Response to Changing Contingencies in Infants at High and Low Risk for Autism Spectrum Disorder

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One recently proposed theory of autism spectrum disorder (ASD) hypothesizes that individuals with the disorder may have difficulty using prior experiences to predict future events [Hellendoorn et al., 2015; Northrup, 2016; Sinha et al., 2014]. To date, this theory has not been tested in infancy. The current study analyzed how young infants at heightened (HR; older sibling with ASD) vs. low risk (LR; no first degree relatives with ASD) for ASD responded to changing contingencies when interacting with two visually identical rattles—one that produced sounds during shaking (Sound), and one that did not (Silent). Infants were given the rattles in a Sound-Silent-Sound order at 6 and 10 months, and shaking behavior was coded. Results indicated that LR and HR infants (regardless of ASD diagnosis) did not differ from each other in shaking behavior at 6 months. However, by 10 months, LR infants demonstrated high initial shaking with all three rattles, indicating expectations for rattle affordances, while HR infants did not. Significantly, HR infants, and particularly those with an eventual ASD diagnosis, did not demonstrate an "extinction burst"—or high level of shaking—in the first 10 sec with the "silent" rattle, indicating that they may have difficulty generalizing learning from one interaction to the next. Further, individual differences in the strength of this "extinction burst" predicted cognitive development in toddlerhood among HR infants. Difficulty forming expectations for new interactions based on previous experiences could impact learning and behavior in a number of domains. ***Autism Res*** *2017, 10: 1239–1248*. © 2017 International Society for Autism Research, Wiley Periodicals, Inc.

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Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by deficits in social interaction and communication and the presence of restricted and repetitive behaviors [American Psychiatric Association, 2013]. Studying the early development of ASD remains challenging as most cases are not diagnosed until 3 years of age or older [Christensen et al., 2016; Daniels & Mandell, 2014]. Therefore, researchers have studied the younger siblings of individuals with ASD (high risk siblings; HR) due to their heightened risk for developing the disorder [Ozonoff et al., 2011]. Thus far, these efforts have identified relatively few markers before 12 months of age that are predictive of subsequent ASD diagnosis. However, much of this research has focused on examining early social and communicative behaviors as precursors to what is later considered the autism phenotype [for a review, see Jones, Gliga, Bedford, Charman, & Johnson, 2014]. In a recent review, Elsabbagh and Johnson [2016] highlight the lack of support for deficits specific to the social domain in the first year and increasing evidence for more widespread atypicalities in brain functioning. Accordingly, researchers have begun shifting from a focus on social specific accounts of early ASD development to considering more domain-general accounts.

One recently proposed domain-general account of ASD development hypothesizes that individuals with the disorder may have difficulty using prior experiences to predict future events [see Hellendoorn, Wijnroks, & Leseman, 2015; Northrup, 2016; Sinha et al., 2014]. In particular, these theories suggest that individuals with ASD have difficulty anticipating future events due to a deficit in learning predictive relationships or structural regularities in the environment. The ability to perceive patterns and regularities in the environment helps individuals reduce uncertainty and interact with the environment more efficiently. When the environment is predictable, individuals are able to allocate attention effectively and act on their environment in appropriate ways. Using past experiences to make predictions about future events also allows for learning to build on itself, as an already learned relationship does not need to be relearned each time it is encountered.

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The hypothesis that individuals with ASD have a deficit in using regularities in the environment to anticipate future events is supported by evidence that children and adults with ASD have difficulty adjusting to changing environmental contingencies [Koegel & Schreibman, 1977; South, Newton, & Chamberlain, 2012; South, Ozonoff, & Mcmahon, 2007], appear to prefer high levels of predictability and repetitiveness [e.g. Bodfish, Symons, Parker, & Lewis, 2000; Gergely, 2001; Nadel et al., 2000], and have difficulty engaging in complex and dynamic exchanges [Constantino, Przybeck, Friesen, & Todd, 2000; Leekam & Ramsden, 2006]. However, to date this hypothesis has not been tested in infants at heightened risk for ASD.

Detecting Regularities in Typical Development

The ability to detect temporal relationships between the occurrences of two events is fundamental to learning across the lifespan [Tarabulsy, Tessier, & Kappas, 1996]. Infants are highly efficient in detecting contingencies from very early in life and appear motivated to do so [Watson & Ramey, 1972]. The detection of behavior-based contingencies, or the temporal relationship between one's own behavior and a consequence, is an early emerging skill that enables infants to perceive regularities in their interactions with the environment. Contingency detection allows infants to predict future events and act on the world in an efficient and logical manner that increases opportunities for learning and decreases undesired or unexpected consequences [Gibson, 1988].

