not facilitate conflict resolution as effectively as the non-social cues used in the ANT. We thus expected our overall RT to be slower and our measures of the executive attention network to be less efficient than those using the ANT.

## Method

All participants in this experiment were administered both a shortened version of the ANT (Fan et al., 2002) and the SANT. The task administration order (either ANT or SANT first) was randomly assigned and counterbalanced across subjects.

### *Subjects*

We collected data from 4 male ASD participants between the ages of 14 and 19. Data from one participant has been excluded from these analyses due to procedural errors. The mean age of the ASD group was 14.7 years (S.D. = 0.6). For our nonclinical group, we used the same data reported in Experiment 2.2.

ASD participants were recruited using investigator personal references.

All nonclinical control participants were self-selected, recruited using through Cornell University's Psychology Experiment participation website, via advertisements posted throughout the Cornell University campus, and from within Cornell University Psychology and Human Development courses.

Prior to participation, all participants completed the Subject Data Form (see Appendix A). No control participants reported either a current or past diagnosis of attention disorders or ASD. Data were also collected about handedness, age and gender.

Informed consent was obtained following the established guidelines of the Cornell University Committee on Human Subjects. Parental consent was obtained for participants under age 18. Those subjects in the control group were compensated with extra course credit. Subjects in the ASD group were compensated with a twenty-dollar monetary award.

#### *ASD Diagnosis Verification*

To confirm diagnoses, all ASD participants were asked to complete a Diagnosis Verification Form (see Appendix C). This form, derived from The Autism-Spectrum Quotient instrument (Baron-Cohen et al., 2001), is a brief, self-administered questionnaire used to identify autistic-like traits and place individuals along a continuum within the Autism Spectrum Diagnosis. The AQ is comprised of 50 short questions, used to assess five areas of function (social skill, attention switching, attention to detail, communication and imagination), reported to be atypical amongst the autistic population. Each question's response is a choice from a 4-point scale. The AQ has proven to be a valid assessment tool for the quantification of autistic qualities among adolescent and adult populations (Baron-Cohen et al., 2001).

#### *Apparatus*

Stimuli were presented on a white background on a 12-inch Dell laptop computer monitor using E-Prime software version 1.1. Responses were collected using the left and right buttons of a standard personal computer external mouse. Each subject's seated position was adjusted so the center of the screen was at approximately eye level at a distance of about 18 inches from the eyes.

### *Stimuli*

We used the shortened version of the ANT and SANTI, both discussed in detail in Chapter Three.

### *Procedure*

We followed identical testing procedures as those followed for Part one of Experiment 2.1. Total testing time for nonclinical participants was approximately 35 minutes. Total testing time for ASD participants was approximately 40 minutes.

### *Measures*

For each participant, we calculated the same measures for each task as those calculated for Part One of Experiment 2.1.

For ASD participants, in addition to the attention network efficiency effects calculated, we assigned a *Total AQ* score and five AQ area scores corresponding to the five areas of function previously discussed. These scores were based on point values assigned for particular responses to each of the 50 instrument questions. See Baron-Cohen et al. (2001) for details concerning AQ scoring methodology.

### *Analyses*

We analyzed RT for all correct responses. For both groups of participants, we performed identical analyses to those discussed in Experiment Two. For the ASD group, we performed additional ANOVAs to examine the effects of Total AQ and area scores on efficiency effects and overall RT.

## Results

Nonclinical ANT and SANTI RT and efficiency effects are those reported in experiment 2.2. The mean ASD total AQ score was 15.7 (S.D. = 6.4). The AQ social skills area score was 2.0 (S.D. = 2.6); attention switching, 3.7 (S.D. = 2.5); attention to

detail, 5.33 (S.D. = 2.1); communication, 3.3 (S.D. = 2.5); and imagination, 1.3 (S.D. = 0.6). There were no significant relationships between any of the six AQ scores and any RT measures or measures of network efficiency effects.

#### ANT Results

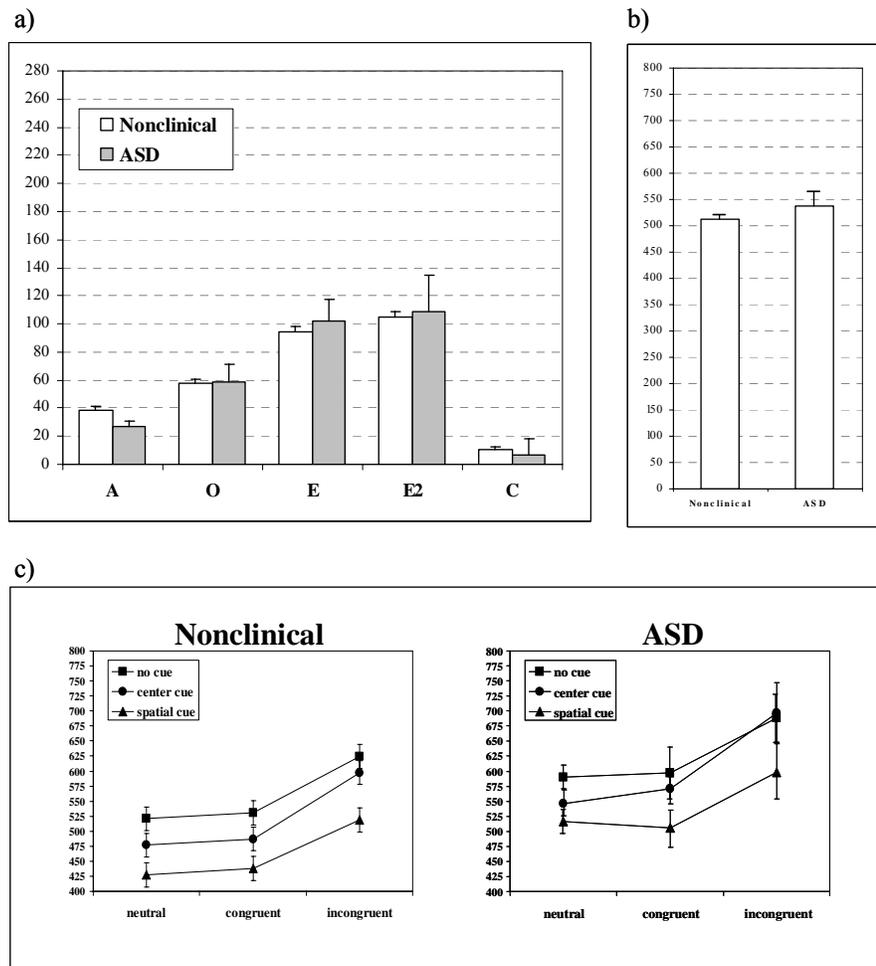
The ASD group showed significant effects of cue [ $F(2,18) = 8.79, p < .01$ ] and flanker type [ $F(2,18) = 4.58, p < .05$ ] on RT. The interaction between cue and flanker type was found to be nonsignificant. Compared with data from the nonclinical group, ASD group RT data analyses indicate significantly slower RT in spatial cue [ $F(1,61) = 4.30, p < .05$ ] and neutral flanker [ $F(1,61) = 5.03, p < .05$ ] conditions as well as in both congruent [ $F(1,61) = 4.27, p < .05$ ] and incongruent [ $F(1,61) = 4.98, p < .05$ ] center cue conditions. The ASD group elicited a near significantly slower RT in all center cue conditions [ $F(1,61) = 4.30, p = .055$ ] than did the nonclinical group. All other combinations of cue and flanker type yielded nonsignificantly slower RT in the ASD group than in the nonclinical group. Overall ANT mean RT was 25 msec slower in the ASD group than in the nonclinical group, yet was a nonsignificant difference [ $F(1,61) = .43, ns$ ]. We observed a mean RT pattern in the ASD group which is dissimilar to any of the other participant groups we have tested thus far in this study, whereby the mean ASD incongruent center cue conditions (696 msec, S.D. = 51) yielded a slower, yet nonsignificantly different, RT than the incongruent no cue conditions (688 msec, S.D. = 44).

There were no significant differences in network efficiency effects between the ASD and nonclinical groups. See Figure 13.

#### SANT Results

The ASD group showed a significant effect of cue type [ $F(2,18) = 10.44, p < .001$ ], and a nearly significant effect of flanker type [ $F(2,18) = 3.02, p = .07$ ] on RT.

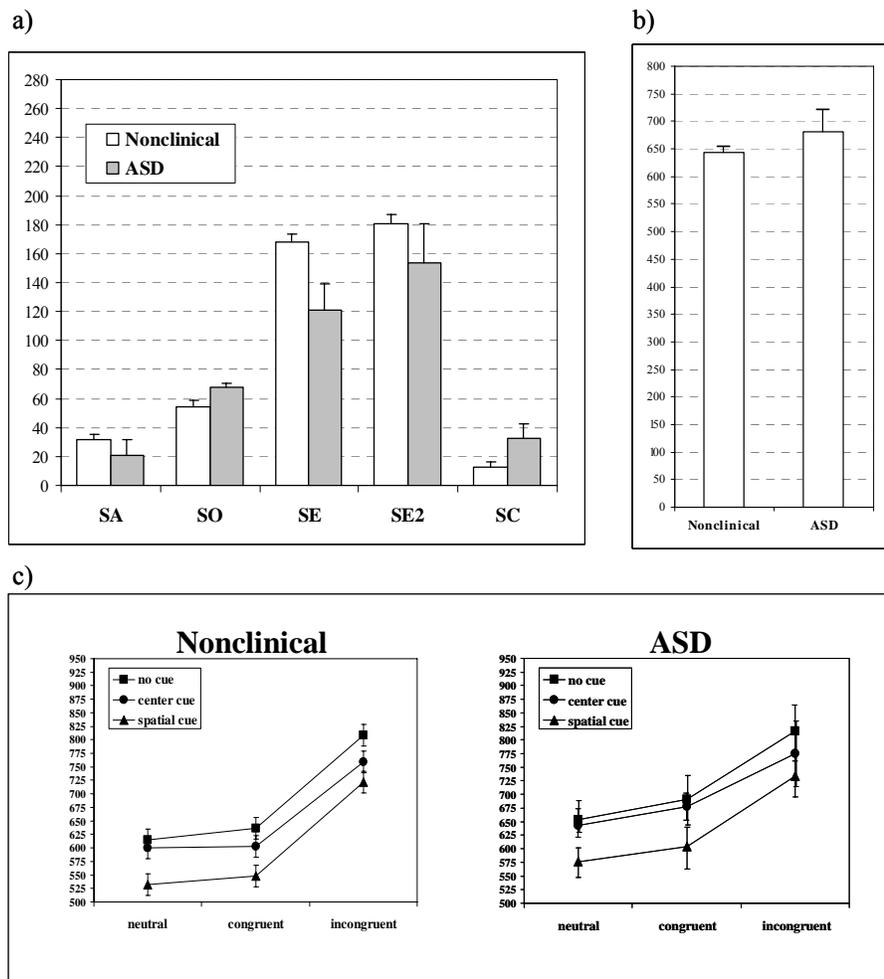
The interaction between cue and flanker type was found to be nonsignificant. Compared with nonclinical SANT data, the ASD group performed more slowly in congruent center cue conditions [ $F(1,61) = 4.52, p < .05$ ]. All other conditions yielded nonsignificantly slower RT in the ASD group than in the nonclinical group. Overall SANT mean RT was 37 msec slower in the ASD group than in the nonclinical group, yet was a nonsignificant group difference [ $F(1,61) = .77, ns$ ].



