

## Review Article

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## Challenging Weak Central Coherence: A Brief Exploration of Neurological Evidence from Visual Processing and Linguistic Studies in Autism Spectrum Disorder

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### Abstract

Previous theories have attempted to locate the root cause of Autism Spectrum Disorder (ASD) in terms of atypical central cognitive processes. However, the field of neuroscience is increasingly finding structural and functional differences between autistic and neuro-typical individuals using neuro-imaging technology which either support or challenge earlier cognitive theories. One main area upon which this research has focused is in visuospatial processing, with specific attention to the notion of "weak central coherence" (WCC), which refers to the tendency of individuals with ASD to be unable to interpret "global" information while hyper-focusing on local information. The current paper offers a brief review of findings from selected studies in order to explore available research that challenges the "deficit" characterization of a WCC theory as opposed to a "superiority" characterization of a strong local coherence.

**Keywords:** Autism spectrum disorder, Weak central coherence

### Introduction

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by persistent deficits in social communication and social interaction (i.e., deficits in social-emotional reciprocity, nonverbal communicative behaviors, and establishing/maintaining social relationships), as well as by the presence of repetitive behaviors and perseverative areas of interest (i.e., stereotyped or repetitive motor movements, use of objects, or speech, rigidity, restricted interests, and hypo or hyperactivity to sensory input or unusual interest in sensory aspects of the environment). Additionally, diagnoses of ASD require the presentation of symptoms in the early developmental period, marked impairments in adaptive functioning, and a lack of explanation by general intellectual impairment or global developmental

delay (although these conditions may be co-occurring) [1]. Over the past several decades, many theories have been developed in effort to explain the root cause of autism in terms of atypical central cognitive processes. The field of neuroscience is increasingly finding structural and functional differences between autistic and neuro-typical individuals using neuro-imaging technology. One main area this research has focused upon is in visuospatial processing, with specific attention to the notion of "weak central coherence" (WCC). This paper will offer a brief review of findings from selected studies in order to explore some research that challenges the "deficit" characterization of a weak central coherence theory as opposed to a "superiority" characterization of a strong local coherence, a potential function of neuroplasticity.

## Weak central coherence

A foundational cognitive theory used to describe the way in which individuals with ASD process visual information is known as “weak central coherence” (WCC) or the tendency of individuals with ASD to be unable to interpret “global” information while hyper-focusing on local information. This has typically been viewed as an impairment of global processing, as compared to the processing style of those individuals without ASD. WCC has been postulated to lie at the root of characteristic ASD symptoms, such as rigidity or insistence on sameness, attention to parts of objects, and uneven cognitive profiles, including savant skills [2]. In general, the notion of WCC has been widely accepted in the ASD community, and has been noted to account for previously unexplained areas of talent, super-acute perceptual abilities, and the pervasive lack of ability to generalize [2]. The current working model of WCC postulates that a continuum of cognitive style may exist in the general population, from strong coherence (a tendency to miss details while concentrating on the larger concept) to weak coherence (detail focus and verbatim information) [2]. Regarding this conceptualization, people with ASD lie at the extreme “weak coherence” end of the normal continuum. WCC theory also encompasses notions of both “low” and “high” levels of information processing; with low-level referring to the tendency to ignore context in sensory domains, while favoring the processing of individual stimulus features, whereas high-level WCC refers to the impairments of more abstract contextual processes [2,3].

## WCC theory - the history

Origins of the WCC theory date back to Kanner’s [4] original description of autism that notes this “over-attention to detail” and “general inability to experience wholes without full attention to the constituent parts”. Decades later, Frith [5] noted the tendency for typically developing persons to process incoming information for meaning and gestalt (global), often at the expense of attention to detail and surface structure; which has been termed “central coherence”. The processing bias proposed by the WCC theory was demonstrated in early work on verbal memory [6,7], as well as early work on visuospatial tasks [8-10].