Contingency learning is typically assessed by examining how an individual's behavior changes when a contingency is introduced, with an increase in the behavior being indicative of learning. In addition, infants' response to the removal of a contingency provides valuable information about the behavioral consequences that occur when their expectations are violated. If a particular contingent relationship is learned, and the contingency is subsequently removed, infants will persist in the learned behavior for a period of time before stopping [Alessandri, Sullivan, & Lewis, 1990; Goldstein, Schwade, & Bornstein, 2009]. This persistence in the face of the removal of a contingency, sometimes called an "extinction burst," is an indicator that infants have developed an expectation for, or a prediction about, the consequences of their behavior, and are motivated to produce those consequences [Tarabulsy et al., 1996].

Over repeated encounters, infants use contingencies to learn about the affordances, or specific functions and opportunities, available in interactions with particular objects or social partners [Gibson & Pick, 2000]. Their interactions become less exploratory and more specific as they learn to make predictions about future interactions based on previous experiences. For example, by as early as 3 months of age, young infants will vocalize in the presence of an unresponsive person with whom they have never interacted, but not in the presence of an unfamiliar object [Dunham, Dunham, Hurshman, & Alexander, 1989, experiment 3; Legerstee, 1997], indicating that by this age typically developing infants have learned about the types of contingencies available in interactions with people vs. objects.

Early emerging skills ranging from language development to motor planning to object categorization require infants not only to detect contingencies between their actions and consequences in their environment, but also to apply that knowledge to new contexts and interactions. The ability to detect regularities in the environment and act accordingly reduces uncertainty and makes the environment more predictable for the infant, subsequently allowing allocation of resources to detecting and responding to higher level contingencies. Thus, a disruption in this ability may impact development.

The Present Study

In light of recent theories that individuals with ASD have difficulty predicting future events based on the detection of regularities in the environment, and the importance of behavior-based contingency detection in early development, the current study examined the hypothesis that young infants who go on to receive an ASD diagnosis will show deficits in detecting and responding to contingencies in their environment and have difficulty using prior experiences to make inferences about future interactions. To this end, we observed how young infants at heightened vs. low risk (LR; no first degree relatives with ASD) for ASD responded to changing contingencies when interacting with a conventional infant toy (a rattle), how these interactions varied in relation to infants' age and diagnostic outcome, and how infants' response to changing contingencies related to later ASD symptom severity and cognitive development.

We observed infants longitudinally at 6 and 10 months of age playing with a rattle that made a sound when shaken, followed by a visually identical rattle that did not make a sound, and finally followed by the sounding rattle again. Our first aim was to examine how infants changed their rattle shaking over time with each rattle. We hypothesized that LR infants would demonstrate contingency detection by adjusting shaking behavior based on available contingencies, thus displaying an increase over time in shaking with the sounding rattle and a decrease over time in shaking with the silent rattle. We hypothesized that HR infants, and in particular those with a later ASD diagnosis, would be slower to increase their shaking with the sounding rattles.

Second, and perhaps more crucially, we examined infants' initial responses to each rattle. If infants learned about the affordances offered by an object over time, we would expect their actions to reflect those expectations from the very beginning of the interaction. Thus, we hypothesized that 10-month-old infants would show increased initial shaking with the rattles compared to 6-month-old infants, indicating that older infants have learned the affordances offered by rattles more generally, and that this pattern would be attenuated in HR infants, particularly those later diagnosed with ASD.

Our final aim was to examine how infants' response to the removal of a contingency related to later cognitive development. The presence of an "extinction burst," or persistence in shaking when a contingency is removed, is a marker that the contingency has been learned and is being applied to the new interaction [Alessandri et al., 1990; Fagen, Morrongiello, Rovee-Collier, & Gekoski, 1984; Tarabulsy et al., 1996]. Thus, high initial shaking with the silent rattle would indicate not only that infants learned the relationship between shaking and sound afforded by the rattles, but that they generalized this learning. We hypothesized that high initial shaking with the silent rattle would be indicative of the ability to use past experiences to make predictions about future events and would positively predict later cognitive development and negatively predict ASD severity.

Methods

Participants

Participants included 56 infants from two larger longitudinal studies investigating language and motor development over the first years of life. Thirty-nine infants had an older sibling with a confirmed diagnosis of ASD (HR infants), and 17 infants had no first-degree relatives with ASD (LR infants). Families in the HR group were recruited through a university-based Autism Research Program, parent support organizations, and local agencies and schools serving families of children with ASD. Prior to infant enrollment, the Autism Diagnostic Observation Schedule [ADOS; Lord et al., 2000] was administered to all older siblings by a trained clinician to confirm their diagnosis. Families in the LR group were recruited through local newspaper birth announcements and word of mouth.

