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# Differences in global and local level information processing in autism: An fMRI investigation

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ABSTRACT

People with autism spectrum disorders (ASD) have atypical visual perception of global and local information. Previous neuroimaging studies have examined the functional anatomy of *locally* directed attention during visual processing in ASD, but few have examined differences in both *globally* and *locally* directed attention. We performed functional magnetic resonance imaging (fMRI) in 17 adults with ASD and 16 typically developing (TD) subjects to examine the neurobiology of both global- and local-level information processing in ASD using an abstract hierarchical design task. TD subjects showed no regions of increased brain activation relative to subjects with ASD as assessed using whole brain analysis. Subjects with ASD exhibited greater activation in right superior frontal gyrus during locally directed attention. During globally directed attention, the ASD group showed greater right lateral occipital activation. Additionally, subjects with ASD showed less deactivation in medial prefrontal cortex (part of the default mode network) in the globally directed attention condition. Our findings help elucidate networks of brain activation related to atyipcal global and local feature processing in ASD.



## 1. Introduction

Autism spectrum disorders (ASD) are characterized by impaired social interaction and communication accompanied by repetitive behaviors and restricted interests (American Psychiatric Association, 2000). Despite the characterization of the disorder as a constellation of deficits, there may also be relative advantages. One such advantage is an enhanced ability to focus on details, exemplified by superior performance on visual search tasks such as the Embedded Figures Task (EFT) (Shah and Frith, 1983; Jolliffe and Baron-Cohen, 1997; Frith, 2003). The EFT involves searching for a particular shape within a larger, more complex figure (Briskman et al., 2001; Happé and Frith, 2006). At least two major theories attempt to explain how this constellation of symptoms and advantages might arise. One theory, known as weak central coherence (WCC), proposes that people with ASD exhibit a preference for local details compared with global perception, whereas most people show a strong bias for global, holistic perception (Happé and Frith, 2006). The WCC theory emphasizes a relative primacy of local processing and a deficit in global processing (although recent revisions have altered this to ambivalence regarding impairment in global processing). A second theory, known as enhanced perceptual functioning (EPF), posits that the default setting of autistic perception is more locally oriented than that of typically developing persons, without deficits in the processing of global aspects of information (Mottron et al., 2006; Wang et al., 2007). A major difference between the theories is that the revised WCC emphasizes enhanced local processing while remaining undecided regarding inferior global processing, whereas EPF emphasizes that persons with ASD can process globally when required. Although several neuroimaging studies have attempted to provide a functional neuroanatomic understanding of these concepts, continued exploration is needed to provide a robust explanation of pathways underlying altered visual processing in ASD.

Individuals with ASD perform atypically on a range of tasks involving integration of parts and wholes (Happé and Booth, 2008). In the visual domain, subjects with ASD have shown preserved or superior performance of the Block Design subtest of the Wechsler Intelligence Scales and the EFT (Briskman et al., 2001; Happé and Frith, 2006). Other studies have shown performance on the EFT equivalent to that of typically developing (TD) subjects (Brian and Bryson, 1996; Ring et al., 1999). It is noteworthy that in the EFT, attention to the global form confers no advantage on target identification. Presumably, ASD participants perform better than intelligence quotient (IQ)-matched controls because they show a reduced global attention, enhanced local attention, or both. Other studies have also demonstrated the relative advantage in locally directed attention in ASD (Plaisted et al., 1998; O'Riordan et al., 2001). Conversely, people with ASD may have difficulty with tasks that load heavily on global

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perception (Happé and Frith, 2006). This was previously exemplified by studies showing people with ASD exhibit lower performance on tasks involving the recognition of faces—representing reduced configural processing (Behrmann et al., 2006). However, recent evidence has shown that the deficit in face recognition is related to face memory and eye recognition specifically, and not face recognition as a whole (Weigelt et al., 2012). These differences exemplify atypical global and local processing increasingly thought to contribute to the ASD endophenotype.

At least three lines of research highlight the value of functional neuroanatomic exploration of this aspect of the neurocognitive phenotype of autism. First, one recent study found that individuals with macrocephaly (measured by greater head circumference—an index of brain overgrowth that is a known neurodevelopmental correlate of autism) showed evidence of atypical local processing (White et al., 2009). Second, some broad autism phenotype studies have identified altered global processing among parents of individuals with ASD (Baron-Cohen and Hammer, 1997; Briskman et al., 2001). Third, in a Navon-type task participants with ASD demonstrated increased local-to-global interference in naming time and accuracy (Navon, 1977; Wang et al., 2007). These findings demonstrate the need for continued exploration of the neuroanatomical basis of altered global and local processing in ASD.

Neuroanatomical studies have examined global and local visual processing differences in healthy subjects using functional magnetic resonance imaging (fMRI). Studies have shown preferential processing of global information in the right hemisphere (RH) and local information in the left hemisphere (LH), specifically in the right and left occipital cortex, respectively, and in anterior cingulate and parietal areas during local recognition (Fink et al., 1996; Martinez et al., 1997; Lux et al., 2004). A more recent study found at least two components produce hemispheric asymmetries of global and local visual processing (Weissman and Woldorff, 2005). Structures that appear in task-relevant contrasts for healthy individuals include areas such as the cuneus, middle frontal gyrus, inferior frontal gyrus, middle occipital gyrus, superior occipital gyrus, inferior and posterior parietal regions and superior temporal gyrus (Ring et al., 1999; Weissman and Woldorff, 2005; Lee et al., 2007; Manjaly et al., 2007).

