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Object exploration at 6 and 9 months in infants with and without risk for autism

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Abstract

During the first year of life, infants spend substantial amounts of time exploring objects they encounter in their daily environments. Perceptuo-motor information gained through these experiences provides a foundation for later developmental advances in cognition and language. This study aims to examine developmental trajectories of visual, oral, and manual object exploration in infants with and without risk for autism spectrum disorder before the age of 1 year. A total of 31 infants, 15 of whom had an older sibling with autism and who were therefore at heightened risk for autism spectrum disorder, played with sounding and nonsounding rattles at 6 and 9 months of age. The results suggest that heightened-risk infants lag behind their low-risk peers in the exploration of objects. The findings are discussed in terms of how delays in object exploration in infancy may have cascading effects in other domains.

Keywords

autism spectrum disorder; motor development; object exploration

Introduction

Considerable empirical attention has been focused recently on infants who have an older sibling with autism spectrum disorder (ASD) because they are at heightened biological risk for the disorder (e.g. Ozonoff et al., 2011). While much of this attention has been devoted to the identification of potential early markers of ASD in infancy (see Rogers, 2009, for a review), one of the most reliable and widely replicated findings in this rapidly growing body of research is the extensive variability in the early development of heightened-risk (HR) infants who do not receive an ASD diagnosis compared to infants with no family history of ASD (low-risk (LR) infants). Many of these HR infants exhibit early-emerging delays in multiple aspects of development, while others are indistinguishable from their LR peers. For example, a substantial number of HR infants with no subsequent ASD diagnosis are delayed in the acquisition of early motor skills, such as reaching (Bhat et al., 2009) and postural control (Iverson and Wozniak, 2007). Furthermore, several studies point to delays in the development of communication and language (Cassel et al., 2007; Toth et al., 2007; Yirmiya

et al., 2006), with many HR infants' language abilities lagging significantly behind those of LR peers by 18 months of age (Iverson and Wozniak, 2007).

In this study, we seek to further our understanding of this enhanced variability in the early development of HR infants by focusing on the development of object exploration in the first year. From as early as 4 months of age, typically developing (TD) infants begin to explore objects with their eyes, mouths, and hands (e.g. transferring objects from hand to hand, turning and rotating them; e.g. Rochat, 1989). Visual, oral, and manual exploratory behaviors are at their peak frequency between the ages of 6 and 9 months; when TD infants in this age range are presented with objects, they spend substantial amounts of time engaged in systematic exploration (e.g. Rochat, 1989; Ruff, 1984). They also tailor their exploration to the properties of the object being explored, spending more time, for example, manipulating novel than familiar objects (e.g. Sigman, 1976).

Object exploration provides infants with opportunities to learn about the characteristics of objects (e.g. Doolittle and Ruff, 1998; Ruff, 1984). An infant who visually examines an object while simultaneously rotating it is receiving rich perceptuo-motor feedback from multiple perspectives, feedback that contributes, for example, to perception of the object as a three-dimensional entity (Soska et al., 2010). Similarly, an infant who alternately mouths and looks at an object has the opportunity to integrate haptic and visual information about its properties. Such exploratory experiences also create opportunities for object categorization, a foundational ability for subsequent cognitive and language development. Indeed, frequency of object manipulation and exploration as early as 4 months is positively related to the Bayley Mental Developmental Index (MDI) scores and expressive vocabulary size at 1, 2, and 3.5 years of age (Ruddy and Bornstein, 1982; Siegel, 1981).

One implication of these findings is that delays in the development of object exploration behaviors in infancy—delays that may impact the extent to which exploration is both effective and efficient—may have cascading effects on subsequent development in other domains (see Bhat et al., 2011 for a similar argument). For example, work with preterm infants has indicated that reduced frequency of exploratory behaviors at 7 and 9 months (corrected age) is related to poorer cognitive and language outcomes at 2 years (Ruff et al., 1984).

