Research Report

A Sex Difference in Mental Rotation in Young Infants

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ABSTRACT—*Three- to 4-month-old female and male human infants were administered a two-dimensional mental-rotation task similar to those given to older children and adults. Infants were familiarized with the number 1 (or its mirror image) in seven different rotations between 0° and 360°, and then preference-tested with a novel rotation of the familiar stimulus paired with its mirror image. Male infants displayed a novelty preference for the mirror-image stimulus over the novel rotation of the familiar stimulus, whereas females divided attention between the two test stimuli. The results point toward an early emergence of a sex difference in mental rotation.*

Sex differences in spatial cognition, favoring males, have been reported since the 1970s (Maccoby & Jacklin, 1974; Voyer, Voyer, & Bryden, 1995). Sex differences in mental rotation, which refers to the ability to rotate representations of two- or three-dimensional figures in visual short-term memory, are particularly robust (Linn & Petersen, 1985). In a classic study, Shepard and Metzler (1971) showed participants two-dimensional drawings of three-dimensional block structures, and asked them to decide whether another drawing of blocks was a rotation or a mirror image of the original structure. Others have asked similar questions about two-dimensional forms such as letters (Cooper & Shepard, 1973) or simple shapes (Thurstone, 1962). The major findings are that response time for deciding whether the second shape is a rotated version versus a mirror image of the first is a function of the amount of angular separation between the shape and its upright version (e.g., Shepard & Cooper, 1982), and that females are slower than males in carrying out the rotation (e.g., Kail, Carter, & Pellegrino, 1979).

Developmental research has demonstrated a male advantage in mental rotation in preschoolers (Levine, Huttenlocher, Taylor, & Langrock, 1999) and older children (Linn & Petersen, 1985).

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Research on infants' visual cognitive abilities, however, has generally failed to show sex differences or has found them to be inconsistent or transient (e.g., Spelke, 2005; Wilcox, 2007). Furthermore, no sex differences were identified in earlier work in which the task required infants as young as 4 months of age to extrapolate an object's trajectory to anticipate its probable future orientation and to discriminate it from an improbable future orientation (Hespos & Rochat, 1997; Rochat & Hespos, 1996). However, in this work, the improbable orientation was a 180° rotation in the same plane as the probable orientation (i.e., an inversion) rather than a mirror image, and thus the task was somewhat different from the mental-rotation tasks used with older children and adults.

The lack of clear sex differences in infancy might suggest that early cognitive processes are so basic that they must develop equivalently in girls and boys, but it might instead suggest that the tasks used in infant research have not yet tapped cognitive processes analogous to the rotation tasks demonstrating sex differences in adults and children. Therefore, we explored whether 3- to 4-month-old infants would reveal a sex difference on a familiarization and novelty-preference task designed to be closer to the procedures that have been used to study mental rotation in older children and adults. Stimuli were eight different versions of the number 1 (or its mirror image), depicted in 45° rotations from 0° to 360° (Fig. 1). Infants were shown a randomly selected set of seven of the eight rotations of the number 1 (or its mirror image) during familiarization trials (two identical copies of each stimulus per trial), and then presented with the remaining rotation paired with its mirror image during a preference test. Figure 2 depicts the stimuli and experimental design. The rationale is that, if infants recognize the novel rotation of the familiar stimulus and perceive the mirror-image stimulus as novel, then the mirror-image stimulus should be preferred and attract more looking time.

METHOD

Participants

Participants were 3- to 4-month-old infants, including 12 females (mean age = 112.17 days, *SD* = 9.60 days) and 12 males (mean

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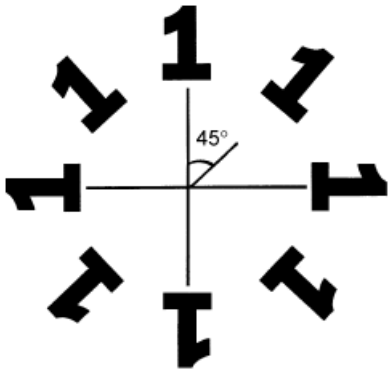

Fig. 1. The number 1 depicted at 45° rotations on the coordinate axis system.

age = 106.75 days, *SD* = 11.58 days). We tested an additional 4 infants whose data were not included: 1 female and 2 males who did not complete the procedure because of fussiness and 1 male who failed to compare the test stimuli (i.e., looked at only one of the test stimuli over the two trials). All of the infants were from middle-class backgrounds and 23 of the 24 infants were Caucasian.

