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Local-global processing bias is not a unitary individual difference in visual processing

Rebecca Chamberlain [a,b,*], Ruth Van der Hallen [a], Hanne Huygelier [a], Sander Van de Cruys [a], Johan Wagemans [a]

[a] Laboratory of Experimental Psychology, KU Leuven, Tiensestraat 102, Box 3711, Leuven 3000, Belgium
[b] Department of Psychology, Goldsmiths University of London, 8 Lewisham Way, New Cross, London SE14 6NW, United Kingdom

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ABSTRACT

A large body of research reports individual differences in local and global visual processing in relation to expertise, culture and psychopathology. However, recent research has suggested that various different measures of local-global processing are not strongly associated with one another, calling its construct validity into question. The current study sought to further explore the validity of local-global processing biases in perception by developing three tasks based on two existing paradigms: the Embedded Figures Test (EFT) and the Navon hierarchical letters task. The newly developed tasks aimed to control for stimulus and response factors that may have impacted upon the reliability of previous research. They were administered to a large sample of undergraduate students (N > 100). The results of two new versions of the EFT indicated that disembedding performance is influenced by the structure of the embedding context. In addition, global precedence and interference in the Navon task remained present even when local attentional approaches to global hierarchical stimuli were restricted. Inter-task correlations within the EFT were high but low between the EFT and the Navon task, lending support to the notion that local-global processing is not a monolithic construct, but representative of a number of distinct perceptual abilities and biases. Future research may use these task distinctions to pinpoint more precisely which aspects of perceptual processing characterise specific (clinical) participant populations.

1. Introduction

The popular notion that we see the forest before the trees is an established and pervasive dogma in perceptual psychology. Sensitivity to global structure in an environment in which visual information must be parsed into scenes and objects is crucial and disruption of this process is often associated with psychopathology. Consequentially, **perceptual organization** is seen as a necessary aspect of healthy perception and a great amount of research is dedicated to understanding the universal perceptual organizational principles of the human visual system (for comprehensive reviews, see Wagemans, Elder, et al., 2012; Wagemans, Feldman, et al., 2012). A parallel stream of research explores the **differentiation of individuals** on the basis of the strength of perceptual organization at multiple stages of perceptual processing. This has led to the development of experimental paradigms that measure the degree to which individuals can construct global representations and can extract local detail from global form. An underlying assumption in this line of research is that individuals are characterized by a certain *perceptual profile or style*, with variable degrees of global and local bias. The investigation of perceptual style enables researchers to discover how perceptual organization varies as a function of experience, psychopathology, culture or genetics (Bellgrove, Vance, & Bradshaw, 2003; Caparos, Linnell, Bremner, de Fockert, & Davidoff, 2013; Davidoff, Fonteneau, & Fagot, 2008; de-Wit & Wagemans, 2015; Lewis & Dawkins, 2015; Van der Hallen, Evers, Brewaeys, Van den Noortgate, & Wagemans, 2015). For example, it has been shown that individuals with autism spectrum disorder (ASD) show slower responses to global structure (Van der Hallen et al., 2015) or enhanced lower processing ability (Mottron, Dawson, Soulières, Hubert, & Burack, 2006; Muth, Hönekopp, & Falter, 2014), that artists and musicians demonstrate enhanced local visual processing (Chamberlain, McManus, Riley, Rankin, & Brunswick, 2013; Drake & Winner, 2011; Stoesz, Jakobson, Kilgour, & Lewycky, 2007) and that remote cultures

* Corresponding author at: Department of Psychology, Goldsmiths University of London, 8 Lewisham Way, New Cross, London SE14 6NW, United Kingdom.
E-mail address: r.chamberlain@gold.ac.uk (R. Chamberlain).

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show a reduction in global bias associated with reduced exposure to urbanised environments (Caparos et al., 2012).

Witkin first coined the terms **field-dependence and field-independence** to refer to individuals with a stronger global and local bias, respectively (Witkin, Dyk, Faterson, Goodenough, & Karp, 1962). He argued that field dependence could be measured through tests such as the Rod-and-Frame Test (RFT; Witkin & Asch, 1948) and the Embedded Figures Test (EFT; Witkin, Oltman, Raskin, & Karp, 1971). Individuals who performed better on the RFT and EFT were argued to be more field-independent, as they could discount contextual information and focus on local elements of the visual field. Witkin et al. (1954) found that individual differences in performance for these tasks were stable across time and predicted individual differences in personality. The presence of a general bias for global relations between local parts, notwithstanding individual differences in that bias, was also probed in seminal studies by Navon (1977, 2003) using hierarchical letters (Fig. 1). These hierarchical letters could be congruent or incongruent, with the global level being the same or different, respectively, from the local elements that constitute it. In this way it was possible to assess the impact of incongruence on both local and global processing. This paradigm has revealed that participants respond faster and more accurately to global hierarchical structure (global precedence) and encounter interference from the global level when responding to the local elements (global interference; Navon, 1977, 2003).