In light of the enhanced variability in the development of HR infants who do not receive an ASD diagnosis, emerging reports of delays in cognitive and language development (Brian et al., 2008; Yirmiya et al., 2006), and the foundational relationship between these abilities and object exploration, the overarching goal of this study was to examine the development of visual, oral, and manual exploratory behaviors and the ways in which they are deployed for purposes of object exploration in infants with and without risk for ASD at 6 and 9 months of age. We focus on these ages because they bracket the period during which the exploratory behaviors of interest are at their peak, and we examine infant behavior in a standard paradigm in which a single, salient property of the object (its sound) is altered as a means for assessing changes in exploratory behavior as a function of novelty.

Method

Participants

A total of 34 infants (13 male and 21 female) participated in this study. A total of 18 HR infants (7 male and 11 female) had a full biological older sibling with autistic disorder (AD). The HR infants were recruited by the Autism Research Program at the University of Pittsburgh, parent support organizations, and local agencies and schools serving children with ASD. The Autism Diagnostic Observation Schedule—Generic (ADOS-G; Lord et al.,

2000) was administered to all older siblings by a trained clinician at the Autism Research Program prior to the infants' enrollment in the study. The older siblings had to score above the threshold for autism on the ADOS in order for infants to be eligible for the study. At 36 months, all the HR infants visited the Autism Center of Excellence for diagnostic outcome classification by a trained clinician blind to all previous study data using the ADOS and Diagnostic and Statistical Manual of Mental Disorders (4th ed.; *DSM-IV*) criteria. Three HR infants (2 male and 1 female) received a diagnosis of AD; the remaining 15 HR infants scored below the threshold for ASD. Because the focus of this study was on the development of object exploration behaviors in HR infants who did not receive an ASD diagnosis, these three infants were excluded from the analyses presented below.

A comparison group of 16 LR infants (6 male and 10 female) with an older TD sibling and no family history of ASD (i.e. no first- or second-degree relatives diagnosed with ASD) was selected from a separate longitudinal study (see Iverson et al., 2007). No developmental concerns were ever reported for any of these infants during the course of their involvement in the study. We have remained in contact with these families since this time, and none of the children have subsequently received a diagnosis of a developmental disorder of any sort (e.g. ASD, language impairment).

Infants in both groups were from full-term, uncomplicated pregnancies; had normal hearing; and came from monolingual, English-speaking families. A total of 31 infants (16 HR and 15 LR) were of Caucasian descent, 2 HR infants were Hispanic, and 1 LR infant was Asian American. Parental levels of education were similar across the HR and LR groups, with the majority of parents either holding college degrees or having completed some college. Mean maternal ($M_{HR} = 35.88$, standard deviation (SD) = 4.75; $M_{LR} = 33.0$, SD = 5.12) and paternal ($M_{HR} = 36.71$, SD = 3.63; $M_{LR} = 34.83$, SD = 4.10) ages also did not differ significantly between the groups. Although information on family income was unavailable, parental occupations were identified for the purpose of providing a general index of social class. Because a majority of mothers (10 of 15 in the HR group and 7 of 15 in the LR group) were at home raising their children, Nakao–Treas occupational prestige scores (Nakao and Treas, 1994) were only calculated on fathers' occupations. In two cases in the LR group and one in the HR group, it was impossible to identify the father's occupation with enough precision to assign a prestige score. Results from the remaining families indicated that the occupational prestige of HR fathers ($M = 59.85$, SD = 16.95) was slightly higher than that of LR fathers ($M = 58.28$, SD = 10.23), but both generally fell within the managerial/professional range, and this difference was not statistically significant ($t(26) = .289$, $p = .768$).

Procedure

Infants were videotaped for 45 min at home with a primary caregiver (usually mothers). The HR infants were seen at monthly intervals from 5 to 14 months of age and at 18 months. Same-age data points from the LR infants were utilized for comparison (see Iverson and Wozniak, 2007, for more information). Every effort was made to schedule home visits within 3 days of the monthly anniversary of the infant's birthday and at a time when infants would be alert and playful, but not hungry. Informed consent was obtained from parents of participating infants prior to the first observation.