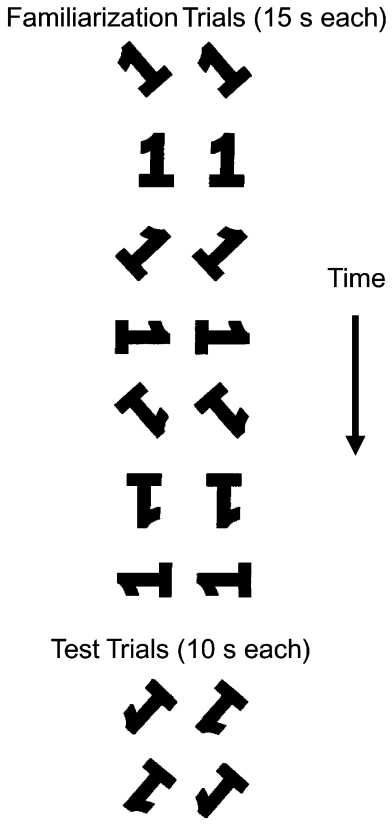

Fig. 2. Schematic depiction of the experimental design. Infants were presented with seven different rotations of the number 1 stimulus (or its mirror image) during familiarization, with two identical copies of each stimulus presented on each trial. For familiarization, we randomly selected seven of the eight possible rotations and their order of presentation for each infant in the female group and a corresponding infant in the male group. The test stimuli paired the novel rotation of the familiar stimulus with its mirror image.

Stimuli

Each stimulus consisted of a black number 1 (or its mirror image) in a particular degree of rotation that was centered on a 17.7 × 17.7 cm white posterboard. The number 1 and its mirror image were 5.2 cm high and 3.2 cm wide at the base. The width of both the base and stem of the number 1 and its mirror image was 1.2 cm.

Apparatus

Infants were tested in a visual preference apparatus, modeled after the one described by Fagan (1970). The apparatus has a gray display panel that includes two compartments to hold the posterboard stimuli. The stimuli were illuminated by a fluorescent lamp that was shielded from the infant's view. The center-to-center distance between compartments was 30.5 cm, and on all trials the display panel was situated approximately 30.5 cm in front of the infant. There was a 0.62-cm peephole located midway between the two display compartments that permitted an observer to record the infant's visual fixations. A second peephole, 0.90 cm in diameter, was located directly below the first peephole, and permitted a Pro Video CVC-120PH pinhole camera and a JVC video recorder to record infants' gaze duration.

Procedure

Familiarization included seven 15-s familiarization trials, each presenting the number 1 (or its mirror image) in a different degree of rotation. Two identical copies of each stimulus were presented on each trial. The seven values of rotation and their order of presentation were randomly chosen for each infant in the female group and a corresponding infant in the male group. There were two 10-s preference test trials, each of which paired the rotation of the number 1 (or its mirror image) not experienced during familiarization with its mirror image. For both male and female infants, left-right positioning of the two test stimuli was counterbalanced on the first test trial and reversed on the second test trial.

Trained observers, naive to the hypotheses, recorded looking times to the stimuli. Interobserver agreement, as determined by comparing looking times measured by two independent observers, one recording on-line and the other coding off-line from videotape records, was calculated for the preference trials of 6 randomly selected infants (3 females, 3 males). Average level of agreement for the novelty-preference scores was 95.50% (*SD* = 8.28).

Preliminary analyses indicated that familiar stimulus (number 1 vs. mirror image) did not impact looking times during familiarization or novelty preferences, nor did it interact with any of the other factors to influence these performance measures.

RESULTS

Familiarization Trials

Individual looking times were summed over the left and right copies of the stimulus presented on each familiarization trial,

TABLE 1

Mean Fixation Times During the Familiarization Trials and Mean Novelty-Preference Scores for the Mirror-Image Stimulus During the Preference Test Trials

	Fixation time (s)				Novelty preference		
	Trials 1–3		Trials 4–6		Score (%)		
Participant group	*M*	*SD*	*M*	*SD*	*M*	*SD*	$t(11)$[a]
Females	7.68	2.82	6.05	2.72	50.20	11.87	0.06
Males	8.07	2.88	6.69	2.22	62.67	6.08	7.22*

[a]The *t* tests indicate whether the means differed significantly from chance.
*$p < .001$.

and then averaged across the first three trials and last three trials. Mean looking times are shown in Table 1. An analysis of variance (ANOVA), Sex (female vs. male) × Trial Block (first three vs. last three), performed on the looking time scores revealed a significant effect of trial block, $F(1, 22) = 8.61$, $p < .01$, but no effect of sex, $F(1, 22) = 0.29$, $p > .20$, and no interaction between sex and trial block, $F(1, 22) = 0.06$, $p > .20$. The trial-block effect indicates that the infants displayed a reliable decrement in looking time from the first to the last half of familiarization that is consistent with the presence of habituation (Cohen & Gelber, 1975).