**Figure 13.** Experiment 3 ANT (a) mean (SEM) attention network efficiency effects, (b) mean (SEM) overall RT, and (c) mean (SEM) RT from correct trials by cue and flanker types in nonclinical and ASD groups.

SANT alerting and orienting network effects were similar between the ASD and nonclinical groups, the ASD group eliciting a slightly larger *O* effect than the nonclinical group [ $F(1,61) = .46, ns$ ]. None of the three executive network measures were significantly different between the ASD and nonclinical groups. See Figure 14.

Within-group analyses indicate the ASD group had significantly slower RT in SANT incongruent spatial cue conditions [ $t(2) = -7.42, p < .05$ ] than in the ANT. Additionally, the ASD group's overall center cue conditions in the SANT were slower than in the ANT [ $t(2) = -4.75, p < .05$ ], yet only the combinations of neutral flanker center cue [ $t(2) = -6.40, p < .05$ ] and congruent flanker center cue [ $t(2) = -12.09, p < .01$ ] elicited significant SANT-ANT differences. Overall SANT RT in the ASD group was 145 msec slower than that in the ANT, yet the difference only neared significance [ $t(2) = -3.92, p = .059$ ].



**Figure 14.** Experiment 3 SANT (a) mean (SEM) attention network efficiency effects, (b) mean (SEM) overall RT, and (c) mean (SEM) RT from correct trials by cue and flanker types in nonclinical and ASD groups.

## Discussion

The Attention Network Task (Fan et al., 2002) seems to be an inappropriate task for the assessment of attention deficits in the ASD population. A deficit in attention shifting is one of the more frequently reported attention dysfunctions in ASD (e.g. Harris et al., 1999). Additionally, there are recent reports of a specific difficulty with attention orienting in autism (Belmonte, 2000). Our data reported herein

obtained using the ANT indicate the opposite is true, as we measured nearly identical measures of the orienting attention network in our ASD and nonclinical groups. However, further examination of RT data indicates that this similarity in group orienting effects is due to a significantly slower RT in spatial cue conditions and a near-significantly slower RT in center cue conditions in the ASD group as compared to the nonclinical group. Both center and spatial cues in the ANT require the shifting of attention from one location to another, the shift in center cue conditions upon target stimulus presentation, and the shift in spatial cue conditions upon cue stimulus presentation. We interpret this to demonstrate a slower shifting of attention in the ASD group in center and spatial cue conditions than in the nonclinical group, despite the nearly identical orienting effects calculated using a subtraction of these conditions. In addition, data indicated no significant group differences in the executive attention networks. Although these network efficiency effects contradict published reports of poor attention orienting and conflict resolution in ASD, we believe it is due to the network effect calculations used in the ANT task rather than to identical attention processes operating in our participant groups.

Analyses of ANT data in our ASD participants also show slightly faster RT in congruent no- and spatial cue conditions than in neutral no- and spatial cue conditions. This is interesting given that RT in our nonclinical participants were shown not to benefit from congruent flankers. It is also interesting to note that center cue conditions in ASD resulted in very significant differences between flanker types. We can interpret this to indicate a sensitivity in our ASD participants to flanking arrows and, again, a slow shifting of attention to the actual target location following a center cue presentation.

SANT data indicated no group differences in measures of the attention network efficiency effects. This, too, was unexpected based on what is known about atypical

responses to eye gaze in ASD (Klin et al., 2002). While we didn't expect a large group alerting difference, the highly nonsignificant group differences on measures of the orienting and executive networks were unexpected results due to the previously discussed neurophysiological and behavioral differences reported between healthy persons and those with ASD. It is interesting that the SANT orienting efficiency effect measured in our ASD group was slightly larger than that in the nonclinical group. As is the case with the ANT in ASD, although the differences are nonsignificant, SANT center and spatial cue mean RT in the ASD group were both slower than those in the nonclinical group. Furthermore, results of our within-group analyses indicate that the ASD center cue conditions in the SANT were slower than those in the ANT. We can determine three things from these combined results. First, the ASD group was less sensitive to the center eye-gaze cues, a simple wide eye, more surprised type of eye gaze, than was the nonclinical group, thus the slower RT on center cue conditions. Second, the ASD group was less alerted by the change from central eye gaze fixation to the center cue condition in the ANT. Third, the resulting SANT orienting effect measure is larger than that in the nonclinical group due only to this slow SANT center cue RT in the ASD group compared with the faster RT in spatial cue conditions. The ASD participants seemed able to follow gaze, but unable to alert to a slight gaze change or to shift gaze away from a center cue presentation. As previously argued, we believe this type of attention task is not appropriate to use with an autistic population.

As expected, although nonsignificant, the ASD group mean overall RT was slower in both the ANT and SANT than in our nonclinical group. Our ASD group also elicited slower condition and overall RT in the SANT than in the ANT. We did not observe a similar pattern of overall slow, yet correlated, SANT RT in our ASD

group as that reported for our typical group in Experiment 2.3, yet we believe this was due to a limited amount of trials in the ASD group due to the small participant group.

Interestingly, in the ASD group, SANT cue type had a more significant effect on RT than did cues in the ANT, a result attributable to the slow RT in center cue conditions. Furthermore, flanker type had a less significant effect on RT in the SANT than did those in the ANT. Interpretation of this effect would need more in-depth analyses with a larger participant group. We believe our nonsignificant interaction between cue and flanker types in both the ANT and SANT in our ASD group were due to our small ASD sample size.

We further suggest our results indicate our ASD participants were of an age by which they had developed mechanisms to compensate for deficits in attention processes. Belmonte & Yurgelun-Todd (2003) give imaging evidence of the recruitment of atypical regions in the occipital cortex by ASD persons during attention tasks rather than the prefrontal, parietal and temporal areas of the brain previously discussed to be typically activated in the attention process. These patterns of atypical brain activations indicate different information processing styles in ASD (Belmonte & Yurgelun-Todd, 2003), styles that develop when ASD persons are young and learning to process and interpret environmental stimuli. As our data did not show many significant group differences in either of the attention tasks administered, we believe such compensatory processing styles were already developed in our ASD participants and allowed them to perform our tasks comparably to those in the nonclinical group.

Analyses of ANT data from our ASD group and data collected from ADHD participants in Experiment One show no group differences in any combination of cue and flanker types. Because the ANT task administered in Experiment One was the

original ANT (Fan et al., 2002) rather than the shortened version used in this experiment, we cannot compare the data sets directly. However, it is interesting that no group effects were found and we feel that further investigations of attention differences between the two groups must be performed.

While these data do not indicate any differences in attention networks between typical persons and those diagnosed with Autism Spectrum Disorders, this is to date the only investigation of ASD using the ANT. Further investigations with larger participant groups are necessary to further identify the range of attention deficits of those who are diagnosed along the spectrum.

#### *Limitations and Considerations*

Our ASD participants were recruited from among contacts known to the investigator. All participants had been given a diagnosis on the autism spectrum upon entering elementary school programs and currently remain in special education programs due to disability. Because we did not have participation of a mental health clinician in this study, we used the AQ to verify our participants' diagnoses and identify autistic-like traits among our ASD populations. All of our participants, however, received low AQ scores after completing the questionnaire. As we did not have clinician involvement in this study, and as our obtained AQ scores were not as high as those often reported amongst the autistic population, the data reported herein can be applied to a broader autistic population in a very limited manner. AQ, ANT and SANT data must be collected from a larger ASD participant before any generalizations may be made.

## CHAPTER FIVE

### Conclusions

When considered together, the three experiments discussed herein have several implications. The first, and most important, is that the Attention Network Task (Fan et al., 2002) seems inappropriate to use to measure attention networks in Attention-Deficit Hyperactivity Disorder and Autism Spectrum Disorders. Our use of the task's traditional cognitive subtractions of attention network efficiency effects based on reaction times failed to obtain results which are consistent with published reports of attention deficits in either population. Experiment One failed to find a difference in executive attention between nonclinical and ADHD persons using Fan et al.'s (2002) [incongruent flanker – congruent flanker] calculation. Experiment Three failed to find executive, as well as orienting [center cue – spatial cue], differences between ASD and nonclinical persons. Neurophysiological data give evidence of atypical brain activations in ADHD and ASD during conflict resolution tasks (Konrad et al., 2005; Siegel et al., 1995), as well as in ASD for tasks requiring attention shifting and orienting to environmental stimuli (Belmonte, 2000). Because RT data analyses do indicate there are slowed reaction times in specific conditions requiring the use of executive and orienting networks, perhaps reaction time measures should be used to examine differences between the groups rather than calculations of efficiency effects. It is understood that there are significantly different attentional processes operating in ADHD and ASD than in typical populations. The Attention Network Task, however, seems unable to measure these processes in our two target populations.