All participants were born full-term, from uncomplicated pregnancies and deliveries, and came from English-speaking homes. Table 1 presents demographic information for infants in the HR and LR groups. Groups did not differ significantly with regard to sex, ethnicity, mother or father education, or paternal occupational prestige.

Table 1. Demographic Information for Low Risk and High Risk Groups

	Low risk *n* = 17		High risk *n* = 39	
Female (%)	10	(59%)	16	(41%)
Racial or ethnic minority (%)	1	(6%)	4	(10%)
Hispanic or Latino	0	(0%)	2	(5%)
Mixed race	1	(6%)	2	(5%)
Maternal education				
Graduate of professional school (%)	8	(47%)	17	(44%)
Some college or college degree (%)	8	(47%)	20	(51%)
High school (%)	1	(6%)	2	(5%)
Paternal education[a]				
Graduate of professional school (%)	6	(35%)	14	(36%)
Some college or college degree (%)	10	(59%)	22	(56%)
High school (%)	1	(6%)	2	(5%)
Mean paternal occupational prestige (SD)[b]	57.06	(15.96)	56.43	(15.08)

[a] Paternal education not available for one father.

[b] Nakao–Treas occupational prestige scores [Nakao & Treas, 1994]. Paternal occupation information was not available in eight cases (4 HR; 4 LR).

Measures

The Mullen Scales of Early Learning [MSEL; Mullen, 1995] was administered to HR infants at 6, 12, 18, 24, and 36 months. The MSEL is a normed, standardized measure of cognitive development. Scores from the Visual Reception, Fine Motor, Expressive Language, and Receptive Language scales can be combined to produce an Early Learning Composite (ELC), which is considered a measure of overall cognitive functioning [Mullen, 1995]. As a measure of cognitive ability in toddlerhood, a composite of ELC Standard Scores at 18, 24, and 36 months was calculated for all HR infants by taking the mean of scores at these three ages. Level of internal consistency for the composite was more than adequate (Cronbach's $a = 0.889$).

ELC scores were missing for 4 HR infants at 18 months (3 ASD), 4 at 24 months (3 ASD), and 4 at 36 months (4 ASD). At these ages, infants with ASD are more likely to have trouble sitting through standardized table-top tasks, and thus more likely to have missing scores for one or more scales, making it impossible to calculate an ELC standard score [Akshoomoff, 2006]. One ASD infant was missing ELC scores at all three ages and was therefore excluded from the analysis predicting cognitive development. For all other infants with missing ELC scores, composites were calculated based on available data (i.e. if an infant only had ELC scores at 18 and 36 months, the average of these scores was used).

At 36 months, all infants in the HR group were assessed for ASD by a clinician blind to study data. Diagnoses were made based on administration of the ADOS, DSM-IV-TR criteria, and clinical best estimate. Nine infants (three female) met criteria for ASD. The remaining 30 infants did not receive an ASD diagnosis (HR-NoASD). Raw scores from the ADOS administration were used to calculate symptom severity scores [Gotham, Pickles, & Lord, 2009], a standardized metric of severity of ASD-specific features ranging from 1 to 10 (with 1 = no ASD features and 10 = severe ASD symptoms). Severity scores were available for all but one HR infant (HR-NoASD). As expected, ASD infants ($M = 7.22$, SD = 1.79, range 5–10) had significantly higher severity scores than HR-NoASD infants ($M = 1.66$, SD = 1.044, range 1–4), $P < 0.001$.

Procedure

As part of a larger longitudinal study, HR infants were visited at home monthly between 5 and 14 months, and at 18, 24, and 36 months. LR infants were visited once every 2 weeks from 2 to 19 months of age (for further details describing the procedures employed in the two larger studies, see Parladé & Iverson, 2015). At 6 and 10 months, infants in both groups were videotaped interacting with two visually identical rattles, one that made sounds during shaking (sounding rattle), and one with the noisemakers removed (silent rattle). The procedure employed an ABA design wherein infants were presented first with the sounding rattle (Sound 1), followed by the silent rattle (Silent), followed by the sounding rattle again (Sound 2). Infants were given 90 seconds to interact with each rattle before it was removed and the next rattle was given.