Preference Test Trials

The time each infant spent looking at the novel mirror-image stimulus was divided by the time each infant spent looking at both test stimuli and converted to a percentage score. Mean novelty-preference scores for the novel stimulus are shown in Table 1. As seen there, *t* tests comparing the preference scores to 50% (chance responding) revealed that, as a group, male infants preferred the mirror image significantly above chance, whereas, as a group, female infants showed no preference. In addition, when the mean novelty preferences for the male and female infants were compared, the difference was significant, $t(22) = 3.24$, $p < .05$. At the level of individuals, 11 of 12 males had novelty preference scores greater than 50%, $p < .01$, whereas only 5 of 12 females did, $p = .77$. The proportion of infants preferring the mirror image was greater for males than females, Fisher exact test, $p = .027$. Taken together, these results show that males, more strongly than females, generalize familiarization to the novel rotation of the familiar stimulus and prefer the corresponding novel mirror-image stimulus.

DISCUSSION

Three- to 4-month-old males performed differently than same-aged females on a mental-rotation task modeled after those used with children and adults. As summarized in the preceding section, the data showed that after familiarization with multiple rotations of the number 1 (or its mirror image), males generalized familiarization to a novel rotation of the familiar stimulus and displayed a preference for a mirror-image stimulus, whereas females divided attention between the novel rotation and the mirror-image stimulus. Although the current study with infants cannot provide the precise temporal data about mental rotation that has been available from studies with older children and adults (i.e., a function relating response time to amount of angular deviation between the familiarized and test stimuli), the results provide evidence that male infants were more likely than female infants to recognize as equivalent a figure rotated in the same way as were the figures shown during familiarization (i.e., rotations within the same plane), and to perceive a mirror image of that figure as novel. Convergent evidence for this conclusion comes from a recent study conducted with 5-month-old infants using a similar experimental design with three-dimensional stimuli rotating in three-dimensional space (Moore & Johnson, 2008).

One might attempt to account for infant performance without invoking the notion of mental rotation. For example, perhaps infants simply detect that the top portion of the number 1 extends to the left and, in the mirror image, to the right. However, such an account runs into difficulty because, in some familiarization images, the directional portion of the 1 or its mirror image extends in the opposite direction. One might also propose that infants form a prototype of the familiarization images and then perceive the novel rotation, but not the mirror image, as corresponding with that prototype. However, if one were to enter the familiarization images into a prototype averaging system via superpositioning, the resulting summary image would actually be a figure with lines crossing through the middle in multiple directions so that both test images would be perceived as novel. The difficulties encountered by these alternative accounts suggest that successful performance in the task requires infants to relate the novel rotation to the familiarized rotations so that its correspondence with the familiarized rotations can be detected.

To the degree that the present task provides an infant analogue of the mental-rotation tasks given to older children and adults, the results suggest that a sex difference in mental rotation emerges early in development. The findings point toward the importance of examining both biological and experiential factors that operate very early in life. Past research has shown that differential experience during the first 3 to 4 months influences processing of the social attributes of faces (Kelly et al., 2007). In addition, mothers may respond differentially to male and female infants as early as 3 to 6 months of age, and such differential responding may play a role in gender differences in emotional behavior (Donovan, Taylor, & Leavitt, 2007; Malatesta & Haviland, 1982). Effects of early experience have also been documented in nonsocioemotional domains, including phoneme perception (e.g., Werker, 1989) and binocular and spatial vision (e.g., Mitchell, 2004). Future research is needed to study the possible role of differential experiences that may foster differences in mental-rotation sensitivity in males and females.

With regard to potential biological determinants, sex differences on mental-rotation tasks have been linked with hormonal

effects, but with mixed results (e.g., Hausmann, Slabbekoorn, Van Goozen, Cohen-Kettenis, & Güntürkün, 2000; Hines, 2004; Liben et al., 2002; Puts, McDaniel, Jordan, & Breedlove, 2008). Sex differences in mental-rotation skills have further been connected with cerebral lateralization, although again with inconsistent outcomes (e.g., Roberts & Bell, 2003; Unterrainer, Wranek, Staffen, Gruber, & Ladurner, 2000). Although the current research was not designed to provide data bearing on the causal determinants of sex differences in mental rotation, the results of the present study help to guide future theoretical and empirical work by suggesting that sex differences in mental rotation are already apparent within the first 3 to 4 months of life.

Acknowledgments—This research was supported by National Institute of Child Health and Human Development Grants HD-42451 and HD-46526. We thank Julie G. Johnson for help developing the project, Laurie A. Yarzab for assistance testing participants, and Nora Newcombe and an anonymous reviewer for comments.

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(RECEIVED 4/16/08; REVISION ACCEPTED 6/2/08)