Also important is the validity of the Attention Network Task. As discussed in Chapter Three, asterisk cues in the ANT are presented at the precise location of the upcoming target stimulus. The extent to which target flankers in the ANT affect

extraction of the target stimulus from its flanked array must be further investigated. In Experiment One, we discuss slowed reaction times in all arrowhead (congruent and incongruent) flanker conditions as compared with neutral conditions. Compared with neutral flankers, congruent flankers are typically shown to speed reaction times (Diedrichsen et al., 2000). Our data from nonclinical participants in Experiments One and Two do not show a facilitating effect of congruent flankers. These inconsistent data indicate there are additional interacting factors in the ANT. We attempted to isolate one of these using the W-ANT, yet further investigation is required to understand additional factors. One such possibility is that the congruence of arrowhead flankers has no facilitating effect when presented around a target presented immediately above or below a cue, as is the case with the ANT. In these target locations, while the presence of flankers is perceived, perhaps the flankers, whether congruent or incongruent, are processed as distracting noise rather than facilitating arrows, causing slower response times than flankers without arrowheads. Nevertheless, the ANT is currently considered a strong tool for the assessment of the three components of attention. Yet if a task can only measure these components in typical, healthy individuals, it is a weak experimental tool.

Our development of the SANT demonstrates the extent to which a simulated eye gaze may direct attention to specific locations. Interaction within the environment requires rapid interpretation and use of natural social cues such as eye gaze. The effects eye gaze has on attentional processes are important to clarify to understand critical aspects of development such as emotion learning and language acquisition. Although we did not elicit all expected attention effects in an autistic sample using our eye-gaze cueing paradigm, our analyses do show slowed responses in eye-gaze conditions, perhaps indicating slow interpretation of the cues.

Due to a substantial amount of behavioral and neurophysiological research, it is generally accepted that attention is dysfunctional in various clinical disorders. With recent data suggesting the effects of attention on processes such as emotion recognition (Pessoa, Padmala & Morland, 2005) and encoding of faces (Holmes, Vuilleumier & Eimer, 2003), it is critical that attention processes are better understood in those such as ASD. APA (2000) diagnostic criteria for Autism Spectrum disorders currently comprise social and emotional qualities while deprived of attentional symptoms. It seems straightforward that these criteria, and presumably those for other disorders, must be changed as continuing investigations provide new data indicating atypical social responses resulting from deficits in attentional processing.

#### *Limitations and Considerations*

Both the nonclinical group used for our W-ANT analyses and our ASD participant group in Experiment Three were too small to draw any definitive conclusions. Both the W-ANT and the ANT-SANT combination of tasks should be administered again to larger typical and ASD samples to determine if our reported results remain consistent.

Another limitation of the data reported herein is the data collection method itself. As previously discussed, data were collected using E-Prime software and an external personal computer mouse. Plant, Hammond and Whitehouse (2003) report that when using a mouse for data collection with a software package such as E-Prime, response times may be recorded up to 80 milliseconds slower than the subject's actual response time. Similarly, data collected using button presses on a standard computer keyboard may be recorded up to 40 milliseconds slower than the subject's actual response time. The same authors give evidence that the data collection response box provided by manufacturers of the E-Prime software package is the most accurate tool for response time data collection, allowing less than a 10-millisecond error in response

time recording. This may account for the high standard deviations of the mean RT calculated in this investigation.

Attention is a process crucial to nearly every aspect of human thought. Posner and Fan (2004) suggest that ‘viewing attention as an organ system aids in answering many...issues raised in cognitive psychology, psychiatry and neurology.’ Attention is what allows typically developing individuals to read social cues and emotion on another person’s face, to understand naturally-occurring and social stimuli in their environments, and to behave based on how these are interpreted. With dysfunctional attention processes evident in Attention-Deficit Hyperactivity Disorder and Autistic Disorder, these skills are, at best, impaired, and at worst, nonexistent.

Yet additional investigations to develop more appropriate tools must be developed to effectively define attention deficits in both of these disorders. We suggest the use of a more extensive measure of the executive attention network with ADHD persons. The ADHD diagnosis is broad, and those with the disorder, as discussed in Chapter One, have a wide range of deficits. The ANT requires one to alert, maintain, and shift attention while simultaneously solving conflict. While the ANT purportedly measures three of these components of attention, it does not measure the maintenance of attention, and those who fail to maintain attention might obtain a poor executive network efficiency measure with the ANT. As a deficit in attention maintenance is a quality of those with ADHD, a task measuring this in addition to the other attention components would be more appropriate for deficit assessment amongst the ADHD population. Additionally, our data indicates that a task such as the ANT should not be used to assess the efficiencies of attention networks in ASD persons. We suggest a more appropriate paradigm for the ASD population would be one incorporating a social element, as we sought to do with the ANT, and also which

interprets response times rather than subtractions of response times. Further, as a large number of ASD persons are diagnosed with various comorbid Attention Deficit Disorders, a task measuring attention maintenance would be appropriate for the ASD population in the same manner as it would be for those with ADHD. Understanding attention in ADHD and ASD would allow development of proper definitions for the disorders, and effectively defining ADHD and ASD is the first and critical step to a complete understanding of their underlying neural deficits.

APPENDIX A

SUBJECT DATA FORM: EXPERIMENTS ONE and THREE

**SUBJECT DATA FORM**  
**INVESTIGATION OF ATTENTION PROCESSES**

Please complete information inside the shaded box. Seal in white envelope upon completion.

Date: \_\_\_\_\_

Investigator Name: \_\_\_\_\_

ID Number: \_\_\_\_\_

Task Order:      A-S      S-A

Notes: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Gender: \_\_\_\_\_

Age: \_\_\_\_\_

Handedness: \_\_\_\_\_  
(with which hand do you typically write?)

Diagnosis: \_\_\_\_\_

APPENDIX B

SUBJECT DATA FORM: EXPERIMENT TWO

**SUBJECT DATA FORM**  
**INVESTIGATION OF ATTENTION PROCESSES**

Please complete information inside the shaded box. Seal in white envelope upon completion.

Date: \_\_\_\_\_

Investigator Name: \_\_\_\_\_

ID Number: \_\_\_\_\_

Task One:           A           S           W

Task Two:           A           S           W

SANT Version:     1           2           3           4

Notes: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Gender: \_\_\_\_\_

Age: \_\_\_\_\_

Handedness: \_\_\_\_\_  
(with which hand do you typically write?)

Diagnosis: \_\_\_\_\_

## APPENDIX C

### DIAGNOSIS VERIFICATION FORM

<b>PARTICIPANT ID NBR</b>		<b>DATE</b>	
<b>PARTICIPANT GENDER</b>		<b>TASK ORDER</b>	<b>A-S S-A</b>
<b>PARTICIPANT AGE</b>		<b>ADMINISTRATOR</b>	

**Please respond to each statement by circling the appropriate response to the right of each statement.**

1. I prefer to do things with others rather than on my own.	definitely agree	slightly agree	slightly disagree	definitely disagree
2. I prefer to do things the same way over and over again.	definitely agree	slightly agree	slightly disagree	definitely disagree
3. If I try to imagine something, I find it very easy to create a picture in my mind.	definitely agree	slightly agree	slightly disagree	definitely disagree
4. I frequently get so strongly absorbed in one thing that I lose sight of other things.	definitely agree	slightly agree	slightly disagree	definitely disagree
5. I often notice small sounds when others do not.	definitely agree	slightly agree	slightly disagree	definitely disagree
6. I usually notice license plates or similar strings of information.	definitely agree	slightly agree	slightly disagree	definitely disagree
7. Other people frequently tell me that what I've said is impolite, even though I think it is polite.	definitely agree	slightly agree	slightly disagree	definitely disagree
8. When I'm reading a story, I can easily imagine what the characters might look like.	definitely agree	slightly agree	slightly disagree	definitely disagree
9. I am fascinated by dates.	definitely agree	slightly agree	slightly disagree	definitely disagree
10. In a social group, I can easily keep track of several different people's conversations.	definitely agree	slightly agree	slightly disagree	definitely disagree
11. I find social situations easy.	definitely agree	slightly agree	slightly disagree	definitely disagree
12. I tend to notice details that others do not.	definitely agree	slightly agree	slightly disagree	definitely disagree
13. I would rather go to a library than a party.	definitely agree	slightly agree	slightly disagree	definitely disagree
14. I find making up stories easy.	definitely agree	slightly agree	slightly disagree	definitely disagree
15. I find myself drawn more strongly to people than to things.	definitely agree	slightly agree	slightly disagree	definitely disagree
16. I have strong interests and get upset if I can't pursue them.	definitely agree	slightly agree	slightly disagree	definitely disagree
17. I enjoy social chit-chat.	definitely agree	slightly agree	slightly disagree	definitely disagree
18. When I talk, it isn't always easy for others to get a word in.	definitely agree	slightly agree	slightly disagree	definitely disagree
19. I am fascinated by numbers.	definitely agree	slightly agree	slightly disagree	definitely disagree
20. When I read a story, I find it difficult to work out the characters' intentions.	definitely agree	slightly agree	slightly disagree	definitely disagree
21. I don't particularly enjoy reading fiction.	definitely agree	slightly agree	slightly disagree	definitely disagree
22. I find it hard to make new friends.	definitely agree	slightly agree	slightly disagree	definitely disagree

