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Review article

New insights into the role of motion and form vision in neurodevelopmental disorders

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ABSTRACT

A selective deficit in processing the global (overall) motion, but not form, of spatially extensive objects in the visual scene is frequently associated with several neurodevelopmental disorders, including preterm birth. Existing theories that proposed to explain the origin of this visual impairment are, however, challenged by recent research. In this review, we explore alternative hypotheses for why deficits in the processing of global motion, relative to global form, might arise. We describe recent evidence that has utilised novel tasks of global motion and global form to elucidate the underlying nature of the visual deficit reported in different neurodevelopmental disorders. We also examine the role of IQ and how the sex of an individual can influence performance on these tasks, as these are factors that are associated with performance on global motion tasks, but have not been systematically controlled for in previous studies exploring visual processing in clinical populations. Finally, we suggest that a new theoretical framework is needed for visual processing in neurodevelopmental disorders and present recommendations for future research.

1. Introduction

Vision plays a critical role in human brain development. Even when babies are still in utero retinal cells fire spontaneously in preparation for the incoming stream of visual information that needs to be processed after birth (Ackman et al., 2012). Abnormal processing of visual information during infancy and early childhood initiates a cascade of events in the brain that have adverse affects upon motor, language, and cognitive development (Gori et al., 2016). Several studies have uncovered a visual deficit in various neurodevelopmental disorders and children born very preterm (Braddick et al., 2003; Grinter et al., 2010). What is interesting about this impairment is its apparent selectivity. Individuals with Williams Syndrome, Developmental Dyslexia, Autism Spectrum Disorder (ASD), Developmental Coordination Disorder (DCD) and children born preterm are all purported to have a deficit in the processing of global (overall) motion, relative to global form. Current theories for why such a pattern of impairment might arise are challenged by very recent research (e.g. Johnston et al., 2016, 2017). The aim of this review is to explore alternative explanations for why deficits in the processing of global motion but not global form might arise in neurodevelopmental disorders and children born preterm, by taking account of the new psychophysical evidence.

First, we will describe visual tasks that have been used to investigate the processing of global motion and global form in clinical populations. We will then critically evaluate studies that have administered these tasks to individuals across a range of neurodevelopmental disorders (Williams Syndrome, Developmental Dyslexia, Autism Spectrum Disorder, Developmental Coordination Disorder) and children born preterm. Some studies have only administered global motion tasks. However, we have chosen to focus our attention on those that have compared performance across both global motion and global form tasks, as these provide a more comprehensive assessment of visual processing and have a direct bearing on the selectivity of the underlying impairment. Table 1 presents a summary of the research we cite so as to facilitate comparisons across studies on key variables, such as matching criteria, age, the sex of an individual, and visual tasks used. We also calculate and report between-group effect sizes but this was only possible for ~40% of the studies we cite. We will then consider contemporary theories that have been proposed to explain why deficits in the processing of global motion, relative to global form might arise. These include the dorsal stream vulnerability hypothesis (Atkinson and Braddick, 2013; Braddick et al., 2003; Braddick and Atkinson, 2011), the anchoring-deficit hypothesis (Ahissar et al., 2006; Ahissar, 2007), and the noise exclusion hypothesis (Sperling et al., 2005, 2006). We will also review research that has suggested the origin of visual impairment in these clinical populations might reflect genotypic variation (Cicchini et al., 2015; Gori et al., 2015a; Morrone et al., 2011). We will outline each of these frameworks in turn and explain why they are

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Table 1
A summary of research that has used global motion and global form tasks to investigate visual processing in neurodevelopmental disorders and children born preterm. NVIQ: Non-verbal IQ; VIQ: Verbal IQ; FSIQ: Full-scale IQ; RDKs: Random-dot kinematograms; PVL: Periventricular leukomalacia. The symbol – indicates that the relevant information is unavailable.

		Age (years)		Sex ratio (m: f)		Visual tasks		Visual deficit		Effect size (Cohen's *d*)	
Study	Matching criteria	Disorder group	Control group	Disorder group	Control group	Global motion	Global form	Global motion	Global form	Global motion	Global form
Williams Syndrome											
Atkinson et al. (1997)	–	9.7	8.1	–	–	Segmentation	Line segments	Yes	No	–	–
Atkinson et al. (2003)	VIQ	4.7–15.3	4.0–10.0	–	–	Segmentation	Line segments	No	No	–	–
Atkinson et al. (2006)	FSIQ	28.3	27.5	–	–	Segmentation	Line segments	Yes	Yes	1.7	1
Palomares and Shannon (2013)	VIQ & NVIQ	8.3–35.8	4.7–27.7	–	–	RDKs & dynamic glass patterns	Static Glass patterns	Yes	Yes	–	–
Developmental Dyslexia											
Conlon et al. (2009)	FSIQ	22.8	22.1	–	–	RDKs	Line segments	Yes	No	–	–
Hansen et al. (2001)	NVIQ	28.9	24.0	–	–	RDKs	Line segments	Yes	No	–	–
Johnston et al. (2016)	NVIQ	22.5	21.9	17:26	16:27	RDKs	Oriented dot clusters	Yes	No	0.6	0.1
Kevan and Pammer (2009)	FSIQ	5.7	5.5	11:8	20:19	RDKs	Line segments	Yes	No	–	–
Tsermentseli et al. (2008)	FSIQ	23.4	28.4	12:8	11:9	RDKs	Glass patterns	No	No	–	–
White et al. (2006)	NVIQ	10.5	10.3	14:9	9:13	RDKs	Line segments	No	No	0.1	0.2
Autism Spectrum Disorder											
Koldewyn et al. (2010)	NVIQ	15.1	15.8	28:2	30:2	RDKs	Glass patterns	No	No	0.7	0.1
Milne et al. (2006)	NVIQ	10.1	10.3	22:1	10:13	RDKs	Line segments	No	No	0.6	0.6
Spencer et al. (2000)	VIQ	7.0–11.0	7.0–11.0	–	–	Segmentation	Line segments	Yes	No	–	–
Tsermentseli et al. (2008)	FSIQ	28.3	28.4	8:2	11:9	RDKs	Glass patterns	Yes	Yes	–	–
Developmental Coordination Disorder											
O'Brien et al. (2002)	VIQ	8.2	8.4	6:2	–	Segmentation	Line segments	No	Yes	–	–
Sigmundsson et al. (2003)	–	10.6	10.5	6:7	6:7	RDKs	Line segments	Yes	Yes	–	–
Children born preterm											
Taylor et al. (2009)	VIQ	7.3	7.3	11:12	10:10	RDKs	Glass patterns	Yes	No	0.6	0.3
Children born preterm (no PVL)											
Guzzetta et al. (2009)	–	10.7	10.1	4:9	6:7	RDKs Segmentation	Line segments	Yes	No	1.4 0.6	0.7
Children born preterm (with PVL)											
Guzzetta et al. (2009)	–	10.4	10.1	7:6	6:7	RDKs Segmentation	Line segments	Yes	Yes	1.9 1.6	1.6