Milne and Szczerbinski (2009) conducted a comprehensive review and investigation of the factorial structure of individual differences in local and global processing. When analysing inter-task correlations in a large battery of local-global tasks[1] taken by 90 participants, the authors found the pattern of correlations to be relatively diffuse. Only two meaningful factors were extracted from a factor analysis of the data: disembedding (upon which the Block Design Task and the EFT loaded significantly) and global bias (upon which slow performance on local trials and accurate performance on global trials in the Navon task loaded significantly). The authors argued that the construct of local and global visual processing is marred by conceptual and terminological inconsistencies. They identified a prevailing assumption in the literature that field-independence and the closely related construct of Weak Central Coherence, used to characterise the reduced global bias in ASD (Happé & Frith, 2006), are assumed to relate to reduced global processing in tasks like the Navon. However, given that the tasks in this study demonstrated little common variance, they concluded that this assumption is false and that the primary factor extracted from the data (disembedding) demonstrated the most conceptual overlap with field-independence and Weak Central Coherence. This factor was independent of the majority of the tasks included in the study ostensibly measuring either local or global processing.

In line with the field-dependence/-independence continuum, Dale and Arnell (2013) recently probed the validity of using one's bias for Navon figures as a proxy for global and local visual processing biases in general. They tested 60 participants on a classic Navon paradigm, a Navon matching paradigm and a face matching task in which spatial frequency was manipulated. Test-retest reliability was high for global bias in the face and Navon letter matching tasks, but was fairly weak for global bias in the standard Navon letter task. There were no significant inter-task correlations for global bias. The results of this study suggest that, although individual differences in performance on individual tasks intending to measure global bias are relatively stable, the convergent validity is questionable.

The research discussed here has called into question the convergent validity of local-global processing tasks as well as the stability of the concept itself. However, a prevailing issue with existing tasks measuring local-global processing is that they were developed some years ago and lack the control and specificity of many contemporary paradigms in vision research. For example, the Group-EFT or G-EFT used in Milne and Szczerbinski (2009) study was a pencil and paper task with only 18 trials that varied unsystematically in their complexity, meaningfulness and three-dimensionality. Therefore, in the current study, two paradigmatic local-global visual processing tasks were selected and modified: the EFT and the Navon task.

An alternative **Leuven Embedded Figures Test** (L-EFT) has already been developed to address lack of stimulus control in the G-EFT (de-Wit, Huygelier, Van der Hallen, Chamberlain & Wagemans, in press). The new version aims to measure individual differences in perceptual disembedding in isolation from other factors involved in task performance on the original EFT such as executive function and intelligence (Huygelier, Chamberlain, Van der Hallen, de-Wit, & Wagemans, 2015). In the current study two additional modified L-EFTs are presented which focus on the impact of meaningful and three dimensional complex contexts (M-EFT and D-EFT, respectively). These issues are particularly pertinent to two subdomains of individual differences in perceptual organization: ASD and artistic expertise and as such may be able to provide an explanation for why specific populations perform better on the EFT.

Individuals with ASD have previously been found to outperform controls on the G-EFT, a pencil and paper variant of the EFT that can be administered to groups of participants at one time (Brosnan, Gwilliam, & Walker, 2012; Jarrold, Gilchrist, & Bender, 2005; Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983). It should be noted however that existing reviews and meta-analyses have produced a heterogeneous picture of the relation between ASD diagnosis and performance on the EFT as well as other tasks ostensibly measuring local visual processing (Dakin & Frith, 2005; Happé & Frith, 2006; Mottron et al., 2006; Muth et al., 2014; Van der Hallen et al., 2015). With respect to the EFT, this could be due to the different kinds of context used within the original G-EFT and subsequent versions of it, such as the children's EFT used in the first study showing a relation between ASD diagnosis and EFT performance (Shah & Frith, 1983). Embedding contexts within the original forms of the EFT include a mixture of meaningful and non-meaningful stimuli. Adjusting the meaningfulness of the context should alter disembedding performance in healthy controls because a unified meaningful stimulus is more difficult to interpret in terms of local parts (especially when these are not typical object parts). One potential reason for the advantage shown by individuals with ASD could be that they are less distracted by a semantically meaningful context, making it easier for them to locate an embedded target. A consequential prediction for individuals with ASD is that the meaningfulness of the complex context will not impact performance to as great an extent, in much the same way as segmentation of a Block Design does not provide as great an advantage to individuals with ASD in comparison with controls (Shah & Frith, 1993). However, it could also be the case that they do not cohere the objects in the embedding contexts whether meaningful or not. Under this interpretation, they could outperform healthy controls on both meaningful and non-meaningful context trials, but it is not possible to dissociate these two explanations using existing forms of the EFT.

In a somewhat similar way to the debate surrounding perceptual processing in ASD, it has also been shown that artists outperform non-artists on the G-EFT (Chamberlain et al., 2013; Drake &

[1] Tasks included in Milne and Szczerbinski (2009) were: the Group Embedded Figures Test (G-EFT), the Block Design Task, the Hidden Patterns Test, the Gestalt Completion Test, the Copying Test, VOSP silhouettes, Spot the Difference, the Rey Osterrieth Complex Figure, the Navon task, the Muller-Lyer illusion, Kanizsa illusory surfaces, visual search, impossible figures, the Good Form Test, global coherent form and motion, choice RT and verbal and performance IQ.

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