23. I notice patterns in things all the time.	definitely agree	slightly agree	slightly disagree	definitely disagree
24. I would rather go to the theater than a museum.	definitely agree	slightly agree	slightly disagree	definitely disagree
25. It does not upset me if my daily routine is disturbed.	definitely agree	slightly agree	slightly disagree	definitely disagree
26. I often find that I don't know how to keep a conversation going.	definitely agree	slightly agree	slightly disagree	definitely disagree
27. I find it easy to "read between the lines" when someone is talking to me.	definitely agree	slightly agree	slightly disagree	definitely disagree
28. I usually concentrate more on the whole picture, rather than the small details.	definitely agree	slightly agree	slightly disagree	definitely disagree
29. I am not very good at remembering phone numbers.	definitely agree	slightly agree	slightly disagree	definitely disagree
30. I don't usually notice small changes in a situation, or a person's appearance.	definitely agree	slightly agree	slightly disagree	definitely disagree
31. I know how to tell if someone listening to me is getting bored.	definitely agree	slightly agree	slightly disagree	definitely disagree
32. I find it easy to do more than one thing at once.	definitely agree	slightly agree	slightly disagree	definitely disagree
33. When I'm on the phone, I'm not sure when it's my turn to speak.	definitely agree	slightly agree	slightly disagree	definitely disagree
34. I enjoy doing things spontaneously.	definitely agree	slightly agree	slightly disagree	definitely disagree
35. I am often the last to understand the point of a joke.	definitely agree	slightly agree	slightly disagree	definitely disagree
36. I find it easy to work out what someone is thinking or feeling just by looking at their face.	definitely agree	slightly agree	slightly disagree	definitely disagree
37. If there is an interruption, I can switch back to what I was doing very quickly.	definitely agree	slightly agree	slightly disagree	definitely disagree
38. I am good at social chit-chat.	definitely agree	slightly agree	slightly disagree	definitely disagree
39. People often tell me that I go on and on about the same thing.	definitely agree	slightly agree	slightly disagree	definitely disagree
40. When I was young, I used to enjoy playing games involving pretending with other children.	definitely agree	slightly agree	slightly disagree	definitely disagree
41. I like to collect information about categories of things (e.g. types of car, types of bird, types of train, etc.).	definitely agree	slightly agree	slightly disagree	definitely disagree
42. I find it hard to imagine what it would be like to be someone else.	definitely agree	slightly agree	slightly disagree	definitely disagree
43. I like to plan any activities I participate in carefully.	definitely agree	slightly agree	slightly disagree	definitely disagree
44. I enjoy social occasions.	definitely agree	slightly agree	slightly disagree	definitely disagree
45. I find it difficult to work out people's intentions.	definitely agree	slightly agree	slightly disagree	definitely disagree
46. New situations make me anxious.	definitely agree	slightly agree	slightly disagree	definitely disagree
47. I enjoy meeting new people.	definitely agree	slightly agree	slightly disagree	definitely disagree
48. I am a good diplomat.	definitely agree	slightly agree	slightly disagree	definitely disagree
49. I am not very good at remembering people's date of birth.	definitely agree	slightly agree	slightly disagree	definitely disagree
50. I find it easy to play games with that involve pretending.	definitely agree	slightly agree	slightly disagree	definitely disagree

## APPENDIX D

### CONSENT AND ASSENT FORMS

#### INDIVIDUAL ADULT TYPICAL CONSENT FORM

##### **Individual Consent Form Investigation of Attention Processes**

You are invited to participate in a research study examining individual attention processes. By contacting us via the SUSAN website or via phone or email in response to our advertisement, you have been selected as a possible participant in the study. We ask that you read this form and ask any questions you may have before agreeing to be in the study.

##### Background

The purpose of this study is to investigate how individuals pay attention to different things. We would like to examine how people with different attention styles attend to the same stimuli.

##### Study Procedures

If you agree to be in this study, we will ask you observe various stimuli presented to you on a computer screen. There will be two tasks we will ask you to complete during the study, and each task consists of four short sections. You will be given instructions prior to each section of the study. You will observe random sequences of images followed by arrows pointing in one of two directions. Following each observation, you will be asked to press a button on a box to indicate your response.

It is anticipated that your participation should take no longer than 60 minutes.

##### Risks and Benefits of Being in the Study

We do not anticipate any risks to you for your participation in this study, other than those encountered in day-to-day life.

There are no direct benefits to you for your participation in this study. Indirect benefits of participation are your contribution to the current knowledge base regarding attention in different individuals.

##### Compensation

Extra course credit will be awarded upon completion of the required tasks to those whose courses permit such.

##### Voluntary Nature of Participation

Your decision whether or not to participate will not affect your current or future relations with Cornell University. If you decide to participate, you are free to withdraw at any time without affecting those relationships. Extra course credit will only be awarded to you upon completion of the study.

##### Confidentiality

The records of this study will be kept private. In any sort of report we might publish, we will not include any information that will make it possible to identify you. Research records will be kept in a locked file; only the researchers will have access to the records.

##### Contacts and Questions

The researcher(s) conducting this study are Kathleen Linnane and Elise Temple. Please ask any questions you have now. If you have questions later, you may contact them at via telephone at 607-254-1510, in MVR Hall, Office G86, or via email at [KML48@cornell.edu](mailto:KML48@cornell.edu) or [ET62@cornell.edu](mailto:ET62@cornell.edu). If you have any questions or concerns regarding your rights as a subject in this study, you may contact the University Committee on Human Subjects (UCHS) at 607-255-5138, via email at [uchs@cornell.edu](mailto:uchs@cornell.edu), or you may visit the committee's website at <http://www.osp.cornell.edu/Compliance/UCHS/homepageUCHS.htm>

You will be given a copy of this form to keep for your records.

##### **Statement of Consent**

I have read the above information, and have received answers to any questions I've asked. I consent to participate in the study.

Signature \_\_\_\_\_ Date \_\_\_\_\_

Printed Name \_\_\_\_\_

Course for which extra credit requested (if applicable) \_\_\_\_\_

**This consent form will be kept by the researcher for at least three years beyond the end of the study and was approved by the UCHS on November 29, 2006.**

# INDIVIDUAL ADULT ADHD CONSENT FORM

## Individual Consent Form Investigation of Attention Processes

You are invited to participate in a research study examining individual attention processes. By contacting us via the SUSAN website or via phone or email in response to our advertisement, you have been selected as a possible participant in the study. We ask that you read this form and ask any questions you may have before agreeing to be in the study.

### Background

The purpose of this study is to investigate how individuals pay attention to different things. We would like to examine how people with different attention styles attend to the same stimuli.

### Study Procedures

If you agree to be in this study, we will ask you observe various stimuli presented to you on a computer screen. There will be two tasks we will ask you to complete during the study, and each task consists of four short sections. You will be given instructions prior to each section of the study. You will observe random sequences of images followed by arrows pointing in one of two directions. Following each observation, you will be asked to press a button on a box to indicate your response.

It is anticipated that your participation should take no longer than 60 minutes.

### Risks and Benefits of Being in the Study

We do not anticipate any risks to you for your participation in this study, other than those encountered in day-to-day life.

There are no direct benefits to you for your participation in this study. Indirect benefits of participation are your contribution to the current knowledge base regarding attention in different individuals.

### Compensation

Compensation will be awarded in the form of either extra course credit upon completion of the required tasks (for those courses which permit such) or in the form a small monetary award.

### Voluntary Nature of Participation

Your decision whether or not to participate will not affect your current or future relations with Cornell University. If you decide to participate, you are free to withdraw at any time without affecting those relationships. Extra course credit will only be awarded to you upon completion of the study. For those volunteers from outside the Cornell University community, regardless of completion of the study as a participant, monetary compensation will be awarded.

### Confidentiality

The records of this study will be kept private. In any sort of report we might publish, we will not include any information that will make it possible to identify you. Research records will be kept in a locked file; only the researchers will have access to the records.

### Contacts and Questions

The researcher(s) conducting this study are Kathleen Linnane and Elise Temple. Please ask any questions you have now. If you have questions later, you may contact them at via telephone at 607-254-1510, in MVR Hall, Office G86, or via email at KML48@cornell.edu or ET62@cornell.edu. If you have any questions or concerns regarding your rights as a subject in this study, you may contact the University Committee on Human Subjects (UCHS) at 607-255-5138, via email at [uchs@cornell.edu](mailto:uchs@cornell.edu), or you may visit the committee's website at <http://www.osp.cornell.edu/Compliance/UCHS/homepageUCHS.htm>

You will be given a copy of this form to keep for your records.

### Statement of Consent

I have read the above information, and have received answers to any questions I've asked. I consent to participate in the study.

Signature \_\_\_\_\_ Date \_\_\_\_\_

Printed Name \_\_\_\_\_

Course for which extra credit requested (if applicable) \_\_\_\_\_

**This consent form will be kept by the researcher for at least three years beyond the end of the study and was approved by the UCHS on November 29, 2006.**

# INDIVIDUAL ADULT ASD CONSENT FORM

## Individual Consent Form Investigation of Attention Processes

You are invited to participate in a research study examining individual attention processes. By contacting us via email or by phone in response to our advertisement or initial contact through study investigators, you have been selected as a possible participant in the study. We ask that you read this form and ask any questions you may have before agreeing to be in the study.

### Background

The purpose of this study is to investigate how individuals pay attention to different things. We would like to examine how people with different attention styles attend to the same stimuli.

### Study Procedures

If you agree to be in this study, we will ask you observe various stimuli presented to you on a computer screen. There will be two tasks we will ask you to complete during the study, and each task consists of four short sections. You will be given instructions prior to each section of the study. You will observe random sequences of images followed by arrows pointing in one of two directions. Following each observation, you will be asked to press a button on a box to indicate your response.

It is anticipated that your participation should take no longer than 60 minutes.

### Risks and Benefits of Being in the Study

We do not anticipate any risks to you for your participation in this study, other than those encountered in day-to-day life.

There are no direct benefits to you for your participation in this study. Indirect benefits of participation are your contribution to the current knowledge base regarding attention in different individuals.

### Compensation

You will receive \$20.00 (twenty dollars) to compensate for your time spent as a participant in this study.

### Voluntary Nature of Participation

Your decision whether or not to participate will not affect your current or future relations with Cornell University. If you decide to participate, you are free to withdraw at any time without affecting those relationships.

### Confidentiality

The records of this study will be kept private. In any sort of report we might publish, we will not include any information that will make it possible to identify you. Research records will be kept in a locked file; only the researchers will have access to the records.