Since these earlier years, the concept of coherence in ASD has been widely researched, and subsequently the WCC theory has been updated to include three major concepts. First, the original idea of a core deficit in central processing has been changed from a primary

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to a secondary problem, focusing more on detail-focused processing. Second, the idea of a core deficit has been replaced by the notion of a processing bias or cognitive style that can be overcome in tasks that demand a global processing approach. Third, it has been recognized that weak coherence may be just one aspect of ASD, and not necessarily a cause of other deficits, such as weaknesses in social cognition [2].

## WCC theory - facial processing

One area of perceptual difference that has garnered much attention in the WCC literature is in facial processing. Findings in this area in general have been widely mixed, including the result of abnormally feature-based face processing in ASD [11], mixed results [12], and contrary (non-impaired) findings [13]. Two main theories that explain deficits in facial recognition suggest that either the problem stems from social interaction/lack of social motivation deficits, or from a visual perception impairment. Behrmann, Thomas, and Humphreys [14] set out to explore the latter, by documenting the psychological and neural alterations that might account for facial processing impairments in ASD. Results of this analysis indicated that “the impairment in face processing need not necessarily arise solely from a social and/or motivational source but that a perceptual impairment might also contribute to the difficulty with face processing” [14], (p262).

This decrement in face processing ability has been shown consistently in functional imaging studies, exhibiting weak activation of the fusiform gyrus (the area of the brain that is responsible for the processing of facial stimuli) in ASD in response to faces with concurrent activation of other cortical regions that are not usually associated with facial processing [15-20]. These findings have been regarded as controversial, however, as some studies have shown fusiform activation in ASD, with greater signal for familiar faces [21,22]. In studies that have shown the weak activation of the fusiform gyrus, it has been noted that the results may be a reflection of the failure to attend to either the eye region, the configural processing, or the failure to engage the fusiform region for face processing over the course of developmental maturation [21,23]. Follow-up research has purported a number of explanations for the mixed findings, ultimately concluding that the impairment in facial processing is an example of a larger perceptual deficit, including a lack of expertise or familiarity with faces that reduces the functional specialization of face-selective cortical areas [14].

## WCC theory - various modalities

In addition to studying facial recognition, Happe and Frith [2] cited over fifty studies that include research on this concept of WCC in ASD across all modalities including auditory, visual, and verbal. Conflicting findings in this area have highlighted the need for the use of open-ended tasks to adequately capture the bias towards features rather than wholes [24], as well as to demonstrate the boundaries of WCC, such as the ability of people with ASD to integrate properties of single objects and words [25,26]. Happe and Frith [2] also explored the notion of WCC as a normal individual difference, again, going back to the notion of the “coherence continuum” in which weak coherence is viewed as a cognitive style in which persons who gravitate toward seeing the big picture are at one end (strong coherence), while people who are readily detail oriented are on the other end (weak coherence). In this light, it is important to consider that these styles can be viewed as biases, and that people can, with application of effort and motivation, overcome their predisposition toward one style or another.

## Challenging weak central coherence theory via neuroscientific findings

As it is noted that coherence “styles” can be dynamic, Happe and Frith [2] went on to challenge the idea of the WCC theory through examination of two related theories. The first being that WCC may represent a superiority in “local processing,” or altered neural circuitry, rather than a deficit in global processing. Second, WCC may be a processing *bias*, rather than a deficit. The superiority in local processing theory purports that there is an amplification of early perceptual processes, which boosts processing of local stimulus properties, without affecting the processing of global context.

An influential finding in ASD research in this area is that persons with ASD tend to show superiority for tasks in which local processing strategies are beneficial. The most classical example of this is the Embedded Figures Task (EFT), which presents complex shapes with simpler shapes hidden within them. Originally devised by Gottschaldt [27], the EFT involves searching for a target figure hidden in a complex visual pattern. In this task, subjects are required to determine (as quickly as possible) whether the target shape is hidden within the larger more complex shape. Shah and Frith [8] were the first to discover that autistic children responded both faster and more accurately on the EFT compared to matched control children. This advantage of individual with ASD

has been interpreted in two ways: either in terms of WCC [3,5,8,28,29], and/or from the perspective of theories that support enhancements of early perceptual processes in ASD [25,30].