This study focused on a segment of sessions at 6 and 9 months during which infants played with a pair of visually identical standard infant rattles—one sounding and one with the noisemaker removed. Rattles are commonly used in studies of object exploration in infancy (e.g. Ejiri and Masataka, 2001; Locke et al., 1995) as they are designed to elicit exploratory movements. Furthermore, the shape and size of the rattles, each with a round plastic head that attached to a hard plastic handle in the shape of a ring, allow infants to grasp them

easily. Following a procedure employed by Locke and colleagues (1995), the rattles were presented to infants for a total of three trials. Using an ABA design, trial order was held constant such that each infant was presented the sounding rattle first (Rattles Sound 1 (RS1)), the nonsounding rattle second (Rattles No Sound (RNS)), and the sounding rattle again third (Rattles Sound 2 (RS2)). Each trial lasted approximately 1.5 min. The point of the ABA design, which by its nature requires a fixed order of presentation, was to observe infants' baseline level of exploration of the rattles (i.e. Condition A, RS1), then evaluate the effect on exploratory behavior of altering a salient characteristic of the rattle (i.e. removing the noisemaker, Condition B, RNS) by comparing performance in Condition B not only to the baseline (Condition A) but to that when the infant returns to Condition A. If behavior changes in going from Condition A to Condition B and then changes back in going back from Condition B to Condition A, it is possible to infer an effect of Condition B. Infants were seated on the caregiver's lap with their torso supported and facing the experimenter. At the beginning of each trial, the experimenter held the rattle at midline until the infant grasped the rattle. If the infant dropped the rattle during the trial, it was presented again at midline.

Coding

Three primary observers blind to infant group membership completed the coding for this study using a time-linked, computer-based video interface system (The Observer, Noldus Information Technologies). Focusing on behaviors identified by Ruff (1984) as commonly employed at 6 and 9 months of age, we coded four target behaviors: (a) looking: visual fixation of the rattle, evidenced by direction of eyes and/or head; (b) mouthing: contact between the rattle and the infant's mouth or lips; (c) transfer: after grasping with one hand, grasping the rattle with a second hand and subsequently releasing the hand initially grasping the rattle; and (d) turn/rotate: turning the rattle over in the hands while simultaneously looking directly at it. Onset and offset times were recorded for each instance of looking and mouthing, from which durations were calculated. Each instance of transfer and turn/rotate was coded, and frequencies of occurrence were calculated for each behavior.

Reliability

Intercoder reliability was assessed by having the three trained coders independently code 20% of the observations selected at random. Using this procedure, mean percentage agreement was above 80% for all behaviors. Following reliability calculations, disagreements were resolved through discussion.

Results

This study was designed to examine visual, oral, and manual object exploration in two groups of infants at 6 and 9 months of age: (a) LR infants with no diagnosis of AD and (b) HR infants with no diagnosis of AD. Because we were interested in variation in infant exploratory behavior as a function of the rattle type (sounding and nonsounding), the data from the 6- and 9-month sessions were analyzed separately.

Data reduction and preparation

To control for small variations in rattles segment length, all duration data were converted to time as a proportion of trial length. These proportions were calculated separately for looking and mouthing data for each infant by dividing the total amount of time spent looking/mouthing by the total length of the trial. The data were then arcsine transformed before conducting statistical analyses.

Histograms of all variables were inspected prior to carrying out statistical analyses; all were generally normally distributed. Unless otherwise noted, all statistical analyses involved 2 (Group: LR, HR) $\times$ 3 (Rattles Segment: RS1, RNS, RS2) repeated-measures analysis of variance (ANOVA), with Group as the between-subjects factor and Rattles Segment as the within-subjects factor.

Looking

The data on looking time during the three rattles segments for the LR and HR infants at 6 months are presented in Figure 1a. The ANOVA revealed a significant main effect of Rattles Segment, $F(2, 58) = 5.987, p = .004$, partial $\eta^2 = .171$, which was qualified by a significant Group $\times$ Rattles Segment interaction, $F(2, 58) = 5.033, p = .010$, partial $\eta^2 = .148$. As is apparent in Figure 1a, patterns of looking in each group varied across trials. Looking times for the LR and HR infants were roughly equivalent in RS1 ($M_{LR} = 32.32\%$, $SD = 19.31$; $M_{HR} = 40.68\%$, $SD = 20.08$; $t(29) = 1.181, p = .247$). But while LR infants' looking increased from RS1 to RNS ($M = 48.29\%$, $SD = 15.52$; $t(15) = 8.748, p < .001$) and then declined in RS2 ($M = 36.90\%$, $SD = 18.78$; $t(15) = 3.226, p = .006$), looking tended to decrease across trials for the HR infants ($M_{RNS} = 37.85\%$, $SD = 21.80$; $M_{RS2} = 26.27\%$, $SD = 13.82$), but only the difference between RS1 and RS2 was significant ($t(14) = 2.512, p = .025$). Examination of the numbers of infants who increased versus decreased looking from RS1 to RNS in each group indicated that looking times for all 16 LR infants increased from RS1 to RNS. In contrast, only six HR infants exhibited the same pattern; looking times for the remaining nine HR infants decreased from RS1 to RNS ($\chi^2(1) = 13.57, p < .001$). No other effects were statistically reliable.