In ASD, functional imaging studies have focused mostly on tasks that demand attention to local detail, and in which the global percept confers no advantage, such as the EFT. One recent study was the first, in our knowledge, to examine global-level interference during local processing in ASD, using a functional connectivity analysis (Liu et al., 2011). In this study subjects had to count colored lines associated with a three-dimensional (3D) object. The study found subjects with ASD to have a lower level of activation of executive brain regions and synchronization between executive and posterior visuospatial regions, and the investigators concluded that subjects with ASD were less or not at all affected by the presence of a 3D figure, whereas control subjects needed to suppress automatic processing of global information. In fMRI studies emphasizing attention to detail, such as those using the EFT or Hidden Figures Task (HFT), subjects with ASD have generally exhibited increased task-related activations in posterior regions including the right cuneus, right occipital gyri and right inferior parietal areas in adults (Ring et al., 1999), adolescents (Manjaly et al., 2007), and children (Lee et al., 2007; Malisza et al., 2010) with ASD. Additionally, in a visual matrix reasoning task including Raven's Standard Progressive Matrices, subjects with ASD demonstrated greater occipital activation combined with lesser prefrontal activation compared with typically developing subjects (Soulieres et al., 2009). A meta-analysis using Activation Likelihood Estimation (ALE) of fMRI studies of visual processing in ASD demonstrated atypical allocation of activity in visual regions in ASD for object processing (Samson et al., 2012). Objects included in that meta-analysis included nameable objects. We are not aware, however, of studies to date examining whole brain differences in global and local processing in ASD using an abstract hierarchical figure (as opposed to nameable letters such as in traditional Navon-type tasks). Using a hierarchical abstract figure reduces confounding cognitive processes from mental identification of letters, numbers, or other nameable objects, thus focusing on visual perception alone. Therefore, neural processes known to be involved with reading are avoided and the emphasis is placed on processes related to early visual perception and attention.

The goal of the present study was to examine whole brain differences in both local- and global-level attention in ASD using a hierarchical, abstract shape recognition task (Martinez et al., 1997). We hypothesized greater activation of primary visual cortex and other visual areas in subjects with ASD in both global and local conditions. Additionally, we predicted that the ASD group would exhibit decreased activity in the right hemisphere during the global condition, and increased left hemispheric activity in the local condition.

## 2. Methods

### 2.1. Participants

The study included 33 adult participants, 17 individuals with ASD (high-functioning autistic disorder or Asperger syndrome) (mean age 32, range 18–55, of which three were female) and 16 typically developing (TD) subjects (mean age 33, range 18–55, of which three were female). Subjects were matched for age, gender, intelligence quotient (IQ; using the Wechsler Abbreviated Scale of Intelligence or WASI), and socioeconomic status. See Table 1 for demographic information. Diagnoses were confirmed with the Autism Diagnostic Observation Schedule-Generic (ADOS-G) and DSM-IV checklist completed by an experienced clinician (SH). Nine subjects in the ASD group met clinical criteria (via the DSM-IV checklist) for Autistic Disorder and eight for Asperger syndrome. All met criteria for Autistic Disorder on the ADOS-G. Full scale IQ for all subjects was greater than 70. Exclusion criteria were any known seizure disorder or single-gene genetic association with autism such as fragile X, tuberous sclerosis, etc. In addition, typically developing subjects were screened for any personal or family history of a developmental disorder, Axis I illness or neurological disorder. All subjects gave written consent to participate in the research consistent with the Declaration of Helsinki and the local guidelines of the Colorado Multiple Institution Review Board.

### 2.2. fMRI task design and stimuli

During fMRI sessions, subjects were engaged in a hierarchical shape-recognition task conducted in a blocked fashion (Martinez et al., 1997). There were three task conditions: (1) attend to the global pattern level, (2) attend to the local pattern, or (3) watch a control stimulus (see Fig. 1). The stimuli were abstract shapes made up of smaller abstract shapes. The control condition consisted of passive viewing of gray squares and was alternated between blocks of attending to local or global patterns. Prior to entering the magnet, subjects were presented with a practice module using E-Prime to verify understanding of the task. Subjects were asked the following: "Silently count the number of figures that match the global (or local) target figure; you will be asked to state how many matching figures you counted". The target figure appeared in each block 11–13% (only at the attended level). Each global- and local-block lasted for 20 s and was repeated 12 times per condition. Control blocks also lasted 20 s and were repeated 24 times. Block order was counterbalanced by subject, with every other subject starting with the global block, the remaining with the local block. The total experiment comprised 24

**Table 1**
Demographic information.

| | | ASD | TD | *t* value | *P* value |
|---|---|---|---|---|---|
| Age (years) | Mean±S.D. | 31.8±12.0 | 34.8±11.4 | 0.49 | NS |
| Handedness | Right: Left | 13:3 | 14:1 | NA | NA |
| Gender | Male: Female | 13:3 | 12:3 | NA | NA |
| VIQ | Mean±S.D. | 108.3±15.7 | 115.9±16.8 | 0.38 | NS |
| PIQ | Mean±S.D. | 109.5±12.5 | 116.8±18.0 | 0.29 | NS |
| FSIQ | Mean±S.D. | 109.6+±12.1 | 116.7±18.1 | 0.24 | NS |