It is important to note that WCC as a theory was proffered during a time in which there was more limited knowledge of neuroscience, specifically that of the neural structure of ASD. Therefore, it is necessary to attempt to bridge the gap between a predominately cognitive theory with a challenge that is based out of neuroscience. While the full reconciliation between these two theories extends the scope of the current argument, it is important to note that the neuroscience research reported in the following sections appear to be compatible with the cognitive basis of the theory. However, it is important that future writing and discussion in the neuroscience of ASD consider such challenges, and develop such a reconciliation.

## Evidence supporting a superiority of local processing

### Visual processing - embedded figures task:

Manjaly, Bruning, and Neufanget al. [31] set out to examine the difference between the two aforementioned accounts of EFT performance in individuals with ASD by looking at the visual processing of shapes. 12 adolescents with ASD (9 = Asperger’s Disorder (AspD); 3 = High Functioning Autism (HFA), with a mean of 14.4 years, with age matched non-ASD controls (matched for gender, IQ, handedness, age) were studied using the EFT. Subjects were required to “dissect” the larger structure in order to find the target “substructure”; an additional control task in which the shapes were highlighted was used. Magnetic Resonance Imaging (MRI) and Functional Resonance Imaging (fMRI) analyses were conducted in an attempt to determine, on neurophysiological grounds, between the two accounts of EFT performance (weak central coherence versus local processing advantage) in persons with ASD. This study is unique in that it is one of the only studies to look at the performance on both the EFT and an additional visuospatial control task (CT). Interestingly, no significant difference was found in behavioral performance on the EFT or CT, however results were suggestive that ASD persons have a relative advantage for local processing.

Despite the lack of significant findings for behavioral differences between the two groups in the aforementioned study, interesting neural imaging patterns emerged. For both groups, when comparing EFT to CT, areas of the gyrus and thalamus were activated. Regarding the

activation pattern, there were significant differences at the  $p < .05$  level. For the control group, activation was found in the left posterior parietal cortex and left dorsal premotor cortex. In the autistic group, activation was found in the left *and* right extrastriate cortex, right sulcus, and right cerebellar hemisphere. This finding is significant as it indicates a difference laterally, despite the matched “handedness” of controls. This study did not examine the capacity for global integration, which could be achieved in future studies by comparing fMRIs of local and global processing capacities.

### **Visual processing - block design test**

Another way of demonstrating enhanced local processing on visual tasks in persons with ASD has been through looking at performance on the block design test (BDT) on the Wechsler Intelligence Scales. In one particular study, Bolte, Hubl, Dierks et al. [32] examined striate and extrastriate areas of the visual cortex during the administration of the BDT. 14 total children (7 ASD, and 7 neurotypical control) were matched on age and intelligence quotient scores (IQ). fMRI was used to analyze hemodynamic responses in the striate and extrastriate visual cortex during BDT performance and a color counting control task in subjects with and without ASD. Results revealed no significant behavioral differences on the BDT between the two groups. However, analysis of covariance (ANCOVA) analysis revealed significant activation and BOLD (Blood Oxygen Level Dependent) differences in the right hemisphere. Specifically, in ASD, BDT processing was accompanied by low blood oxygenation level-dependent signal changes in the right ventral quadrant of V2. These results further signal potential differences in visual processing in the right hemisphere between individuals with and without ASD.