### Contacts and Questions

The researcher(s) conducting this study are Kathleen Linnane and Elise Temple. Please ask any questions you have now. If you have questions later, you may contact them at via telephone at 607-254-1510, in MVR Hall, Office G86, or via email at KML48@cornell.edu or ET62@cornell.edu. If you have any questions or concerns regarding your rights as a subject in this study, you may contact the University Committee on Human Subjects (UCHS) at 607-255-5138, via email at [uchs@cornell.edu](mailto:uchs@cornell.edu), or you may visit the committee's website at <http://www.osp.cornell.edu/Compliance/UCHS/homepageUCHS.htm>

You will be given a copy of this form to keep for your records.

### Statement of Consent

I have read the above information, and have received answers to any questions I've asked. I consent to participate in the study.

Signature \_\_\_\_\_ Date \_\_\_\_\_

Printed Name \_\_\_\_\_

**This consent form will be kept by the researcher for at least three years beyond the end of the study and was approved by the UCHS on November 29, 2006.**

# PARENT TYPICAL CONSENT FORM

## Parent/Guardian Consent Form Investigation of Attention Processes

Your child is invited to be in a research study examining individual attention processes. Your child was selected as a possible participant because we have been contacted directly regarding your child's eligibility for this study due to your child being in the age range we are interested in studying. We ask that you read this form and ask any questions you may have before agreeing to allow your child to participate in this study.

### Background and Study Procedures

The purpose of this study is to investigate how individuals pay attention to different things. If you agree to allow your child to participate, your child will be asked to observe various stimuli presented on a computer screen. There will be two tasks we will ask your child to complete during the study, and each task consists of four short sections. There will be instructions prior to each section of the study. During both tasks, your child will observe random sequences of images, either asterisk(s) or line drawing(s) of a face, each followed by arrows pointing in one of two directions. Following each observation, your child will be asked to press a button on a box to indicate a response.

It is anticipated that your child's participation should take no longer than 60 minutes.

### Risks and Benefits of Being in the Study

We do not anticipate any risks to your child for participation in this study, other than those encountered in day-to-day life.

There are no direct benefits to your child as a participant in this study. Indirect benefits of participation are your contribution to the current knowledge base regarding attention in different individuals.

### Compensation

Each child participating in this study will receive a \$10.00 (ten dollars) as compensation for participating in this study, regardless of whether or not she or he completes the session or withdraws from participation before completion.

### Voluntary Nature of Participation

Your decision whether or not to allow your child to participate will not affect your current or future relations with Cornell University or with your child's school. If you decide to allow your child to participate, you are free to withdraw your child at any time without affecting your relationship with Cornell University or your child's school. Furthermore, your child may refuse to participate or discontinue participation at any time without affecting his or her relationship with Cornell University.

### Confidentiality

The records of this study will be kept private. Investigators will assign code numbers to each participant's results; these code numbers will be kept in a computer file separate from any results obtained during the study.

In any sort of report we might publish, we will not include any information that will make it possible to identify you or your child. Research records will be kept in a locked file; only the researchers will have access to the records.

### Contacts and Questions

The researcher(s) conducting this study are Kathleen Linnane and Elise Temple. Please ask any questions you have now. If you have questions later, you may contact them at via telephone at 607-254-1510, in MVR Hall, Office G86, or via email at KML48@cornell.edu or ET62@cornell.edu. If you have any questions or concerns regarding your rights as a subject in this study, you may contact the University Committee on Human Subjects (UCHS) at 607-255-5138, via email at [uchs@cornell.edu](mailto:uchs@cornell.edu), or you may visit the committee's website at <http://www.osp.cornell.edu/Compliance/UCHS/homepageUCHS.htm>

You will be given a copy of this form to keep for your records.

### Statement of Consent:

I have read the above information, and have received answers to any questions I've asked. I consent to participate in the study.

Child's Name \_\_\_\_\_

Printed Name \_\_\_\_\_

Parent Signature \_\_\_\_\_

Date \_\_\_\_\_

**This consent form will be kept by the researcher for at least three (3) years beyond the end of the study and was approved by the UCHS on November 29, 2006.**

# PARENT ADHD/ASD CONSENT FORM

## Parent/Guardian Consent Form Investigation of Attention Processes

Your child is invited to be in a research study examining individual attention processes. Your child was selected as a possible participant either because we have been contacted directly regarding your child's eligibility for this study due to your child's clinical diagnosis. Furthermore, your child is in the age range we are interested in studying. We ask that you read this form and ask any questions you may have before agreeing to allow your child to participate in this study.

### Background and Study Procedures

The purpose of this study is to investigate how individuals pay attention to different things. If you agree to allow your child to participate, your child will be asked to observe various stimuli presented on a computer screen. There will be two tasks we will ask your child to complete during the study, and each task consists of four short sections. There will be instructions prior to each section of the study. During both tasks, your child will observe random sequences of images, either asterisk(s) or line drawing(s) of a face, each followed by arrows pointing in one of two directions. Following each observation, your child will be asked to press a button on a box to indicate a response.

It is anticipated that your child's participation should take no longer than 60 minutes.

### Risks and Benefits of Being in the Study

We do not anticipate any risks to your child for participation in this study, other than those encountered in day-to-day life.

There are no direct benefits to your child as a participant in this study. Indirect benefits of participation are your contribution to the current knowledge base regarding attention in different individuals.

### Compensation

Each child participating in this study will receive \$20.00 (twenty dollars) as compensation for participating in this study, regardless of whether or not she or he completes the session or withdraws from participation before completion.

### Voluntary Nature of Participation

Your decision whether or not to allow your child to participate will not affect your current or future relations with Cornell University or with your child's school. If you decide to allow your child to participate, you are free to withdraw your child at any time without affecting your relationship with Cornell University or your child's school. Furthermore, your child may refuse to participate or discontinue participation at any time without affecting his or her relationship with Cornell University.

### Confidentiality

The records of this study will be kept private. Investigators will assign code numbers to each participant's results; these code numbers will be kept in a computer file separate from any results obtained during the study.

In any sort of report we might publish, we will not include any information that will make it possible to identify you or your child. Research records will be kept in a locked file; only the researchers will have access to the records.

### Contacts and Questions

The researcher(s) conducting this study are Kathleen Linnane and Elise Temple. Please ask any questions you have now. If you have questions later, you may contact them at via telephone at 607-254-1510, in MVR Hall, Office G86, or via email at KML48@cornell.edu or ET62@cornell.edu. If you have any questions or concerns regarding your rights as a subject in this study, you may contact the University Committee on Human Subjects (UCHS) at 607-255-5138, via email at [uchs@cornell.edu](mailto:uchs@cornell.edu), or you may visit the committee's website at <http://www.osp.cornell.edu/Compliance/UCHS/homepageUCHS.htm>

You will be given a copy of this form to keep for your records.

### Statement of Consent:

I have read the above information, and have received answers to any questions I've asked. I consent to participate in the study.

Child's Name \_\_\_\_\_

Printed Name \_\_\_\_\_

Parent Signature \_\_\_\_\_

Date \_\_\_\_\_

**This consent form will be kept by the researcher for at least three (3) years beyond the end of the study and was approved by the UCHS on November 29, 2006.**

## CHILD ASSENT FORM

### **Child Participant Consent Form Investigation of Attention Processes**

We are asking you to take part in a study of how kids your age pay attention to different types of pictures. We ask that you read this form carefully and ask ANY questions before you agree to be in our study.

#### **Procedure**

If you do agree to be in our study, we are going to show you some pictures on a computer screen. We will then show you some arrows which will be either pointing to the left (←) or to the right (→). We will ask you to press a button on a box to tell us if a certain arrow is pointing to the left or to the right. Before you begin, we will give you a practice session.

You can ask questions that you might have about this study at any time. Also, if you decide at any time not to finish, you may stop whenever you want. Please remember that this is not a test. We are interested in how you pay attention. We will not show your answers to anyone else, including your parents, teachers and friends.

When you are finished looking at all the pictures, we will reward you with \$20.00 (twenty dollars) to thank you for spending time with us and answering our questions. Again, if during our study you feel uncomfortable or do not wish to finish, you may quit at any time. We will still give you the \$20.00 reward if you choose to quit our study.

If you sign this paper, it means that you have read this paper and that you want to be in the study. If you do not want to be in the study, do not sign the paper. Remember, being in this study is up to you, and no one will be mad if you do not sign this paper or if you change your mind later.

Signature \_\_\_\_\_

Printed Name \_\_\_\_\_

Date \_\_\_\_\_

How old are you? \_\_\_\_\_

Are you a girl or a boy? \_\_\_\_\_

Which hand do you write with most of the time? \_\_\_\_\_

This assent form will be kept by the researcher for at least three years beyond the end of the study and was approved by the UCHS on November 29, 2006.

## REFERENCES

- Adolphs, R. (2002). Neural systems for recognizing emotions. *Current Opinion in Neurobiology*, *12*, 1–9.
- Adolphs, R., Baron-Cohen, A. & Tranel, D. (2002). Impaired Recognition of Social Emotions following Amygdala Damage. *Journal of Cognitive Neuroscience*, *14*, 1–11.
- Adolphs, R., Tranel, D., Damasio, H., & Damasio, A. (2002). Impaired recognition of emotion in facial expressions following bilateral damage to the human amygdala. *Nature*, *372*, 669–672.
- American Psychiatric Association (2000). *Diagnostic and statistical manual of mental disorders* (4<sup>th</sup> ed., rev). Washington, DC: Author.
- Bachevalier, J. & Loveland, K. A. (2006). The orbitofrontal-amygdala circuit and self-regulation of social-emotional behavior in autism. *Neuroscience and Biobehavioral Reviews*, *30*, 97–117.
- Badgaiyan, R.D. & Posner, M.I. (1998). Mapping the cingulate cortex in response selection and monitoring. *Neuroimage*, *7*, 255–260.
- Bailey, A., Luthert, P., Dean, A., Harding, B., Janota, I., Montgomery, M., Rutter, M. & Lantos, P. (1998). A clinicopathological study of autism. *Brain*, *121*, 889–905.
- Bar-Haim, Y., Shulman, C., Lamy, D. & Reuveni, A. (2006). Attention to eyes and mouth in high-functioning children with Autism. *Journal of Autism and Developmental Disorders*, *36*(1), 131–137.
- Barkley, R. A. (1997). Behavioral inhibition, sustained attention and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin*, *121*, 65–94.