Coding

Trained observers naïve to infant risk and outcome used custom frame-by-frame coding software [Libertus & Needham, 2010] to quantify infants' shaking of the rattles. One frame was coded every 100 msec, excluding periods when the toy was dropped or when someone interrupted the experiment. Given variability in the length of time individual infants explored the rattles within each 90 sec presentation (e.g. due to dropped rattles), coding ended when the child had held the rattle in his/her hand for 60 sec. All infants held the rattle for at least 60 sec. A random sample of 20% of videos were double coded, and average inter-rater reliability was high ($r = 0.84$).

To examine change in shaking over time, the proportion of time spent shaking per 20 sec was used as a dependent variable. For our examination of initial shaking, we focused on the proportion of time spent shaking in the first 10 sec with each rattle. We chose this shortened time period as we were interested in examining infants' expectations for each rattle, and therefore wanted to capture how they responded before they had significant experience with the rattle.

Results

Data Analytic Plan

We conducted repeated measures ANOVAs in order to examine the impact of Age, Rattle Type, and Outcome (LR, HR-noASD, ASD), and the interactions between these variables on the proportion of time spent shaking the rattle over time (per 20 sec time bin) and on proportion of time spent shaking the rattle in the first 10 sec. When statistically indicated, Greenhouse-Geisser corrections were applied. Significant results were followed up with simple effects analyses using a Sidak adjustment. Additionally, linear regressions were used to analyze the relationship between initial shaking with the silent rattle and later outcome.

Change over Time

Our first set of analyses focused on how shaking changed over time with each rattle. A 2 (Age: 6, 10) by 3 (Rattle: Sound 1, Silent, Sound 2) by 3 (Time: Bin 1, Bin 2, Bin 3) by 3 (Outcome: LR, HR-NoASD, ASD) repeated-measures ANOVA with proportion of time spent shaking per 20 sec as the dependent variable revealed main effects of Age, $F(1, 53) = 16.35$, $P < 0.001$, $\eta_p^2 = 0.24$, and Rattle, $F(2, 106) = 9.72$, $P < 0.001$, $\eta_p^2 = 0.16$, as well as interactions between Age and Rattle, $F(2, 106) = 3.40$, $P = 0.037$, $\eta_p^2 = 0.06$, Rattle and Outcome, $F(4, 106) = 2.47$, $P = 0.049$, $\eta_p^2 = 0.09$, Time and Rattle, $F(3.14, 166.39) = 7.17$, $P < 0.001$, $\eta_p^2 = 0.12$, and a three-way interaction between Time, Rattle, and Outcome, $F(6.28, 166.39) = 2.76$, $P = 0.013$, $\eta_p^2 = 0.09$. No other main effects or interactions were significant ($Ps > 0.08$).

Figure 1 displays the proportion of time spent shaking across the three time bins for each of the outcome groups with each rattle at 6 and 10 months. The Age by Rattle interaction indicated that the effect of age on shaking differed for the three rattles. While infants increased their shaking with all three rattles from 6 to 10 months, this increase was particularly sharp for Sound 1. Thus, at 6 months, the proportion of time spent shaking with the Silent rattle was less than the proportion of time spent shaking with Sound 2 only ($P = 0.015$); by 10 months, the proportion of time spent shaking with the Silent rattle was less than the proportion of time spent shaking with both Sound 1 ($P < 0.001$) and Sound 2 ($P = 0.048$).

The three-way interaction between Time, Rattle, and Outcome indicated that the relationship between Time and Outcome differed for the three rattles. To follow up

