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Children with autism spectrum disorder spontaneously use scene knowledge to modulate visual object processing

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ABSTRACT

Several studies have investigated contextual influences on visual object processing in individuals with autism spectrum disorder (ASD) and failed to find reduced context effects. However, these studies did not properly account for local inter-object effects and/or the influence of post-perceptual processes, leaving it unclear whether individuals with ASD display equally large global top-down effects of context, or whether they rely on a more local mechanism producing the same result. In this study, an eye-movement paradigm was used to investigate implicitly induced context effects on visual object processing in children with ASD compared to matched controls. To find out whether the context effects in the ASD group were, to the same extent, due to early top-down influences on object recognition, we also examined the interaction between context effects and the ease of object recognition. Both groups displayed equally large context effects and congruent contextual information facilitated object recognition to the same extent in both groups. This indicates that the context effects in the ASD group did not result from the operation of a more local, less top-down mechanism. These findings contradict predictions based on the weak central coherence account. However, a good alternative to explain all inconsistencies is currently lacking.

1. Introduction

Autism spectrum disorders (ASDs) are characterized by the co-occurrence of impairments in social reciprocity and communication, combined with restricted and repetitive patterns of interests and activities (American Psychiatric Association, 2000). According to the weak central coherence (WCC) account, some of these symptoms are related to or even caused by their atypical information processing. This account claims that individuals with ASD show reduced central coherence, or global processing, meaning that the normal tendency to process information in its context and integrate information for higher-level meaning is diminished, favoring piecemeal or local processing (Frith, 1989). In the ASD

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literature, the evidence for increased local processing is strong while that for reduced global processing is more mixed, especially for ASD individuals with (at least) normal intelligence (for a review, see Happé & Frith, 2006). To account for these inconsistencies, the WCC theory was further refined (Happé & Booth, 2008; Happé & Frith, 2006). Firstly, the authors state that diminished global processing is not a 'core deficit' but rather a 'processing bias' or 'cognitive style', which can be overcome when explicitly instructed to do so. Thus, reduced global processing may only become apparent when individuals with ASD are not guided to attend to global information. Accordingly, they encourage the use of open-ended tasks to capture spontaneous modes of processing information. Secondly, they make a distinction between local and global coherence, emphasizing that individuals with ASD may only display diminished global coherence, but intact local coherence. Local coherence refers to item-to-item processing (chaining), or intra-domain coherence, whereas global coherence refers to inter-domain coherence, requiring more top-down modulation of information. Taken together, the revised WCC account suggests that individuals with ASD will mainly show reduced global processing on open-ended implicit tasks requiring global coherence.

One way to test this revised WCC account is by investigating implicitly induced context effects on visual object processing in ASD individuals. In what follows we will first discuss context effects on visual object processing in typically developing (TD) individuals. Afterwards, shortcomings of studies that have investigated these effects in ASD will be mentioned and an alternative paradigm will be presented.

Contextual modulation of visual object processing is demonstrated by numerous studies in TD individuals (for a review, see Bar, 2004; Henderson & Hollingworth, 1999). A consistent effect found across all of these studies is contextual facilitation of object processing: an object in a plausible scene context is processed faster than that same object in an implausible context. This is evidenced by a shorter naming latency (Boyce & Pollatsek, 1992) and a shorter fixation duration (De Graef, Christiaens, & d'Ydewalle, 1990) for scene-consistent objects. Additionally, eye-movement studies showed that context influences the spontaneous allocation of attention. One of the first studies investigating this found that scene-inconsistent objects were fixated earlier and more often than consistent objects (Loftus & Mackworth, 1978). The same finding was also reported by Brockmole and Henderson (2008), but overall, these results are quite inconsistent and depend on the specific paradigm used (for a review, see De Graef, 2005a; Henderson & Hollingworth, 1999).

Different models try to account for the scene-context effects on visual object processing (De Graef, 2005b). According to Henderson and Hollingworth (1999), they can be divided into three groups: the perceptual schema model, the priming model and the functional isolation model. The idea underlying each of these models is that perception of a scene leads to the activation of the corresponding scene schema. A scene schema contains generalized expectations about which objects are likely to be in a particular scene and which objects are not (e.g., in a kitchen, a car is normally not present, while a fridge is). Activation of this schema subsequently alters and facilitates the processing of objects present in that scene. However, the specific level at which object processing is influenced differs for each of the models (Henderson & Hollingworth, 1999). According to the *perceptual schema model*, the activation of the scene schema facilitates the first stages of the subsequent perceptual analysis of schema-consistent objects. The *priming model* proposes that the effect of context occurs at a later stage: 'activation of the scene schema primes the stored representations of schema-consistent objects' (Henderson & Hollingworth, 1999, p. 261). This reduces the amount of perceptual information necessary to identify a primed object. So, both of these models predict contextual facilitation of object identification, meaning that scene consistent objects will be recognized faster than inconsistent objects. On the contrary, the *functional isolation model* suggests that context does not influence object identification, but only influences the later 'post-perceptual', semantic phase. According to this model, object identification results from a purely bottom-up visual analysis. When an object is embedded in a scene, this will activate the scene-schema and trigger an additional processing step aimed at integrating the object in the scene representation. The activated schema thereby acts as an interpretational template for the output of the object identification process: objects that fit the template merely need to be tagged as present, those that do not will require more extensive processing in order to be integrated (De Graef, 2005b).

One aspect that is often neglected is that not only global scene information (as described above), but also local object information induces context effects (De Graef, 2005b; De Graef, De Troy, & D'Ydewalle, 1992). A scene typically contains several semantically related objects. When seeing one object, this leads to the activation of the corresponding object-cohort (i.e., a prototypical representation of objects that are episodically and/or semantically related) and also facilitates the processing of cohort-consistent objects. It is important to mention this because these object-to-object context effects are the result of intra-level or local coherence and require less top-down processing than inter-level, scene-to-object effects.

Furthermore, although post-perceptual processes can indeed produce context effects, there is convincing evidence that congruent contextual information does facilitate object recognition in TD individuals, thereby refuting the functional isolation model (Bar, 2004). Brain imaging studies have provided further insight in the underlying cortical mechanisms and have proven that a low-spatial frequency representation of the scene is projected early and rapidly from the visual cortex to the parahippocampal and the prefrontal cortex, resulting in a guess about the most likely context. This information is then fed back to the inferior temporal cortex, activating a set of object representations that are likely to occur in that particular scene. As such, the recognition of scene-consistent objects is facilitated by substantially limiting the number of object representations that need to be considered (Bar, 2004; Bar et al., 2006).

Based on this overview it is clear that different mechanisms can lead to context effects on visual object processing. In summary, the effects of context can arise due to global scene information and/or local object information. Furthermore, context effects can result from early top-down processes facilitating object identification and/or post-perceptual processes facilitating integration within the activated schema.