- Baron-Cohen, S. & Belmonte, M. K. (2005). Autism: A window onto the development of the social and the analytic brain. *Annual Review of Neuroscience*, 28, 109–126.
- Baron-Cohen, S., Knickmeyer, R. C. & Belmonte, M. K. (2005). Sex differences in the brain: Implications for explaining autism. *Science*, 310(5749), 819 – 823.
- Baron-Cohen, S., Leslie, A. M. & Frith, U. (1985). Does the autistic child have a “theory of mind”? *Cognition*, 21, 37–46.
- Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J. & Clublet, E. (2001). The Autism Spectrum Quotient (AQ): Evidence from Asperger Syndrome/High Functioning Autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders*, 31, 5–17.
- Baron-Cohen, S., Ring, H. A., Bullmore, E. T., Wheelwright, S., Ashwin, C. & Williams, S. C. R. (2000). The amygdala theory of autism. *Neuroscience and Biobehavioral Reviews*, 24, 355–364.
- Baron-Cohen, S., Ring, H. A., Wheelwright, S., Bullmore, E. T., Brammer, M. J., Simmons, A. & Williams, S. C. R. (1999). Social intelligence in the normal and autistic brain: an fMRI study. *European Journal of Neuroscience*, 11, 1891–1898.
- Baron-Cohen, S., Wheelwright, S. & Joliffe, T. (1997). Is there a ‘language of the eyes’? Evidence from normal adults, and adults with autism or Asperger’s syndrome. *Visual Cognition*, 4, 311–331.
- Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and theory of mind*. Cambridge, MA: The MIT Press.
- Barry, R. J. & James, A. L. (1988). Coding of stimulus parameters in autistic, retarded, and normal children: Evidence for a two-factor theory of autism. *International Journal of Psychophysiology*, 6(2), 139–149.

- Bauman, M. L. & Kemper, T. L. (2005). Neuroanatomic observations of the brain in autism: a review and future directions. *International Journal of Developmental Neuroscience*, 23, 183–187.
- Bayliss, A. P. & Tipper, S. P. (2005). Gaze and arrow cueing of attention reveals individual differences along the autism spectrum as a function of target context. *British Journal of Psychology*, 96, 95–114.
- Belmonte, M. (2000). Abnormal attention in autism shown by steady-state visual evoked potentials. *Autism*, 4(3), 269–285.
- Belmonte, M. K., Allen, G. Beckel-Mitchener, A., Boulanger, L. M., Carper, R. A. & Webb, S. J. (2004). Autism and abnormal development of brain connectivity. *The Journal of Neuroscience*, 24(42), 9228–9231.
- Belmonte, M. K. & Yurgelun-Todd, D. A. (2003). Functional anatomy of impaired selective attention and compensatory processing in autism. *Cognitive Brain Research*, 17, 651–664.
- Berger, A. & Posner, M. I. (2000). Pathologies of brain attentional networks. *Neuroscience and Biobehavioral Reviews*, 24, 3–5.
- Breiter, H. C., Etcoff, N. L., Whalen, P. J., Kennedy, W. A., Rauch, S. L., Buckner, R. L., Strauss, M. M., Hymn, S. E. & Rosen, B. R. (1996). Response and habituation of the human amygdala during visual processing of facial expression. *Neuron*, 17, 875–887.
- Bush, G., Frazier, J. A., Rauch, S. L., Seidman, L. J., Whalen, P. J., Jenike, M. A., Rosen, B. R. & Biederman, J. (1999). Anterior cingulate cortex dysfunction in Attention-Deficit/Hyperactivity Disorder revealed by fMRI and the counting Stroop. *Biological Psychiatry*, 45, 1542–1552.
- Bush, G., Luu, P. & Posner, M. I. (2000). Cognitive and emotional influences in anterior cingulate cortex. *Trends in Cognitive Sciences*, 4(6), 215–222.

- Bush, G., Valera, E. M. & Seidman, L. J. (2005). Functional neuroimaging of Attention-Deficit/Hyperactivity Disorder: A review and suggested future directions. *Biological Psychiatry*, *57*, 1273–1284.
- Callejas, A., Lupiáñez, J. & Tudela, P. (2004). The three attentional networks: On their independence and interactions. *Brain and Cognition*, *54*, 225–227.
- Carper, R. A. & Courchesne, E. (2005). Localized enlargement of the frontal cortex in early autism. *Biological Psychiatry*, *57*, 126–133.
- Casagrande, M., Martella, D., DiPace, E., Pirri, F. & Guadalupi, F. (2006). Orienting and alerting: effect of 24 h of prolonged awareness. *Experimental Brain Research*, *171*, 184–193.
- Casey, B., Gordon, C., Manheim, G. & Rumsey, J. (1993). Dysfunctional attention in autistic savants. *Journal of Clinical and Experimental Neuropsychology*, *15*(6), 933–946.
- Casey, B. J., Trainor, R., Giedd, J., Vauss, Y., Vaituzis, C. K., Hamburger, S., Kozuch, P. & Rapoport, J. L. (1997). The role of the anterior cingulate cortex in automatic and controlled processes: A developmental neuroanatomical study. *Developmental Psychobiology*, *30*, 61–69.
- Centers for Disease Control and Prevention (2007). Prevalence of autism spectrum disorders. Surveillance Summaries, February 9, 2007. *MMWR 2007*, *56*(SS-1).
- Courchesne, E. (2004). Brain development in autism: Early overgrowth followed by premature arrest of growth. *Mental Retardation and Developmental Disabilities Research Reviews*, *10*, 106–111.
- Courchesne, E., Carper, R., & Akshoomoff, N. (2003). Evidence of brain overgrowth in the first year of life in autism. *Journal of the American Medical Association*, *290*, 337–344.

- Courchesne, E., Chisum, H. & Townsend, J. (1994). Neural activity-dependent brain changes in development: Implications for psychopathology. *Development and Psychopathology*, 6(4), 697–722.
- Courchesne, E., Townsend, J., Askhoomoff, N. A., Yeung-Courchesne, R., Lincoln, A. J., Press, G. A., Murakami, J. W., James, H. E., Saitoh, O., Egaas, B., Haas, R. H. & Schreibman, L. (1994). A new finding: Impairment in shifting attention in autistic and cerebellar patients. In *Atypical Cognitive Deficits in Developmental Disorders: Implications for Brain Functions*. (Sarah H. Broman & Jordan Grafman, Eds.) Hillsdale, New Jersey: Lawrence Erlbaum Associates.
- Critchley, H. D. (2005). Neural mechanisms of autonomic, affective, and cognitive integration. *Journal of Comparative Anatomy*, 493, 154–166.
- Critchley, H. D., Daly, E. M., Bullmore, E. T., Williams, S. C. R., Van Amelsvoort, T., Robertson, D. M., Rowe, A., Phillips, M., McAlonan, G., Howlin, P. & Murphy, D. G. M. (2000). The functional anatomy of social behavior: Changes in cerebral blood flow when people with autistic disorder process facial expressions. *Brain*, 123, 2203–2212.
- Daffner, K. R., Mesulam, M. M., Holcomb, P. J., Calvo, V., Acar, D., Chabrierie, A., Kikinis, R., Jolesz, F. A., Rentz, D. M. & Scinto, L. F. M. (2000). Disruption of attention to novel events after frontal lobe injury in humans. *Journal of Neurology, Neurosurgery & Psychiatry*, 68, 18–24.
- Dawson, G., Meltzoff, A. N., Osterling, J., Rinaldi, J. & Brown, E. (1998). Children with autism fail to orient to naturally occurring social stimuli. *Journal of Autism and Developmental Disorders*, 28(6), 479–485.

- D'Entremont, D., Hains, S. M. J. & Muir, D. W. (1997). A demonstration of gaze following in 3- to 6-month olds. *Infant Behavior and Development*, *20*(4), 569–572.
- Deouell, L.Y., & Knight, R.T. (2005). ERP Measures of Multiple Attention Deficits Following Prefrontal Damage. In Itty, L., Rees G. & Tsotos, J. K. (Eds.) *Neurobiology of Attention*. San Diego: Elsevier.
- Dias, R., Robbins, T. W. & Roberts, A. C. (1996). Primate analogue of the Wisconsin Card Sorting Test: Effects of excitotoxic lesions of the prefrontal cortex in the marmoset. *Behavioral Neuroscience*, *110*(5), 872–886.
- Diedrichsen, J., Ivry, R. B., Cohen, A. & Danziger, S. (2000). Asymmetries in a unilateral flanker task depend on the direction of the response: The role of attentional shift and perceptual grouping. *Journal of Experimental Psychology*, *26*(1), 113 – 126.
- Downing, P. E., Dodds, C. M. & Bray, D. (2004). Why does the gaze of others direct visual attention? *Visual Cognition*, *11*(1), 71–79.
- Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E. & Baron-Cohen, S. (1999). Gaze perception triggers reflexive visuospatial orienting. *Visual Cognition*, *6*(5), 509–540.
- Durston, S., Tottenham, N. T., Thomas, K. M., Davidson, M. C., Eigsti, I., Yang, Y., Ulug, A. M. & Casey, B. J. (2003). Differential patterns of striatal activation in young children with and without ADHD. *Biological Psychiatry*, *53*, 871–878.
- Emery, N. J. (2000). The eyes have it: the neuroethology, function and evolution of social gaze. *Neuroscience and Biobehavioral Reviews*, *24*, 581–604.
- Eriksen, B.A., & Eriksen, C.W. (1974). Effects of noise letters on the identification of a target letter in a nonsearch task. *Perception & Psychophysics*, *16*, 143–149.

