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# From local to global processing: The development of illusory contour perception

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ABSTRACT

Global visual processing is important for segmenting scenes, extracting form from background, and recognizing objects. Local processing involves attention to the local elements, contrast, and boundaries of an image at the expense of extracting a global percept. Previous work is inconclusive regarding the relative development of local and global processing. Some studies suggest that global perception is already present by 8 months of age, whereas others suggest that the ability arises during childhood and continues to develop during adolescence. We used a novel method to assess the development of global processing in 3- to 10-year-old children and an adult comparison group. We used Kanizsa illusory contours as an assay of global perception and measured responses on a touch-sensitive screen while monitoring eye position with a head-mounted eye tracker. Participants were tested using a similarity match-to-sample paradigm. Using converging measures, we found a clear developmental progression with age such that the youngest children performed near chance on the illusory contour discrimination, whereas 7- and 8-year-olds performed nearly perfectly, as did adults. There was clear evidence of a gradual shift from a local processing strategy to a global one; young children looked predominantly at and touched the "pacman" inducers of the illusory form, whereas older children and adults looked predominantly at and touched the middle of the form. These data

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show a prolonged developmental trajectory in appreciation of global form, with a transition from local to global visual processing between 4 and 7 years of age.



## Introduction

Visual information about objects is often incomplete. Parts of objects can be occluded or missing or can blend seamlessly into the background, yet adults perceive the objects as complete global forms rather than a collection of disconnected local elements. In the laboratory, adults perceive holistic contours of shapes based on illusory edges that have no physical luminance, color, or texture boundary. How does this global perceptual ability come about? Although some researchers have found evidence for perception of illusory figures in young infants (e.g., Bertenthal, Campos, & Haith, 1980; Bulf, Johnson, & Valenza, 2011; Kavsek, 2002; Otsuka & Yamaguchi, 2003), others have reported that global form perception and discrimination of illusory shapes do not reach maturity until late childhood (Abravanel, 1982; Hadad, Maurer, & Lewis, 2010; Kimchi, Hadad, Behrmann, & Palmer, 2005; Sherf, Behrmann, Kimchi, & Luna, 2009). Here, we used a novel approach—accuracy on a match-to-sample (MTS) task paired with several measures of spontaneous manual and visual behaviors—to investigate the development of illusory contour perception as an assay of global form perception in children from 3 to 10 years of age. Our objective methods and converging behavioral evidence show a clear protracted developmental program for global visual processing that begins during the preschool years and reaches adult levels by 7 or 8 years of age.

### *Local to global processing*

The development of object recognition is widely believed to be a hierarchical process, progressing from elemental perceptual function to more complex sophisticated integrative processing with age (e.g., Johnson, Davidow, Hall-Haro, & Frank, 2008; Kimchi, 1992; Kimchi et al., 2005). A critical aspect of this process is the development of global processing—the ability to appreciate coherent global structure over the local elements that make up an entire image (Kimchi, 1992; Navon, 1977). Operationally, local processing is based on selective attention to individual elements of an object or scene, whereas global processing involves establishing spatial relationships among discrete local elements and linking them together to form a coherent global structure (e.g., Kimchi, 1992; Kovács, 1996; Lewis et al., 2004; Neiworth, Gleichman, Olinick, & Lamp, 2006). These two types of processing are thought to rely on different underlying neural substrates (e.g., Conci, Tollner, Leszczynski, & Muller, 2011; Ringach & Shapley, 1996; Spillmann & Dresp, 1995; Wu et al., 2012).

A logical corollary of a hierarchical developmental process is that global perception develops at a later age than local processing, such that infants and young children rely on local perceptual strategies and attend to individual features of an object, whereas older children and adults appreciate global object structure (Dukette & Stiles, 1996; Kimchi et al., 2005; Kovács, Kozma, Feher, & Benedek, 1999; Lewis et al., 2004; Neiworth et al., 2006; Sherf et al., 2009). However, this profile for the later development of global perceptual abilities is a matter of some debate. A number of researchers report that young infants show evidence of global processing by distinguishing global forms such as Gabor contours in noise, Navon letters, and illusory shapes (Bertenthal et al., 1980; Bremner, Slater, Johnson, Mason, & Spring, 2012; Bulf, Valenza, & Simion, 2009; Csibra, 2001; Gerhardstein, Kovács, Ditre, & Feher, 2004; Ghim & Eimas, 1988; Kavsek, 2002; Otsuka, Kanazawa, & Yamaguchi, 2004). Indeed, Freeseman, Colombo, and Coldren (1993), studying 4-month-olds, concluded that global processing is evident *before* local processing. Other studies suggest that global processing and the ability to link discrete elements to extract coherent contours and shapes is weak or lacking in 3- to