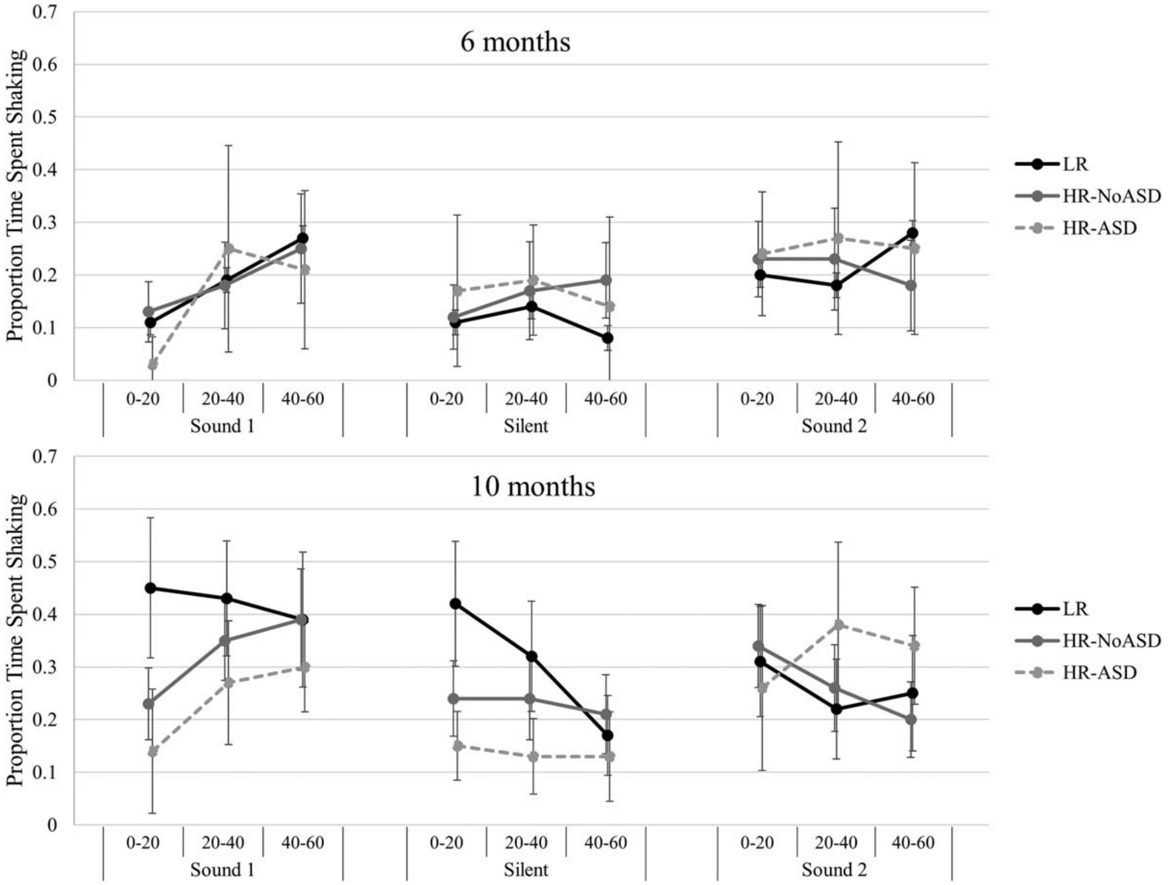

Figure 1. Proportion of time spent shaking per 20 sec bin with each rattle at 6 and 10 months.

on this interaction, we ran separate 3 (Time) by 3 (Outcome) repeated-measures ANOVAs for each of the rattles (collapsing across ages). Analysis of Sound 1 revealed a significant main effect of Time, $F(1.66, 88.11) = 12.97$, $P < 0.001$, $\eta_p^2 = 0.20$, indicating an increase in proportion of time spent shaking from the first 20 sec bin to the second ($P < 0.001$) and third ($P < 0.001$) bins. Although the interaction between Time and Outcome did not reach significance, $F(3.33, 88.11) = 1.66$, $P = 0.177$, $\eta_p^2 = 0.06$, examination of the data suggests that the LR group tended to display a higher and more stable pattern of shaking over time than either of the HR groups.

Analysis of the Silent rattle revealed a non-significant main effect of Time, $F(2,106) = 2.53$, $P = 0.085$, $\eta_p^2 = 0.05$, but a significant interaction between Time and Outcome, $F(4,106) = 2.71$, $P = 0.034$, $\eta_p^2 = 0.09$. Follow-up analyses revealed that only the LR group displayed significant change in proportion of time spent shaking over time with the Silent rattle ($P = 0.003$). Specifically, the LR group reduced the proportion of time spent shaking from the first 20 sec to the last 20 sec ($P = 0.002$), while both HR groups demonstrated relatively low and stable shaking during the Silent rattle.

Finally, analysis of Sound 2 also revealed a significant interaction between Time and Outcome, $F(4,106) = 2.54$, $P = 0.044$, $\eta_p^2 = 0.09$. Only the HR-NoASD group showed significant change over time with Sound 2 ($P = 0.029$). Specifically, the HR-NoASD infants decreased the proportion of time they spent shaking from the first 20 sec to the last 20 sec.

Although the four-way interaction between Rattle, Time, Outcome, and Age was not significant, inspection of the data suggests that the interaction between Rattle, Time, and Outcome was more pronounced at 10 months than at 6 months. All three groups followed a largely similar pattern of shaking at 6 months. However, at 10 months, LR infants displayed a different pattern. While infants in the ASD group, and to a lesser extent infants in the HR-NoASD group, looked strikingly similar to the 6-month-old infants, LR infants displayed high and stable shaking throughout Sound 1 and a decrease in shaking with the Silent rattle (see Fig. 1).