Differences in patterns of looking between the LR and HR infants appeared to be reversed by 9 months, as is evident in Figure 1b. An ANOVA revealed a significant main effect of Rattles Segment, $F(1.746, 50.625) = 6.531, p = .004$. Pairwise comparisons confirmed that looking was greater in RS1 ($M_{LR} = 37.14\%$, $SD = 14.35$; $M_{HR} = 41.91\%$, $SD = 20.73$) than RS2 ($M_{LR} = 23.02\%$, $SD = 10.95$; $M_{HR} = 32.55\%$, $SD = 15.31$; $p < .001$); the comparison between RNS ($M_{LR} = 29.99\%$, $SD = 11.75$; $M_{HR} = 41.52\%$, $SD = 21.92$) and RS2 approached significance ($p = .057$). The Group effect was nearly significant, $F(1, 29) = 3.752, p = .063$, reflecting a tendency of the HR infants to look longer overall than the LR infants across trials. The interaction was not significant.

Because inspection of the distributions for looking times indicated significant skewing and substantial individual variability at the high end, especially among the HR infants, we further evaluated differences in looking by comparing distributional patterns between the LR and HR groups. A Fisher's Exact Test was computed on the distributions of the HR infants whose looking times fell at or above the median for the LR group (and vice versa). Looking times for 10 HR infants fell above the LR group median ($Mdn_{LR} = 30.0\%$), but only 4 LR infants looked longer than the HR group median ($Mdn_{HR} = 34.0\%$), $p = .032$.

Mouthing

At both ages, there were some HR and LR infants who never mouthed the rattles, though these numbers did not vary significantly by group (1 HR and 3 LR at 6 months; four LR and four HR at 9 months). The analyses reported below were conducted with data from these infants excluded.

Figure 2a presents the mean percent of trial that LR and HR infants spent mouthing each of the rattles at 6 months. An ANOVA carried out on these data revealed a reliable Group effect, $F(1, 25) = 8.335, p = .008$, partial $\eta^2 = .250$, with LR infants mouthing the rattles at least three times longer overall than the HR infants. The effect of Rattles Segment was not

significant, but the Group $\times$ Rattles Segment interaction approached significance, $F(2, 50) = 2.507, p = .092$, partial $\eta^2 = .091$. This reflected the tendency of the LR infants to mouth for a *lower* percentage of the trial during RNS ($M_{RNS} = 19.83\%$, $SD = 15.22$) than during RS1 and RS2 ($M_{RS1} = 26.42\%$, $SD = 26.50$; $M_{RS2} = 24.19\%$, $SD = 18.74$), while the HR infants mouthed for a slightly *greater* percentage of trial during RNS ($M_{RNS} = 10.95\%$, $SD = 12.50$) than RS1 or RS2 ($M_{RS1} = 7.37\%$, $SD = 9.36$; $M_{RS2} = 5.75\%$, $SD = 5.84$).

As is evident in Figure 2b, different patterns were evident by 9 months. An ANOVA yielded a highly significant effect of Rattles Segment, $F(1.663, 34.927) = 6.337, p = .007$, partial $\eta^2 = .232$. The pairwise comparisons indicated that overall infants spent more time mouthing in RNS ($M_{LR} = 21.86\%$, $SD = 15.01$; $M_{HR} = 26.08$, $SD = 27.32$) than RS1 ($M_{LR} = 8.85\%$, $SD = 7.75$; $M_{HR} = 5.80\%$, $SD = 6.53$; $p = .008$). The comparison between RS1 and RS2 ($M_{LR} = 19.40\%$, $SD = 17.60$; $M_{HR} = 14.49\%$, $SD = 18.59$) also approached significance ($p = .07$), though the comparison between RNS and RS2 did not ($p = .38$). Neither the Group effect nor the interaction was statistically reliable.