### **Visual processing - an alternate digital visual task**

In a related study by Schwarzkopf, Anderson, de Haas et al. [33], a digital task requiring fixation on a blue dot moving through various positions was used to look at functioning in the extrastriate cortex. A sample of 27 persons (15 diagnosed with Asperger’s Disorder, 12 neurotypical controls) were matched for age and IQ. fMRI and population receptive field (pRF) analyses were used to test whether the response selectivity of human visual cortex is atypical in individuals with “high-functioning” ASDs compared with neurotypical controls. Results revealed a significantly larger (pRF) extrastriate cortex in ASD participants, as indicated by larger perifoveal pRFs in the extrastriate regions in the ASD group compared to the

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control group. In general, individuals with ASD showed stronger, more reliable responses to visual stimulation. Another interesting finding was that pRF sizes correlated with individual differences in the number of exhibited autistic traits, however there were no correlations on behavioral measures of visual processing. It was concluded that visual cortical function in ASDs may be characterized by extrastriate cortical hyper-excitability or differential attentional deployment.

Along the lines of examining individual differences in autistic traits, in studies of visual search tasks (such as the previously mentioned EFT), people with more autistic traits (as measured by the Autism Spectrum Quotient, or AQ) [34], are generally better and faster at visual search tasks than people with fewer autistic traits [35-37]. Findings concerning other perceptual characteristics have looked at dynamic forms of processing, such as biological motion stimuli. In such studies, while it has generally been found that there are no overt differences in behavior (with regard to the number of ASD traits or the differences between ASD and non-ASD populations), neural imaging studies have found significant differences in brain activity across various neural regions [38-41]. The brain regions that have shown the largest differences between ASD and non-ASD populations have been the posterior superior temporal sulcus, which is one of the main regions in the brain underlying social perception and social cognition [42,43].

### **Visual processing - light animations**

The aforementioned findings lead to the question of why the two populations show similar behavioral performance, yet differ significantly in brain activity in key regions of the brain during biological motion perception tasks. A study by Van Boxtel and Lu [44] used light animations to investigate such differences. 30 participants, with a mean age of 19 years, were examined, and it was found that individuals with fewer autistic traits were automatically and involuntarily attracted to global biological motion information, whereas individuals with more autistic traits did not show this observed distraction. It was further investigated to determine that individuals with more autistic traits were able to account for deficits in global processing with an increased involvement in local processing.

### **Visual processing - visual processing task**

In an additional recent study that investigated cortical dynamics associated with visual perception in individuals with ASD, Milne, Scope, Pascalis, Buckley, and Makeig

[45], used electroencephalogram (EEG) data to determine differences in the striate and extrastriate cortex. 20 children with ASD (two female) and 20 neurotypical control subjects (also two female) were examined. EEG was continuously recorded while participants were instructed to respond by pressing a response button with the index finger of their dominant hand as quickly as possible whenever they saw a zebra on a screen. This was to ensure that participants paid attention to the screen. There were no group differences in the behavioral responses to the zebra stimuli. Each of four Gabor patches was shown 72 times; the zebra was shown 36 times, and the order of stimulus presentation was randomized. Differences between the ASD and the control group were found only in some of these processes. Specifically, in those components that were in or near the striate or extrastriate cortex, components that were in or near the cingulate gyrus was increased in the participants with ASD.

### **Language processing - semantic category decision**

In addition to looking at the relationship between visual perceptual differences and local processing/WCC, there is a large body of literature that has examined language differences among persons with ASD. We know that language delay and impairment are salient characteristics of ASD, with pragmatics being the most consistently impaired domain [46]. Experiential effects in language acquisition are what are thought to play the largest or most important role with regard to lexicosemantic development. We know that children with ASD do not interact in the world in typical ways, and that ASD children's patterns of interaction with their environment imply that their experience relevant to language acquisition is abnormal [47]. Historically, we also know that ASD children generally do not demonstrate consistency in phonological or syntactic deficits, while semantics and pragmatics tend to be almost always impaired [48].