Initial Shaking

Our next set of analyses focused on how infants responded when they first received each rattle. A 2

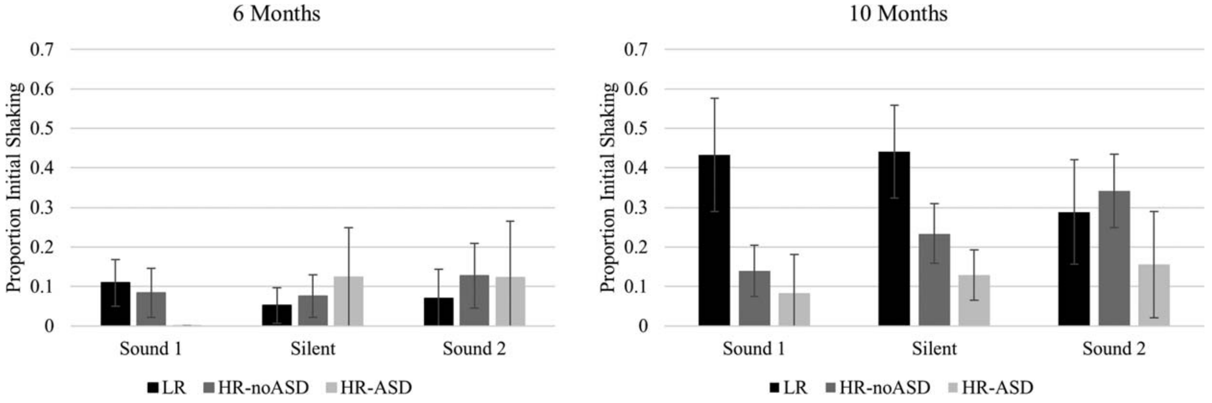

Figure 2. Proportion of time spent shaking in the first 10 sec with each rattle at 6 and 10 months.

(Age: 6, 10) by 3 (Rattle: Sound 1, Silent, Sound 2) by 3 (Outcome: LR, HR-NoASD, ASD) repeated-measures ANOVA with the proportion of time spent shaking in the first 10 sec after receiving the rattle (proportion initial shaking) as the dependent variable revealed main effects of Age, $F(1,\ 53)\ =37.16$, $P < 0.001$, $\eta_p{}^2 = 0.41$, and Outcome, $F(2,\ 53) = 3.53$, $P = 0.036$, $\eta_p{}^2 = 0.12$, as well as interactions between Age and Outcome, $F(2,\ 53) = 7.80$, $P = 0.001$, $\eta_p{}^2 = 0.23$, and Rattle and Outcome, $F(4,\ 106) = 5.64$, $P\ = < 0.001$, $\eta_p{}^2 = 0.18$. These results were qualified by a nearly significant three-way interaction between Age, Outcome, and Rattle, $F(4,\ 106) = 2.41$, $P = 0.054$, $\eta_p{}^2 = 0.08$.

Figure 2 displays the proportion initial shaking for all three outcome groups with each rattle at each age. As is apparent, the nature of the interaction between Rattle and Outcome was different at 6 months than at 10 months. To examine this difference, we ran separate 3 (Rattle) by 3 (Outcome) repeated measures ANOVAs on the 6 and 10 months data respectively. Analysis of the 6 months data revealed no main effects or interactions. At this age, infants in all three groups started off with relatively low proportion initial shaking, regardless of rattle. Although there was no significant interaction at this age, it was notable that all the infants in the ASD group (9 out of 9) showed *no* initial shaking of the first rattle at 6 months. In contrast, only 47% of the LR (8 out of 17) and 73% of the HR-NoASD (22 out of 30) groups showed no initial shaking of the first rattle. A Chi Square test revealed that this Outcome group difference in percentage of infants who shook the Sound 1 rattle in the first 10 sec after receiving it was significant, $\chi^2 = 8.22$, $P = 0.016$.

At 10 months, ANOVA revealed a main effect of Outcome, $F(2,\ 53) = 7.21$, $P = 0.002$, $\eta_p{}^2 = 0.21$, as well as a Rattle by Outcome interaction, $F(4,\ 106) = 5.57$, $P < 0.001$, $\eta_p{}^2 = 0.17$. Overall, LR infants had a significantly higher proportion initial shaking with Sound 1 than infants in either the HR-NoASD ($P < 0.001$) or ASD ($P = 0.001$) group. The same was true for initial shaking with the Silent rattle (LR vs. HR-NoASD: $P = 0.006$; LR vs. ASD: $P = 0.002$). The HR-NoASD and ASD infants displayed a pattern of initial shaking that was similar to the 6-month-old infants.

