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Impact of rotation angle on crawling and non-crawling 9-month-old infants' mental rotation ability

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ABSTRACT

The current study investigated whether 9-month-old infants' mental rotation performance was influenced by the magnitude of the angle of object rotation and their crawling ability. A total of 76 infants were tested; of these infants, 39 had been crawling for an average of 9.0 weeks. Infants were habituated to a video of a simplified Shepard–Metzler object (Shepard & Metzler, 1971), always rotating forward through a 180° angle around the horizontal axis of the object. After habituation, in two different test conditions, infants were presented with test videos of the same object rotating farther forward through a previously unseen 90° angle and with a test video of its mirror image. The two test conditions differed in the magnitude of the gap between the end of the habituation rotations and the beginning of the test rotations. The gaps were 0° and 54°. The results revealed that the mental rotation performance was influenced by the magnitude of the gaps only for the crawling infants. Their response showed significant transition from a preference for the mirror object rotations toward a preference for the familiar habituation object rotations. Thus, the results provide first evidence that it is easier for 9-month-old crawling infants to mentally rotate an object along a small angle compared with a large one.

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Introduction

For a long time, mental transformation abilities have been extensively studied in cognitive and educational research due to their predictive value regarding performances in science, technology, engineering, and mathematics (e.g., Newcombe, Uttal, & Sauter, 2013; Shea, Lubinski, & Benbow, 2001; Wai, Lubinski, & Benbow, 2009). The most prominent one, mental rotation, refers to the ability to rotate mental representations of two- and three-dimensional objects (Linn & Petersen, 1985) and was first systematically examined in chronometric studies by Shepard and colleagues (e.g., Cooper & Shepard, 1973; Shepard & Metzler, 1971). In their initial experiment, Shepard and Metzler (1971) were able to show that the time to judge whether line drawings of two three-dimensional shapes portrayed the same or mirror objects increased linearly with increasing angular differences between them. The internal process underlying a decision about the spatial congruence of the object pairs was understood as being "analog" to real object rotations in three-dimensional space (see Cooper & Shepard, 1973) because the linear growth in reaction times with increasing angular disparities indicated an effect of the same spatiotemporal constraints as for real rotations.

Mental rotation ability has also been studied in infants. Moore and Johnson (2008, 2011) provided evidence that especially boys, from 3 to 5 months of age, are able to mentally rotate two- or three-dimensional objects. While findings by Quinn and Liben (2014) suggest that this advantage for male infants remains up to 9 months of age, another line of research has identified a positive link between crawling and mental rotation ability regardless of gender at that age (Schwarzer, Freitag, Buckel, & Lofruthe, 2013; Schwarzer, Freitag, & Schum, 2013). All of these studies in infants used a paradigm relatively similar to the Shepard–Metzler experiments. Infants were habituated to a stimulus and then preference tested with the habituation stimulus in a novel rotation compared with the mirror stimulus in the same novel rotation that cannot be brought into congruence by any rotation. Mental rotation was determined to have occurred when infants looked longer at the mirror stimulus because this indicates that they had recognized the habituation stimulus in the novel rotation by performing mental rotation and then preferred looking at the novel stimulus. However, these studies did not systematically test whether infants' responses to the mirror object were affected by the magnitude of the angle through which they needed to mentally rotate the stimulus, which was the crucial effect in the adult studies.

The current study was conducted to examine this effect of different rotation angles on 9-month-old infants' mental rotation ability. We also included infants' crawling ability as an independent variable due to its previously demonstrated positive influence on spatial abilities such as mental rotation.

Mental rotation ability during infancy

Evidence for precursors of mental rotation ability in infants was first provided during the 1990s by Hespos and Rochat (1997), Rochat and Hespos (1996). They examined 4- to 8-month-old infants' tracking of occluded rotational movement in order to investigate young infants' ability to generate dynamic mental representations. Infants were presented with a Y-shaped object rotating behind an occluder that covered parts of the object's movement. When the occluder was lowered at the end of the event, the object was shown in a probable or improbable orientation. Results showed that infants of all age groups looked longer to the improbable outcome, suggesting that they were able to mentally continue the object's invisible rotation and anticipate its final orientation. Moore and Johnson (2008, 2011), however, argued that these first studies differ qualitatively from studies that investigated full-scale mental rotation in older children and adults (e.g., Shepard & Metzler, 1971) because they did not use objects that are mirror images of one another (see also Quinn & Liben, 2008).

In their own mental rotation experiments, Moore and Johnson (2008, 2011) habituated 3- to 5-month-old infants to a video of a three-dimensional simplified Shepard–Metzler object rotating through a 240° arc in depth. During test trials, infants were presented with the familiar habituation object or its mirror image rotating through a previously unseen 120° angle (completing a full 360° rotation). Of the 5-month-old infants, only boys differentiated between the familiar and mirror objects (Moore & Johnson, 2008), preferring to look at the mirror object, whereas the 3-month-old boys