A study by Gaffrey, Kleinhans, Hasit, et al. [49] examined the neuro-functional correlates of semantic decision making in ASD. It was hypothesized that individuals with ASD would present with atypical patterns of neural-activation in response to a semantic division task when compared to neurotypical controls. It was further predicted that reduced overall experience in individuals with ASD would be associated with a less mature pattern of lexicosemantic organization and with greater reliance on perceptual components. fMRI imaging was used to

examine activation associated with semantic category decision. 10 individuals with an ASD diagnosis (mean age 26.1 years  $\pm$  10.5) were individually matched with 10 neurotypical control subjects (mean age 25.3 years  $\pm$  9.8) for age, gender, and handedness. In the experimental condition, participants were asked to indicate category membership for visually presented words via a yes/no button response. Each experimental block started with a category word and a question mark (e.g., TOOL?), which alerted participants to the target category and was presented for 3.7 seconds. After controlling for multiple comparisons, the simple effects for group and condition were explored. Results indicated that the ASD group performed significantly better on the perceptual control condition than for "feelings" (mean difference = 11.32). No difference in accuracy across conditions was found for the control group. A significant between-group difference for task accuracy was found as well, with the control group performing significantly more accurately than the ASD group for "colors" and "feelings".

From a neuro-physiologic perspective, in the aforementioned study, significant activation for semantic decision in the left inferior frontal gyrus (Brodmann areas 44 and 45) was found in the control group. Corresponding activation in the ASD group was more limited, with small clusters in the left inferior frontal areas 45 and 47. ASD participants showed significantly greater activation compared to controls in the extrastriate visual cortex bilaterally (areas 18 and 19), which correlated with greater numbers of errors on the semantic task. These findings suggest an important role of perceptual components during semantic decision making, which is consistent with previous evidence for atypical lexicosemantic performance in ASD.

### **Language processing - semantic division task**

In a similar study, Shen, Shih, Ottl, Keehn, Leyden et al. [50] sought to examine atypical lexicosemantic function of extrastriate cortex in ASD. Participants were 14 male adolescents and adults diagnosed with ASD (including ten from an earlier study by Gaffrey et al. [49]), individually matched with 14 typically developing participants on age, gender, handedness, and nonverbal IQ. A similar procedure was followed as in the previously mentioned study [49], in which participants indicated by button press whether a visually presented word belonged to a target category (e.g., Tools, Colors, and Feelings). Structural equation modeling showed that whereas right extrastriate cortex did not impact function of language regions (left and right inferior frontal gyrus

(IFG, left middle temporal gyrus) in the control group, it was an integral part of a language circuit in the ASD group. These results suggest that atypical extrastriate activation during language processing in ASD reflects integrative (not isolated) processing.

Dissimilar to some of the other findings, in the aforementioned study there were significant differences between ASD and control groups for the semantic decision task, but no difference in the perceptual control task or response times, with the exception of the control times, for which the ASD model took longer. Correlations were conducted to further investigate relationships between age, task accuracy, and response time, for which there were none. However, there did appear to be differences between the ASD and control group for language, not shapes.

## Conclusions

The purpose of this article was to provide a brief examination of the strong local coherence versus weak central coherence theories through a review of literature focused on visual processing and linguistic studies in ASD. The weak central coherence theory has long been both supported and refuted in the ASD literature, and has most recently been increasingly challenged by advances in neuroscience. The selected studies lend evidence to the notion of amplified localized perception rather than deficient global perception. In other words, WCC may represent a superiority in "local processing" rather than a deficit in global processing. Additionally, the right hemisphere, and the specific area of the extrastriate appear to be key in both the visual and lexicosemantic process. Overactivity in the striate region seems to suggest inaccuracy in semantic language, which lends itself to support for the link between the striate region and the atypical organization of the lexicosemantic system in ASD. In conclusion, there is evidence from recent neuroscientific studies that supports the notion that WCC, or the tendency of individuals with ASD to be unable to interpret "global" information while hyper-focusing on local information, is likely a function of a superiority in local processing abilities, rather than a deficit in global processing. Future research and reviews of existing literature should continue to look at these concepts in-depth, as well as to examine the question of whether or not a localization superiority as opposed to a globalization deficiency exists.

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