Manual exploration

Finally, we examined two manual exploratory behaviors: transferring and turning/rotating the rattles. Transfer data were converted to rate per minute to control for slight variation in segment length. This was done by dividing the total number of transfers by the total trial length for each infant. Because turning/rotating was relatively infrequent, we analyzed these data by examining the numbers of infants who performed these behaviors at each age.

Transferring—At 6 months, rates of transferring were relatively low overall for both the LR and HR infants, as is apparent in Figure 3a. An ANOVA confirmed that the main effect of the Rattles Segment was significant, $F(2, 58) = 3.894, p = .026$, partial $\eta^2 = .118$. The pairwise comparisons confirmed that the rate of transferring during RNS ($M_{LR} = 1.60$, $SD = 1.64$; $M_{HR} = 1.80$, $SD = 1.95$) was significantly higher than during RS1 ($M_{LR} = 0.73$, $SD = 1.16$; $M_{HR} = 0.94$, $SD = 1.22$; $p = .027$). Neither the Group effect nor the interaction was statistically reliable.

By 9 months, transfers were much more common. All of the infants transferred the rattle from one hand to the other at least once at this age. Figure 3b presents mean transfer rates for the LR and HR infants. The Rattles Segment $\times$ Group interaction was not statistically reliable. However, as Figure 3b illustrates, the LR and HR infants exhibited different patterns of transferring across segments. For the LR infants, transfer rates were highest in RS1 ($M = 4.03$, $SD = 3.23$) and decreased in RNS ($M = 3.05$, $SD = 1.82$) and RS2 ($M = 1.86$, $SD = 1.32$). For the HR infants, transferring rates increased from RS1 ($M = 2.62$, $SD = 2.79$) to RNS ($M = 3.16$, $SD = 2.18$) and RS2 ($M = 3.40$, $SD = 2.51$).

Turn/Rotate—Turning/rotating the rattle was observed in five infants (1 LR, 4 HR; $p = .15$) at 6 months. By 9 months, the number of infants who turned/rotated had tripled: five LR and nine HR infants engaged in this behavior during the session. Despite this overall increase with age, the numbers of infants who engaged in turning/rotating did not differ by group at either 6 or 9 months.

Discussion

The primary goal of the current study was to investigate the development of object exploration among infants at heightened risk for ASD and to compare it to that of infants with no such risk. The results indicate differences in visual and oral but not manual

exploration between the HR infants who did not receive an ASD diagnosis and the LR infants, but the nature and extent of these differences varied with age.

Object exploration in LR and HR infants

At 6 months, LR and HR infants differed in the amounts of time spent looking at and mouthing the rattles. Looking varied as a function of the rattle type, with looking at the nonsounding rattle increasing among LR but decreasing among HR infants. Mouthing differed significantly by group, with LR infants spending more time mouthing the rattles than did HR infants. This latter finding is consistent with the work by Bhat et al. (2009), who also reported significantly reduced durations of object mouthing in 6-month-old HR relative to LR comparison infants.

Together these results are suggestive of early delays in object exploration among HR infants, delays that may have implications for infants' ability to gather information about objects effectively and efficiently. In TD infants, mouthing is a common behavior in the first year of life that typically peaks between 6 and 9 months of age (Belsky and Most, 1981; Palmer, 1989; Rochat, 1989; Ruff, 1984). Oral exploration of objects provides infants with a rich source of information about object properties (e.g. shape and structure), which augments that obtained through exploration via other perceptual modalities (e.g. vision). There is an abundant literature indicating that infants make use of multimodal perceptual information from very early in life (e.g. Lewkowicz, 1996) and that access to multiple and redundant sources of crossmodal information enhances perceptual salience and thereby facilitates perception and learning (e.g., Bahrick et al., 2004; Stein and Meredith, 1993).

