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Perceptual completion of partly occluded contours during childhood

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ABSTRACT

An early functional onset of perceptual completion has been extensively documented during the first several months after birth. However, there is no indication for the developmental time periods at which these skills become fully developed. We used a version of an object-based attention task in which children and adults performed a same–different size judgment of two features appearing at two of four possible ends of overlapping objects. Single-object over two-object superiority (i.e., faster judgments when the features appeared on the same object than when they appeared on different objects) was observed for a complete object as early as at 4 years of age. However, it is only at 5 years of age that such a single-object advantage was obtained also for an occluded object, and even then the advantage of the single-object and occluded-object conditions over the two-object condition was observed only when the two features in the two-object condition were spatially distant, demonstrating the critical role of spatial proximity in perceptual organization during childhood. The results suggest that perceptual completion during infancy and early childhood demonstrates some rudimentary perceptual skills that become more firmly established with age.

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Introduction

Visual objects often partially occlude one another, causing contour discontinuity. Yet, in most cases, visible contours and surface fragments are linked to form a single coherent object without generating any visually experienced structure in the interpolated area (known as amodal completion). These perceptual processes underlying completion of contours seem to emerge quite early during the first several months after birth. There is, however, no indication for the age at which these skills become fully developed. Here, we used a version of the well-established object-based attention task to determine the developmental time periods at which shape representation of partly occluded objects resembles that of a real physically specified object.

Research in adults suggests that partly occluded objects are represented in the visual system as complete forms (e.g., Behrmann, Zemel, & Mozer, 1998; Davis & Driver, 1998; Rensink & Enns, 1998; Sekuler, Palmer, & Flynn, 1994). However, completion takes a measurable amount of time (Murray, Sekuler, & Bennett, 2001; Ringach & Shapley, 1996; Sekuler & Palmer, 1992) that depends on the size of the occluded region (e.g., Guttman, Sekuler, & Kellman, 2003; Rauschenberger & Yantis, 2001; Shore & Enns, 1997), the presence of stereo cues (Bruno, Bertamini, & Domini, 1997), and context (Rauschenberger, Peterson, Mosca, & Bruno, 2004).

Developmental research suggests that visual completion emerges quite early in life, but there is a developmental progression in the perception of object unity that is highly constrained by the perceptual cues that infants are able to detect. Very early onset is seen for perceptual completion of partly occluded objects when the commonly moving visible parts of an object are made more detectable to the newborns' immature visual system (e.g., stroboscopic motion: Valenza, Leo, Gava, & Simion, 2006), but not when the common motion is less detectable (e.g., the parts undergo continuous motion; Slater, Johnson, Brown, & Badenoch, 1996; Slater et al., 1990). As infants develop, the variety of conditions under which they perceive object unity increases (Johnson & Aslin, 1995, 1996; Johnson & Náñez, 1995). Age-related changes in visual completion vary with spatial proximity between the visible parts; for example, 2-month-olds did not seem to perceive unity in displays with a relatively wide occluder but did so when the occluder's width was reduced (Johnson & Aslin, 1995), whereas 4-month-olds showed clear evidence for unity perception in wide-occluder displays (Johnson & Aslin, 1996). Similarly, 2-month-olds failed to perceive the continuity of a linear trajectory as a moving object became progressively occluded and disoccluded, whereas 6-month-olds provided evidence for such ability under the most demanding conditions employed. In addition, 4-month-olds showed an intermediate pattern of performance, perceiving the continuity of a moving object trajectory only under short, but not under long, durations of occlusion (Johnson et al., 2003). At around 7 months of age, infants perceive the unity, but not necessarily the shape, of stationary, partly occluded objects (Craton, 1996).

Despite this extensive evidence for an early functional onset of perceptual completion during the first several months after birth, there is no indication for the developmental time periods at which shape representations of partly occluded objects resemble those of physically specified objects. The evidence for early ability of perceptual completion does not necessarily imply that these processes mature during infancy or soon afterward. In fact, both neurophysiological (Burkhalter, Bernardo, & Charles, 1993; Shankle et al., 1998) and psychophysical (e.g., Kovács, 2000) studies suggest that infants' performance reflects some rudimentary perceptual–organizational skills but that these are not fully developed and continue to improve even beyond the first 10 years of age. Specifically, psychophysical studies indicate that for several domains of perceptual organization, early sensitivity observed at early infancy (e.g., Gerhardstein, Kovács, Ditre, & Feher, 2004; Sireteanu, 2000) is often characterized by a much longer developmental progression later during childhood (e.g., Enns, Burack, Iarocci, & Randolph, 2000; Gervan, Berencsi, & Kovács, 2011; Hadad & Kimchi, 2006; Hadad, Maurer, & Lewis, 2010a; Kimchi, Hadad, Behrmann, & Palmer, 2005; Kovács, 2000; Káldy & Kovács, 2003). For example, Sireteanu (2000) showed that although the earliest evidence for texture-based segregation was observed at 2 months of age, considerable improvements continued to be observed over the first several years in children tested in a more complex display. In clear contrast to the sensitivity to subjective contours observed during early infancy (e.g., Ghim, 1990), considerable improve-