- Fan, J., Flombaum, J. I., McCandliss, B. D., Thomas, K. M. & Posner, M. I. (2003a). Cognitive and brain consequences of conflict. *NeuroImage*, *18*, 42–57.
- Fan, J., Fossella, J., Sommer, T., Wu, Y. & Posner, M. I. (2003b). Mapping the genetic variation of executive attention onto brain activity. *Proceedings of the National Academy of Sciences*, *100*(12), 7406–7411.
- Fan, J., McCandliss, B. D., Fossella, J., Flombaum, J. I. & Posner, M. I. (2005). The activation of attentional networks. *NeuroImage*, *26*, 471–479.
- Fan, J., McCandliss, B. D., Sommer, T., Raz, A. & Posner, M. I. (2002). Testing the efficiency and independence of attentional networks. *Journal of Cognitive Neuroscience*, *14*(3), 340–347.
- Fan, J., Wu, Y., Fossella, J. A. & Posner, M. I. (2001). Assessing the heritability of attentional networks. *BMC Neuroscience*, *2*(14).
- Faraone, S. V. & Biederman, J. (1998). Neurobiology of Attention-Deficit Hyperactivity Disorder. *Biological Psychiatry*, *44*, 951–958.
- Fernandez-Duque, D. & Black, S. E. (2006). Attentional networks in normal aging and Alzheimer's Disease. *Neuropsychology*, *20*(2), 133–143.
- Fernandez-Duque, D. & Posner, M. I. (2001). Brain imaging of attentional networks in normal and pathological states. *Journal of Clinical and Experimental Neuropsychology*, *23*(1), 74–93.
- Fernandez-Duque, D. & Posner, M. I. (1997). Relating the mechanisms of orienting and alerting. *Neuropsychologia*, *35*(4), 477–486.
- Fossella, J., Posner, M.I., Fan, J., Swanson, J. M. & Plaff, D. W. (2002). Attentional phenotypes for the analysis of higher mental function. *The Scientific World*, *2*, 217–223.
- Friesen, C. K., Moore, C. & Kingstone, A. (2005). Does gaze direction really trigger a reflexive shift of attention? *Brain and Cognition*, *57*(1), 66–69.

- Friesen, C. K., Ristic, J. & Kingstone, A. (2004). Attentional effects of counterpredictive gaze and arrow cues. *Journal of Experimental Psychology*, 30(2), 319–329.
- Friesen, C. K. & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin & Review*, 5, 490-495.
- Frith, U. (2001). Mind blindness and the brain in autism. *Neuron*, 32, 969–979.
- George, N., Dolan, R. J., Fink, G. R., Baylis, G. C., Russell, C. & Driver, J. (1999). Contrast polarity and face recognition in the human fusiform gyrus. *Nature Neuroscience*, 2(6), 574–580.
- Gerrans, P. (2002). The theory of mind module in evolutionary psychology. *Biology and Philosophy*, 17, 305–321.
- Goldberg, M. C., Mostofsky, S. H., Cutting, L. E., Mahone, E. M., Astor, B. C., Denckla, M. B., & Landa, R. J. (2005). Subtle executive impairment in children with autism and children with ADHD. *Journal of Autism and Developmental Disorders*, 35(3), 279–293.
- Goldstein, G., Johnson, C. R., & Minshew, N. J. (2001). Attentional processes in autism. *Journal of Autism and Developmental Disorders*, 4, 433-440. *Journal of Autism and Developmental Disorders*, 35, 279–293.
- Happé, F. G. E. (1996). Studying weak central coherence at low levels: Children with autism do not succumb to visual illusions, a research note. *Journal of Child Psychology and Psychiatry*, 37, 873–877.
- Happé, F. & Frith, U. (2006). The weak coherence account: Detail-focused cognitive style in autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 36(1), 5–25.

- Happé, F., Briskman, J. & Frith, U. (2001). Exploring the cognitive phenotype of autism: weak "central coherence" in parents and siblings of children with autism: I. Experimental tests. *Journal of Child Psychology and Psychiatry*, 42(3), 299–307.
- Harris, N. S., Courchesne, E., Townsend, J., Carper, R. A. & Lord, C. (1999). Neuroanatomic contributions to slowed orienting of attention in children with autism. *Cognitive Brain Research*, 8, 61–71.
- Hashimoto, T., Tayama, M., Murakawa, K., Yoshimoto, T., Miyazaki, M., Harada, M., & Kuroda, Y. (1995). Development of the brainstem and cerebellum in autistic patients. *Journal of Autism and Developmental Disorders*, 25, 1–18.
- Haxby, J. V., Hoffman, E. A. & Gobbini, M. I. (2002). Human neural systems for face recognition and social communication. *Biological Psychiatry*, 51, 59–67.
- Holmes, A., Viulleumier, P. & Eimer, M. (2003). the processing of emotional facial expression is gated by spatial attention: evidence from event-related brain potentials. *Cognitive Brain Research*, 16, 174–184.
- James, W. (1890). *Principles of Psychology*. New York: Holt.
- Johnson, M. H., Griffin, R., Csibra, G., Halit, H., Farroni, T., DeHaan, M., Tucker, L. A., Baron-Cohen, S. & Richards, J. (2005). The emergence of the social brain network: Evidence from typical and atypical development. *Development and Psychopathology*, 17(3), 599–619.
- Joseph, R. M. (1999). Neuropsychological frameworks for understanding autism. *International Review in Psychiatry*, 11(4), 309–324.
- Kanner, L. (1943). Autistic disturbances of affective contact. *Nervous Child*, 2, 217–250.

- Kemner, C. & van Engeland, H. (2005). ERPs and eye movements reflect atypical visual processing in pervasive developmental disorder. *Journal of Autism and Developmental Disorders*, 36(1), 45–54.
- Kingstone, A., Smilek, D., Ristic, J., Friesen, C. K. & Eastwood, J. D. (2003). Attention, researchers! It is time to take a look at the real world. *Current Directions in Psychological Science*, 12(5), 176–180.
- Kipp, K. (2005). A developmental perspective on the measurement of cognitive deficits in Attention-Deficit/Hyperactivity Disorder. *Biological Psychiatry*, 57, 1256–1260.
- Klin, A., Jones, W., Schultz, R. & Volkmar, F. (2003). The enactive mind, or from actions to cognition: lessons from autism. *Philosophical Transactions of the Royal Society London B*, 358, 345–360.
- Klin, A., Jones, W., Schultz, R., Volkmar, F. & Cohen, D. (2002). Visual fixation patterns during viewing of naturalistic social situations as predictors of social competence in individuals with autism. *Archives of General Psychology*, 59, 809–816.
- Kobayashi, H. & Kohshima, S. (1997). Unique morphology of the human eye. *Nature*, 387, 767–768.
- Konrad, K., Neufang, S., Hanisch, C., Fink, G. R. & Herpetz-Dahlman. (2005). Dysfunctional Attentional networks in children with Attention Deficit/Hyperactivity Disorder: Evidence from an event-related functional magnetic resonance imaging study. *Biological Psychiatry*, 59(7), 643–651.
- Kylliäinen, A., Braeutigam, S., Hietanen, J. K., Swithenby, S. J. and Bailey, A. J. (2006). Face and gaze processing in normally developing children: a magnetoencephalographic study. *European Journal of Neuroscience*, 23, 801–810.

- Kylliäinen, A. & Hietanen, J. K. (2004). Attention orienting by another's gaze in children with autism. *Journal of Child Psychology and Psychiatry*, 45(3), 435–444.
- Langton, S. R. H., Watt, R. J., & Bruce, V. (2000). Do the eyes have it? Cues to the direction of social attention. *Trends in Cognitive Sciences*, 4, 50–59.
- Langton, S. R. H. & Bruce, V. (1999). Reflexive visual orienting in response to the social attention of others. *Visual Cognition*, 6(5), 541–567.
- LeDoux, J. (2000). Emotion circuits in the brain. *Annual Review of Neuroscience*, 23, 155–184.
- Leekham, S. R., Hunnisett, E. & Moore, C. (1998). Targets and cues: Gaze-following in children with autism. *Journal of Child Psychology and Psychiatry*, 39(7), 951–962.
- Liss, M., Fein, D., Allen, D., Dunn, M., Feinstein, C., Morris, R., Waterhouse, L. & Rapin, I. (2001). Executive functioning in high-functioning children with autism. *Journal of Child Psychology and Psychiatry*, 42(2), 261–270.
- Linnane, K. & Temple, E. (in preparation). Attentional networks in ADHD.
- Magno, E., Foxe, J. J., Molholm, S., Robertson, I. H. & Garavan, H. (2006). The anterior cingulate cortex and error avoidance. *The Journal of Neuroscience*, 26(18), 4769–4773.
- Miyake, A., Friedman, N., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: A latent variable analysis. *Cognitive Psychology*, 41, 49–100.
- Matthews, A., Fox, E., Yiend, J. & Calder, A. (2003). The face of fear: Effects of eye gaze and emotion on visual attention. *Visual Cognition*, 10(7), 823–835.

- Mezzacampa, E. (2004). Alerting, orienting, and executive attention: Developmental properties and sociodemographic correlates in an epidemiological sample of young, urban children. *Child Development, 75*(5), 1373–1386.
- Mottron, L., Dawson, M., Soulières, I., Hubert, B. & Burack, J. (2006). Enhanced perceptual functioning in autism: An update, and eight principles of autistic perception. *Journal of Autism and Developmental Disorders, 36*(1), 27–43.
- National Institute of Mental Health (2006). *Attention Deficit Hyperactivity Disorder*. Bethesda, MD: Author.
- Oberlin, B. G., Alford, J. L. & Marrocco, R. T. (2005). Normal attention orienting but abnormal stimulus alerting and conflict effect in combined type of ADHD. *Behavioral Brain Research, 165*(1), 1–11.
- Ozonoff, S., Pennington, B. J. & Rogers, S. J. (1991). Executive function deficits in high-functioning autistic individuals: Relationship to theory of mind. *Journal of Child Psychiatry and Psychology, 32*(7), 1081–1105.
- Pardo, J. V., Pardo, P. J., Janers, K. W. & Raichle, M. W. (1990). The anterior cingulate cortex mediates processing selection in the Stroop attentional conflict paradigm. *Proceedings of the National Academy of Sciences, 87*(1), 256–259.
- Pascualvaca, D. M., Fantie, B. D., Papageorgiou, M. & Mirsky, A. F. (1998). Attentional capacities in children with autism: Is there a general deficit in shifting focus? *Journal of Autism and Developmental Disorders, 28*(6), 467–478.
- Pellicano, E., Maybery, M., Durkin, K & Maley, A. (2006). Multiple cognitive capabilities/deficits in children with an autism spectrum disorder: “Weak” central coherence and its relationship to theory of mind. *Development and Psychopathology, 18*, 77–98.