In the case of the HR infants in this study, reduced mouthing may have constrained access to perceptuo-motor information provided by oral exploration. When access to multiple, redundant sources of information is limited, infants' learning may be incomplete. This incomplete learning may be reflected in the group differences observed in looking times in the RNS trial. Although the nonsounding rattle was visually identical to the previously presented sounding rattle, it differed strikingly because it did not make the expected noise. Increased visual exploration in response to novelty is a robust phenomenon of infant behavior (e.g. Rubenstein, 1974), and response to novelty is thought to reflect familiarization with prior objects based on past exploration (e.g. Fantz, 1964). Thus, the increase in looking time observed among LR infants from RS1 to RNS presumably reflected a novelty response to the nonsounding rattle. Infants actively compared properties of the familiar sounding rattle to the new nonsounding rattle and detected a difference between them, and this resulted in increased attention to the nonsounding rattle.

While the HR infants' looking at the sounding rattle was similar in duration to that of the LR infants, the fact that they engaged in less mouthing of the rattle raises the possibility that their exploration was less effective and yielded incomplete information about properties of the object. In addition to providing information about other features of the rattle, mouthing may have been a particularly effective means of exploring the sound properties of the rattle because it required moving the rattle (i.e. transporting it to the mouth), and this movement would result in sound production. Thus, the HR infants may not have been familiarized with the sounding rattle to the same degree as the LR infants, and this difference could account for the absence of a novelty response to the nonsounding rattle among the HR (but not the LR) infants.

This interpretation is consistent with the view that when motor development is delayed, opportunities to engage with and learn about the environment are constrained (Iverson, 2010). In addition to the delays in mouthing described above, there is evidence that the HR infants exhibit delays in early motor skills, such as reaching (Bhat et al., 2009) and

independent sitting (Iverson and Wozniak, 2007; Nickel et al., 2012). The emergence of reaching and sitting and advances in the quality and stability of these behaviors have significant implications for infant object exploration. Reaching infants can readily obtain a desired object and grasp it for manipulation (e.g. Wimmers et al., 1998), and infants who can sit alone have both hands and arms free to move in the service of object exploration. In addition, the new, upright head position enlarges the field of view and stabilizes gaze, thereby promoting eye–hand coordination (Bertenthal and von Hofsten, 1998) and the combined use of visual and manual exploratory behaviors (Soska et al., 2010). Thus, delays in reaching and sitting may place limits on infants' ability to explore objects effectively and flexibly. The observed pattern of delay in mouthing may be related to earlier-appearing delays in reaching, which would presumably impact HR infants' ability to grasp the rattle and coordinate arm movements in order to bring it to the mouth for oral exploration.

By 9 months, the nature of the observed group differences had changed. Mouthing no longer differed across groups, but the HR infants spent more time looking at the rattles overall than their LR peers. While this difference was a trend at the group level, it was robust across individual infants. The source of this extended looking among the HR infants is unclear, but two possible explanations are suggested by the literature to date. The first is that it reflects the HR infants' tendency to spend more time looking at nonsocial stimuli than LR infants, a difference that has been observed as early as 6 months of age (Bhat et al., 2010; Ibanez et al., 2008). A second possibility is that it may be indicative of delays in the development of visual disengagement, a known difficulty in older children with ASD (Landry and Bryson, 2004). Additional evidence for this view comes from the finding of reduced rates of gaze shifting in other studies of visual attention in HR infants during the first year (e.g., Ibanez et al., 2008). Further work is needed to examine these possibilities and to consider ways in which they may impact the development of skills that require flexibility in visual disengagement and gaze shifting, such as joint attention.

While it may be tempting to consider the subtle delays in object manipulation among the HR infants in our sample as being of relatively little concern, particularly since none of these infants received an ASD diagnosis, there is reason to believe that they merit serious consideration. As noted in the Introduction, indices of object exploration in early infancy are positively related to standardized measures of cognition and language administered in toddlerhood (Ruddy and Bornstein, 1982; Ruff et al., 1984; Siegel, 1981). Reduced and less effective object exploration may limit infants' experiences with and learning about objects in their environment, and this may impact subsequent development in these domains. While this pathway is not well understood, there is reason to suggest that even relatively small perturbations in early-appearing behaviors may have far-reaching, cascading effects on the emergence of subsequent skills in other domains (see Thelen, 2004).

