Journal of Experimental Child Psychology 161 (2017) 113–125

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

The light-from-above prior is intact in autistic children

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ARTICLE INFO

Article history:
Received 19 November 2016
Revised 10 April 2017
Available online 15 May 2017

Keywords:
Perception
Autism
Bayesian priors
Light-from-above
Development
Bias

ABSTRACT

Sensory information is inherently ambiguous. The brain disambiguates this information by anticipating or predicting the sensory environment based on prior knowledge. Pellicano and Burr (2012) proposed that this process may be atypical in autism and that internal assumptions, or "priors," may be underweighted or less used than in typical individuals. A robust internal assumption used by adults is the "light-from-above" prior, a bias to interpret ambiguous shading patterns as if formed by a light source located above (and slightly to the left) of the scene. We investigated whether autistic children ($n = 18$) use this prior to the same degree as typical children of similar age and intellectual ability ($n = 18$). Children were asked to judge the shape (concave or convex) of a shaded hexagon stimulus presented in 24 rotations. We estimated the relation between the proportion of convex judgments and stimulus orientation for each child and calculated the light source location most consistent with those judgments. Children behaved similarly to adults in this task, preferring to assume that the light source was from above left, when other interpretations were compatible with the shading evidence. Autistic and typical children used prior assumptions to the same extent to make sense of shading patterns. Future research should examine whether this prior is

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http://dx.doi.org/10.1016/j.jecp.2017.04.005

as adaptable (i.e., modifiable with training) in autistic children as it is in typical adults.

Introduction

In human vision, the complex dimensions of a visual scene—the shapes of objects, their spatial arrangement, and their material properties—are reduced to flat patterns of excitation of the cones and rods of the retina. Information entering the brain is inherently ambiguous, compatible with a range of interpretations. Visual input, therefore, is "underspecified" for the task of providing the reliable and stable awareness of the environment that we experience. Consequently, perception has long been considered as a process of "unconscious inference" (Helmholtz, 1866/1911), in which existing knowledge is spontaneously and automatically deployed to interpret the meaning of sensory signals. Expectations based on experience of how the material environment works—for example, of faces being convex or of light sources being overhead—feed into the construction of a percept by the brain.

The framework provided by Helmholz (1866/1911) was extended to characterize perceptual inferences as "hypotheses" or informed speculations using noisy and limited data (Gregory, 1980). Perceptual decisions are made possible by comparing the probability of the sensory evidence and prior experience. The Bayesian framework has since supplied an established mathematical model for perceptual decision making under conditions of uncertainty. In Bayesian terms, if both sensory signals and knowledge-based hypotheses are represented as probability distributions, techniques of statistical inference can be used to locate the combined point of maximal probability, the "best guess" interpretation (Knill, Kersten, & Yuille, 1996). In Bayesian perceptual inference, the prior probability distribution, or "prior," represents a "baseline" understanding of the likelihood of particular environmental conditions on the basis of past experience (Gregory, 1980).

A number of visual priors have been established and are thought to improve overall perceptual efficiency by weighting perceptual hypotheses in a broadly reliable way. For example, a prior for convexity reflects the predominance of convex, over concave, objects in the world (Langer & Bülthoff, 2001; Sun & Perona, 1996). The statistical inference calculation implies a trade-off between the image data and the prior probability, such that perception will be more prior driven when ambiguity in the sensory input is high. In some circumstances, prior-driven expectations will be misguided, resulting in visual illusions. For example, perceiving a hollow mask as a convex mask implies the operation of overriding expectations of convexity in faces. Hence, when problems of object perception are resolved on a probabilistic basis, the optimal solution may still be "inaccurate" (Kersten & Yuille, 2003). Importantly, in the context of this research, Bayesian priors envisage dynamic connections among perceptual inference, experience of the environment, and behavior (Lee, Yang, Romero, & Mumford, 2002).

Atypicalities in sensation and perception are highly characteristic of autism (Baranek, David, Poe, Stone, & Watson, 2006; Leekam, Nieto, Libby, Wing, & Gould, 2007; Mottron, Dawson, Soulieres, Hubert, & Burack, 2006; Simmons et al., 2009). Although difficulties in social communication are considered hallmarks of autism, sensory reactivity, including hypersensitivity (e.g., to light or touch) and hyposensitivity (e.g., to pain), was noted during the first description of autism (Kanner, 1943). Sensory reactivity has since been shown to be present in the majority of autistic children and adults (Ben-Sasson et al., 2009; Leekam et al., 2007; Simmons et al., 2009), to be pervasive and persistent across development (Crane, Goddard, & Pring, 2009; McCormick, Hepburn, Young, & Rogers, 2016), and to have a substantial impact on the lives of autistic people (e.g., Dickie, Baranek, Schultz, Watson, & McComish, 2009; Grandin, 2009; Williams, 1994).

In the perceptual domain, the majority of scientific studies have reported atypical processing in aspects of visual perception and visual attention ranging from characteristically nonsocial stimuli and tasks, such as discrimination of chromatic stimuli (e.g., Franklin et al., 2010), cast shadow (Becchio, Mari, & Castiello, 2010), static gratings (e.g., Bertone, Mottron, Jelenic, & Faubert, 2005), mov-