Relations between "Extinction Burst" and Later Cognitive Scores and ASD Severity

Finally, we examined how response to loss of contingency related to later ASD symptom severity scores and cognitive development among HR infants. We were particularly interested in the presence of an "extinction burst" during infants' initial interaction with the Silent rattle as an index of learning the relationship between shaking and rattle sound. As noted above, high initial shaking with the Silent rattle (i.e. extinction burst) should be indicative of infants having learned this relationship during their Sound 1 exposure and applying that learning to a new context.

Linear regressions revealed no significant relations between proportion initial shaking (i.e. the proportion of time spent shaking in the first 10 sec) with the silent rattle at either 6 or 10 months and ASD severity scores from the 36-month ADOS. Additional regression analyses indicated that while initial shaking at 6 months was not predictive of later cognitive development (i.e. average of MSEL ELC standard scores from 18, 24, and 36 months; see Methods for details), initial shaking at 10 months was, $\beta = 0.47$, $t(36) = 3.21$, $P = 0.003$. Specifically, the higher the proportion of the first 10 sec infants spent shaking the silent rattle at 10 months, the higher the ELC scores in toddlerhood. Percent initial shaking with the Silent rattle at 10 months explained approximately 22% of the variability in the composite outcome measure, $R^2 = 0.223$, $F(1,\ 36) = 10.30$, $P = 0.003$. A separate follow-up analysis showed that this relationship remained significant even with 12 month MSEL ELC standard score included in the model, $\beta = 0.384$, $t(32) = 2.51$, $P = 0.017$.

Discussion

In the current study, infants at both high and low risk for ASD adjusted their behavior to changing contingencies during the first year of life. However, HR infants, and particularly those later diagnosed with ASD, did not appear to generalize their learning from one interaction to the next. By 10 months, LR infants demonstrated generalized knowledge of the affordances offered by rattles, as indicated by high levels of shaking in the first 10 sec with each rattle, regardless of the available contingencies. The extinction burst demonstrated by LR infants in the first 10 sec with the Silent rattle provides evidence that the LR infants had a priori expectations for the rattles. In contrast, HR infants showed no evidence of such a priori expectations, with HR-ASD infants demonstrating the least shaking in the first 10 sec with each rattle.

It is important to note that, contrary to our original hypothesis, HR infants were able to learn from contingencies at a similar rate to their LR peers, as evidenced by similar rates of change in shaking with the first sounding rattle at 6 months. Thus, they do not appear to demonstrate difficulty with contingency detection per se. Additionally, we found no main effect of Outcome on shaking overall, indicating that HR infants were not simply shaking less than LR infants. Instead, in keeping with our hypothesis, differences emerged in how HR infants responded in their *initial* interactions with each rattle. Specifically, in contrast to 10-month-old LR infants, 10-month-old HR infants began each new interaction with a low level of shaking. They did not demonstrate the expected “extinction burst” when given the silent rattle, suggesting that while they are able to learn contingencies, they may have difficulty applying that knowledge to new interactions. In other words, consistent with recent theories of ASD as a disorder of prediction, infants with a later ASD diagnosis appeared to have weaker expectations about their interactions with rattles based on their previous experiences.

The finding that HR-noASD infants were the only group to reduce shaking with the second sounding rattle was unexpected, but could reflect differences in attention to or sustained interest in the task. Although not significant in the overall model, examination of the data (see Fig. 2) suggests that LR infants also reduced shaking with the second sounding rattle at 10 months. Perhaps infants in these two groups were quicker to become bored with the rattles and thus less likely to shake them toward the end of the final protocol. Further research is needed to provide insight into this unexpected finding.

Contrary to our expectations, we did not find significant differences between the group of HR infants with ASD and those without in initial response to the rattles. Further, the strength of the “extinction burst” with the silent rattle at 10 months was not related to later ASD severity. Instead, this measure was predictive of later cognitive development, above and beyond early cognitive skills. On the one hand, this may indicate that difficulty or delay in forming expectations based on prior interactions is not unique to ASD, but is indicative of generalized risk for cognitive delays. Another possibility is that this difficulty is a sign of early risk for ASD, but that whether or not an infant goes on to develop the disorder depends on the unfolding over time of a series of complex interactions between the infant and the environment. Some infants may develop alternate learning strategies (e.g. bottom-up strategies focused on quickly learning the relation between an object and its affordances) that help to counterbalance or compensate for this difficulty, while other infants may become overwhelmed by the perceived complexity of the world and change their behaviors and attentional focus accordingly. The latter explanation is consistent with a recent proposal by Elsabbagh and Johnson [2016], who hypothesize that widespread, domain-general differences in the first year may only become more specific later in development as the demands and expectations for typical development increase. Observing developmental patterns past 10 months of age may help to clarify whether HR infants with and without ASD eventually diverge from each other in their response to this task.