As an example, consider the finding that a substantial proportion of HR infants with no ASD diagnosis exhibit delays in early vocabulary development (Iverson and Wozniak, 2007). There is considerable evidence from the normative developmental literature indicating that advances in object manipulation skills influence the development of object perception (Eppler, 1995; Needham, 2000; Soska et al., 2010), which in turn provides opportunities for developing higher level knowledge about objects. Infants who engage frequently in object exploration and can tailor their exploratory behaviors to the properties of the object being explored have enhanced opportunity to extract information about object categories that are fundamental for lexical development (Ruff et al., 1984). Less effective object exploration would therefore impact the acquisition of categorical knowledge, which would have implications for infants' ability to map words to the categories they represent.

In addition to its potential implications for category formation, variation in object exploratory behaviors may also play a role in infants' opportunities for learning that is relevant to other developmental domains. Consider, for example, the relationship between object mouthing and the production of consonant–vowel (CV) syllables. The production of CV syllables is perhaps the most important language milestone of the first year, and delayed emergence of CV syllables is a reliable predictor of later language delay (Oller et al., 1998). Fagan and Iverson (2007) found that relative to vocalizations unaccompanied by object mouthing, vocalizations produced while infants were mouthing objects were more likely to contain a CV syllable and to contain a greater variety of consonant sounds. They suggested that object mouthing provided infants with opportunities to explore vocal production when the vocal tract was partially blocked (as it is during consonant production). Together with our finding of reduced mouthing among HR infants at 6 months, it is noteworthy that two studies to date have reported that HR infants (even those without a subsequent ASD diagnosis) exhibit delays in the onset of reduplicated babble (characterized by strings of repeated CV syllables; Iverson and Wozniak, 2007) and produce fewer CV syllables than LR peers at 12 months of age (Paul et al., 2011).

Limitations and conclusion

While this study has added to our understanding of the development of object exploration in infants at risk for ASD, a note of caution regarding the interpretation of the findings is in order. First, the sample sizes were relatively small, and the findings clearly merit replication with larger groups of infants and longer observations involving a larger set of objects. Second, standardized developmental assessments were not administered to infants in our sample at these ages. The absence of these data makes it difficult to exclude the possibility that our results reflect differences in the general developmental levels of HR and LR infants. Third, our results cannot speak to the question of whether the pattern of object manipulation delay observed among HR infants is specific to infants at genetic risk for ASD and potentially indicative of the broader autism phenotype. Future studies that incorporate additional comparison groups of infants who are at risk for developmental delays but not ASD (e.g. preterm infants) are needed in order to address this issue.

In sum, we have found that HR infants exhibit early-appearing delays in the visual and oral exploration of objects relative to their LR peers. Given the potentially far-reaching implications of delayed object exploration for subsequent development and mounting evidence that HR infants with no ASD diagnosis are at enhanced risk of delays in language and cognition in the second and third years (e.g. Yirmiya et al., 2006), provision of enriched experiences with objects may be beneficial for HR infants (see Lobo and Galloway, 2008, for an example with TD infants). Early and consistent enhancement of opportunities to engage with and explore objects is a simple and developmentally-appropriate means for increasing infants' experience with objects, experience that may facilitate the emergence of effective exploratory strategies and increase opportunities to learn about objects.

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Figure 1.

Mean percentage of trial spent looking at (a) 6 months and (b) 9 months. Error bars indicate standard deviation. HR: heightened-risk infants; LR: low-risk infants; RS1: Rattles Sound 1; RS2: Rattles Sound 2; RNS: Rattles No Sound.

Figure 2. Mean percentage of trial spent mouthing at (a) 6 months and (b) 9 months. Error bars indicate standard deviation. HR: heightened-risk infants; LR: low-risk infants; RS1: Rattles Sound 1; RS2: Rattles Sound 2; RNS: Rattles No Sound.

Figure 3. Mean transfer rate per minute at (a) 6 months and (b) 9 months. Error bars indicate standard deviation. HR: heightened-risk infants; LR: low-risk infants; RS1: Rattles Sound 1; RS2: Rattles Sound 2; RNS: Rattles No Sound.