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Using the axis of elongation to align shapes: Developmental changes between 18 and 24 months of age

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ABSTRACT

An object's axis of elongation serves as an important frame of reference for forming three-dimensional representations of object shape. By several recent accounts, the formation of these representations is also related to experiences of acting on objects. Four experiments examined 18- to 24-month-olds' ($N = 103$) sensitivity to the elongated axis in action tasks that required extracting, comparing, and physically rotating an object so that its major axis was aligned with that of a visual standard. In Experiments 1 and 2, the older toddlers precisely rotated both simple and complexly shaped three-dimensional objects in insertion tasks where the visual standard was the rectangular contour defining the opening in a box. The younger toddlers performed poorly. Experiments 3 and 4 provide evidence on emerging abilities in extracting and using the most extended axis as a frame of reference for shape comparison. Experiment 3 showed that 18-month-olds could rotate an object to align its major axis with the direction of their own hand motion, and Experiment 4 showed that they could align the major axis of one object with that of another object of the exact same three-dimensional shape. The results are discussed in terms of theories of the development of three-dimensional shape representations, visual object recognition, and the role of action in these developments.

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Introduction

Visual object recognition is central to human cognition in many domains, including category learning (Dickinson, Leonardis, Schiele, & Tarr, 2009), problem solving (Cavanagh, 2011), and tool use (Lockman, 2000). However, as several recent reviews have noted (Nishimura, Scherf, & Behrmann, 2009; Smith, 2009), the development of visual object recognition has received little systematic attention beyond early infancy. The current experiments were motivated by recent findings indicating marked changes in the representation of object shape during the second year of life (Smith, 2009; Smith & Jones, 2011; Yee, Jones, & Smith, 2012). The experiments focused specifically on one structural property of object shape—the most elongated axis—that has been proposed as a key frame of reference for object constancy and object categorization. As background, we first provide the theoretical rationale for focusing on the most elongated or "major" axis as a stepping-stone to understanding early visual object recognition, and then we review the specific findings from previous research with 18- and 24-month-olds that motivated the current experiments.

The axis of elongation

Three-dimensional objects project different two-dimensional contours when viewed from different directions. This fact yields two fundamental problems in explaining human visual object recognition: object constancy and object categorization. These are illustrated in Fig. 1. Object constancy concerns perceivers' ability to recognize the same object—for example, a specific spoon—from different viewing perspectives (e.g., Biederman & Gerhardstein, 1993; see also Pinto, Cox, & DiCarlo, 2008). Object categorization concerns how perceivers recognize instances of the same category—different spoons—given their idiosyncratic variations in shape along with their different viewing perspectives (e.g., Biederman, 1987; Edelman & Duvdevani-Bar, 1997; Rosch, 1978/1999). Proposed theoretical

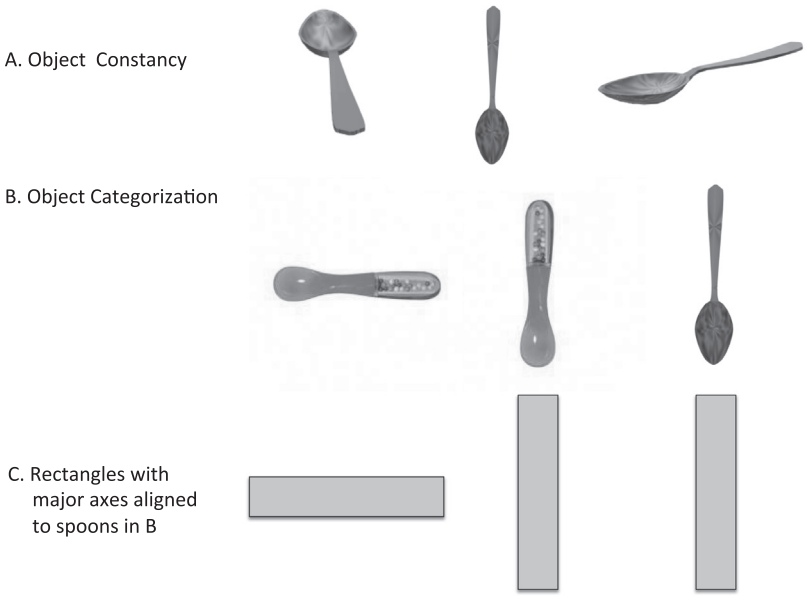

Fig. 1. Panels A and B illustrate how perceived identity (object constancy) and shape similarity (object categorization) benefit from aligning objects by their most elongated axes. Panel C illustrates rectangles with their elongated axis aligned with the spoons in Panel B and the logic behind the task of asking children to align differently shaped objects with a rectangular standard.