- Pelphrey, K. A., Sasson, N. J., Reznick, J. S., Paul, G., Goldman, B.D. & Piven, J. (2002). Visual scanning of faces in autism. *Journal of Autism and Developmental Disorders*, 32(4), 249–261.
- Pessoa, L. (2005). To what extent are emotional visual stimuli processed without attention and awareness? *Current Opinion in Neuroscience*, 15, 188–196.
- Pessoa, L., Padmala, S. & Morland, T. (2005). Fate of unattended fearful faces in the amygdala is determined by both attentional resources and cognitive modulation. *NeuroImage*, 28(1), 249–255.
- Pessoa, L., McKenna, M., Gutierrez, E. & Ungerleider, L. G. (2002). Neural processing of emotional faces requires attention, *Proceedings of the National Academy of Sciences*, 99(17), 11458–11463.
- Piven, J., Arndt, S., Bailey, J., Havercamp, S., Andreasen, N. C. & Palmer, P. (1995). An MRI study of brain size in autism. *American Journal of Psychiatry*, 152, 1145–1149.
- Plant, R. R., Hammond, N. V. & Whitehouse T. (2003). How choice of mouse may affect response timing in psychological studies. *Behavior Research Methods, Instruments and Computers*, 35(2), 276–284.
- Posner, M. I. (2004). Neural systems and individual differences. *Teachers College Record*, 106(1), 24–30.
- Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, 32, 3–25.
- Posner, M.I. & Fan, J. (2004). Attention as an organ system. In J. Pomerantz & M. Crai (Eds.) *Topics in Integrative Neuroscience: From Cells to Cognition*. Cambridge, UK: Cambridge University Press.
- Posner, M. I. & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience*, 13, 25–42.

- Posner, M. I. & Rothbart, M. K. (2000). Developing mechanisms of self regulation. *Development and Psychopathology*, *12*, 427–411.
- Quadflieg, S., Mason, M. F. & Macrae, C. N. (2004). The owl and the pussycat: Gaze cues and visuospatial orienting, *Psychonomic Bulletin and Review*, *11*(5), 826–831.
- Raz, A. (2004). Anatomy of attentional networks. *The Anatomical Record*, *281*(B), 21–36.
- Raz, A. & Buhle, J. (2006). Typologies of attentional networks. *Nature Reviews Neuroscience*, *7*, 367–379.
- Ring, H. A., Baron-Cohen, S., Wheelwright, S., Williams, S. C. R., Brammer, M., Andrew, C. & Bullmore, E. (1999). Cerebral correlates of preserved cognitive skills in autism. A functional MRI study of Embedded Figures Task performance. *Brain*, *122*(7), 1305–1315.
- Ristic, J., Friesen, C. K. & Kingstone, A. (2002). Are eyes special? It depends on how you look at it. *Psychonomic Bulletin & Review*, *9*(3), 507–513.
- Ro, T., Machado, L., Kanwisher, N. & Rafal, R. D. (2002). Covert orienting to the locations of targets and distractors: Effects on response channel activation in a flanker task. *The Quarterly Journal of Experimental Psychology*, *55A*(3), 817–936.
- Rueda, M. R., Fan, J., McCandliss, B. D., Halparin, J. D., Gruber, D. B., Lercari, L. P. & Posner, M. I. (2004). Development of attentional networks in childhood. *Neuropsychologia*, *42*, 1029–1040.
- Russell, J., Jarrold, C. & Hood, B. (1999). Two intact executive capacities in children with autism: Implications for the core executive dysfunctions in the disorder. *Journal of Autism and Developmental Disorders*, *29*(2), 103–112.

- Scaife, M., & Bruner, J. (1975). The capacity for joint visual attention in the infant. *Nature*, 253, 265–266.
- Schmitz, N., Rubia, K., Daly, E., Smith, A., Williams, S. & Murphy, D. G. M. (2006). Neural correlates of executive function in autistic spectrum disorders. *Biological Psychiatry*, 59, 7–16.
- Schuller, A. & Rossion, B. (2004). Perception of static eye gaze direction facilitates subsequent early visual processing. *Clinical Neurophysiology*, 115, 1161–1168.
- Schultz, R. T., Grelotti, D. J., Klin, A., Kleinman, J., Van Der Gaag, C., Marois, R. & Skudlarski, P. (2003). The role of the fusiform face area in social cognition: implications for the pathobiology of autism. *Philosophical Transactions of the Royal Society of London*, 358, 415–427.
- Seidman, L. J., Valera, E. M. & Makris, N. (2005). Structural brain imaging of Attention-Deficit/Hyperactivity Disorder. *Biological Psychiatry*, 57, 1263–1272.
- Senju, A., Tojo, Y., Dairoku, H. & Hasegawa, T. (2004). Reflexive orienting in response to eye gaze and an arrow in children with and without autism. *Journal of Child Psychology and Psychiatry*, 45(3), 445–458.
- Sergeant, J. A., Guerts, H. & Oosterlaan, J. (2002). How specific is a deficit of executive functioning for Attention-Deficit/Hyperactivity Disorder? *Behavioural Brain Research*, 130, 3–28.
- Shallice, T., Marzocchi, G. M., Coser, S., DelSavio, M., Meuter, R. F. & Rumiati, R. I. (2002). Executive function profile of children with Attention Deficit Hyperactivity Disorder. *Developmental Neuropsychology*, 21, 43–71.

- Siegel, B.V., Nuechterlein, K. H., Abel, L., Wu, J.C. & Buchsbaum, M.S. (1995)  
Glucose metabolic correlates of continuous performance test performance in  
adults with a history of infantile autism, schizophrenics, and controls.  
*Schizophrenia Research*, *17*(1), 85–94.
- Stuss, D. T., Alexander, M. P., Shallice, T., Picton, T. W., Binns, M. A., Macdonald,  
R., Borowiec, A. & Katz, D. I. (2005). Multiple frontal systems controlling  
response speed. *Neuropsychologia*, *43*, 396–417.
- Swanson, J. M., Posner, M., Potkin, S., Bonforte, S., Youpa, D., Fiore, C., Cantwell,  
D. & Crinella, F. (1991). Activating tasks for the study of visual-spatial  
attention in ADHD children: A cognitive anatomic approach. *Journal of Child  
Neurology*, *6*, S119–S127.
- Tipples, J. (2005). Orienting to eye gaze and face processing. *Journal of Experimental  
Psychology*, *31*(5), 843–856.
- Vecera, S. P. & Rizzo, M. (2004). What are you looking at? Impaired ‘social  
attention’ following frontal-lobe damage. *Neuropsychologia*, *42*, 1657–1665.
- Vlamings, P. H. J. M., Stauder, J. E. A., van Son, I. A. M., & Mottron, L. (2005).  
Atypical visual orienting to gaze- and arrow-cues in adults with high  
functioning autism. *Journal of Autism and Developmental Disorders*, *35*, 267–  
277.
- Vuilleumier, P., Armony, J., & Dolan, R. (2003). Reciprocal links between emotion  
and attention. (In R. S. J. F. et al. (Ed.), *Human Brain Function* (pp. 419–444).  
San Diego: Academic Press.
- Vuilleumier, P., Armony, J. L., Driver, J. & Dolan, R. J. (2001). Effects of attention  
and emotion on face processing in the human brain: An event-related fMRI  
study. *Neuron*, *30*, 829–841.

- Wang, A. T., Dapretto, M., Hariri, A. R., Sigman, M. & Bookheimer, S. Y. (2004). Neural correlates of facial affect processing in adolescents with autism spectrum disorders. *Journal of the American Academy of Child and Adolescent Psychiatry*, 43(4), 481–490.
- Waterhouse, L., Fein, D. & Modahl, C. (1996). Neurofunctional mechanisms in autism. *Psychological Review*, 103(3), 457–489.
- Whalen, P. J., Rauch, S. L., Etcoff, N. L., McInerney, S. C., Lee, M. B. & Jenike, M. A. (1998). Masked presentations of emotional facial expressions modulate amygdala activity without explicit knowledge. *The Journal of Neuroscience*, 18(1), 411–418.
- Williams, J. G. H., Waiter, G. D., Gilchrist, A., Perrett, D. I., Murray, A. D. & Whiten, A. (2006). Neural mechanisms of imitation and ‘mirror neuron’ functioning in autistic spectrum disorder. *Neuropsychologia*, 44, 610–621.
- Williams, M.A., McGlone, F., Abbott, D. F. & Mattingly, J. B. (2005). Differential amygdala responses to happy and fearful faces depend on selective attention. *NeuroImage*, 24, 417–425.
- Wing, L. & Gould, J. (1979). Severe impairments of social interaction and associated abnormalities in children: Epidemiology and classification. *Journal of Autism and Developmental Disorders*, 9, 11–29.
- Winston, J. S., O’Doherty, J., & Dolan, R. J. (2003). Common and distinct neural responses during direct and incidental processing of multiple facial emotions. *NeuroImage*, 20, 84–97.
- Witte, E. A., Davidson, M. C. & Marrocco, R. T. (1997). Effects of altering brain cholinergic activity on covert orienting of attention: comparison of money and human performance. *Psychopharmacology*, 132, 324–334.

- Witte, E. A., Villareal, M. & Marrocco, R. T. (1996). Visual orienting and alerting in rhesus monkeys: comparison with humans. *Behavioural Brain Research*, 82, 103 – 112.
- Wojciulik, E., Kanwisher, N. & Driver, J. (1998). Covert visual attention modulates face-specific activity in the human fusiform gyrus: fMRI study. (1998). *Journal of Physiology*, 79(3), 1574–1578. Delayed maturation of the frontal cortex in childhood autism. *American Journal of Psychiatry*, 152, 248–252.