Implications for Research on Social Interaction

Although the current study focused only on interactions with objects, difficulty in the ability to generalize learning from one interaction to another has clear implications for social interactions. While infants’ interactions with their caregivers are characterized by contingency, that contingency is much more complex than the contingency experienced in interactions with objects. Consequently, difficulty using past experiences to predict future events may have an even greater impact on infants’ interactions with the social world. For example, while typically developing infants may quickly learn that certain behaviors (e.g. eye contact, smiles, vocalizations) lead to social responses from partners, infants at high risk for ASD may have difficulty forming these types of associations. This could lead to a perception of the social world as unpredictable and overwhelming, and a subsequent reduction in attention.

One method used to study infants’ responses to social contingency is the still face protocol (SFP), in which infants interact with a social partner face-to-face for a period of time before that person becomes “still faced” (i.e. holds a neutral and still expression while continuing to look at the infant) and then resumes interaction during a reunion period. Young infants display negative affect and reduced gaze during the still face period [see Adamson & Frick, 2003; Mesman, van IJzendoorn, & Bakermans-Kranenburg, 2009 for a review; Tronick, Als, Adamson, Wise, & Brazelton, 1978], a response that has been interpreted to indicate that infants have expectations for interactions with people and respond negatively when those expectations are violated. Research on HR infants that has utilized the SFP has not found differences between LR and HR infants, but these studies have typically averaged infant behavior across the entire interaction period [Rozga et al., 2011; Young, Merin, Rogers, & Ozonoff, 2009]. The current research suggests that examining change in behavior over time, and behavior during the initial period of the still face in particular, could be a more fruitful area for investigation. In particular, observing infant behavior immediately following the onset of the still face period may provide insight into potential differences between HR and LR infants in expectations for social interactions, and behavioral response to violation of those expectations. Notably, studies of typically developing infants indicate that in the second half of the first year, infants begin to display "bidding"—or increases in vocalizing, banging, clapping, or touching the partner—during the initial part of the still face period, and presence of this behavior is associated with later language and communication development [Goldstein et al., 2009; Striano & Rochat, 1999]. We expect that examining these types of behavior over time during the SFP in HR infants would reveal results similar to those reported in the current research.

Conclusions and Clinical Implications

These are the first results, to our knowledge, to demonstrate an early emerging difference in infants at high risk for ASD in the ability to use past experiences to predict future interactions. These findings are particularly important in light of increasing evidence that the younger siblings of children with ASD are at heightened risk not only for the disorder itself, but also for other social and communication delays and deficits [Messinger et al., 2013; Yirmiya et al., 2006]. The ability to learn from contingencies in the environment and apply that knowledge to future interactions is a fundamental skill that impacts nearly every aspect of development.

In the current study, we were able to predict variability in later development among infants at heightened risk for ASD and other social-communication delays from a short behavioral protocol at 10 months of age. If replicated, this type of protocol has the potential to be used as a measure of risk for cognitive delays in young HR infants. In addition, the ability to generalize learning from one interaction to another may have important implications for infants' success in early intervention. The majority of evidence-based early interventions for ASD (e.g. Early Start Denver Model, Early Intensive Behavioral Intervention, TEACCH, Pivotal Response Training) depend on teaching strategies that make use of learning through behavioral reinforcement, and while these interventions have been shown to improve outcomes for a subset of children, they are not universally effective [Dawson et al., 2010; Ozonoff & Cathcart, 1998; Peters-Scheffer, Didden, Korzilius, & Sturmey, 2011; Warren et al., 2011]. A deficit in the ability to generalize learning could be one factor that inhibits infants' success in these programs, and individual differences in this ability could potentially be used to predict success. In addition, it may be important for early intervention programs to incorporate methods for improving infants' ability to generalize learning across contexts. For example, interventions that occur in a diversity of naturalistic settings with multiple treatment providers and social partners (e.g. therapists, parents, peers) and utilizing a range of motivating and rewarding stimuli may help to improve generalization of learning and treatment effects.

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