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SOCIOECONOMIC STATUS AFFECTS ORAL AND MANUAL EXPLORATION ACROSS THE FIRST YEAR

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ABSTRACT: Oral and manual exploration are part of the foundation of problem solving and cognition in infancy. How these develop in an at-risk population, infants in poverty, is unknown. The current study tested exploratory behaviors longitudinally at 6, 9, and 12 months in infants from high- and low-socioeconomic (SES) families. Oral exploration consisted of passive and active mouthing and looks after active mouthing. Manual exploration consisted of frequency of fingering, rotating, and transferring the object. High-SES infants replicated the trajectory previously reported in the literature, showing a decrease in mouthing and fingering and an increase in rotating and transferring (e.g., Palmer, 1989). In contrast, low-SES infants showed no change in any of the manual exploratory behaviors over the first year, thus demonstrating reduced overall levels of exploration as well as a different developmental trajectory. Results are discussed in terms of attention, potential physiological mechanisms, and implications for later problem solving.

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Exploration is any activity used to acquire information (Gibson et al., 1987; Ruff, 1989). Sometimes, that information is specific to achieving a goal. For example, Gibson et al. (1987) found that infants explored ambiguous surfaces differently based on each surface's affordance for traversal. Other times, infants' exploratory activity is not goal-directed but instead is designed to learn about an object or a surface. This kind of exploration is more flexible, based on the properties of the object being explored. In the first year of life, infants show remarkable skill and change in their ability to gain information about objects through oral and manual exploration.

The specific exploratory behaviors associated with oral and manual exploration and their developmental trajectories have been well-studied in primarily White, middle-class infants. Although mouthing can serve multiple functions, from feeding (Rochat, Blass, & Hoffmeyer, 1988) to self-soothing (e.g., Korner & Kraemer, 1970,), it also can be exploratory. Ruff, Saltarelli, Capozzoli, and Dubiner (1992) divided mouthing into two categories: passive mouthing, where infants simply hold an object in their mouths without moving either the object or their mouths, and active mouthing, where infants move the object around in their mouths or keep the object still while their tongues and lips clearly move over it. Ruff et al. (1992) argued that active mouthing is certainly exploratory since that kind of movement would lead to a lot of information about texture, shape, and weight of the object. Moreover, active mouthing is often followed by a look significantly more often than a look followed passive mouthing. This suggests that infants learn something valuable from the mouthing and then visually inspect the object to confirm what they learned (Ruff, 1989; Ruff et al., 1992). Numerous studies have found that active mouthing and looks after active mouthing decrease significantly over the first year of life, peaking around 5 to 6 months of age (e.g., Palmer, 1989; Ruff, 1984; Ruff et al., 1992).

Manual exploration in the first year is typically called "examining," which consists of a combination of touching and moving the object, usually while visually inspecting it (e.g., Ruff, 1984, 1986). There are three common touching behaviors that comprise examining: fingering, rotating, and transferring. Fingering is moving one's fingertips over the surface of an object, which provides information about its texture and shape. Rotating the object while visually inspecting it provides additional visual information while the act of rotating it provides information about the weight and distribution of the object. Finally, transferring the object from one hand to another provides information about its size, shape, texture, and weight. These examining behaviors also show a robust developmental trajectory over the first year, with increases in the more sophisticated behaviors of rotating and transferring and decreases in fingering (e.g., Belsky & Most, 1980; Palmer, 1989; Ruff, 1984).

These exploratory behaviors—visual, oral, and manual—form the foundation for early and later cognition. Six-month-old infants

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who more actively manipulate and examine objects attend more to changes in a visual display, suggesting a link between manual exploration and visual attention (Perone, Madole, Ross-Shhehy, Carey, & Oakes, 2008). Examining behaviors at 9 months of age also were directly linked to attention measures at 31/2 years, with longer examining times linked to more attention (Ruff, 1986). Examining behaviors also are thought to underlie early problem-solving skills and tool use (Fontenelle, Kahrs, Neal, Newman & Lockman, 2007; Lockman, 2000). Specifically, fine motor control coordination and visual inspection reflect infants' purposeful exploitation of their own bodies and their environment for the purpose of information intake. This forms the basis of the object relational skills seen in older children (e.g., Belsky & Most, 1980; Lockman, 2000).

Just as advances in exploratory behaviors are linked to advances in attention and cognition, deficits in exploratory behaviors have been linked to reduced cognitive outcomes in high-risk infants. For example, newborn infants from depressed mothers demonstrated decreased oral exploration of objects at 12 days (Hernandez-Reif, Field, Del Pino, & Diego, 2000). Premature infants showed decreases in visual attention that remained stable well into early childhood (Lawson & Ruff, 2004). Low-income, institutionalized 9- to 13-month-old infants showed decreased exploratory responses (a combined measure of haptic examining and oral exploration of objects), as compared to infants from working-class families who showed significantly less examining than did high-SES infants of the same age (Collard, 1971).

The purpose of the present study is to investigate the developmental trajectory of oral and manual exploration in an at-risk population: infants from low-socioeconomic-status (SES) families. The negative developmental consequences of growing up in poverty have been well-documented (e.g., Bradley & Corwyn, 2002; Brooks-Gunn & Duncan, 1997; Duncan & Brooks-Gunn, 2000; Duncan, Yeung, Brooks-Gunn, & Smith, 1998; G.W. Evans, 2004). Children in poverty consistently perform worse than do their nonpoor counterparts on measures of academic achievement (e.g., Bradley & Corwyn, 2002; Brooks-Gunn & Duncan, 1997; Duncan & Brooks-Gunn, 2000), cognitive control and working memory (Farah et al., 2006; Noble, McCandliss, & Farah, 2007), and attention (D'Angiulli, Herdman, Stapells, & Hertzman, 2008; Stevens, Lauinger, & Neville, 2009).

By age 2 years, poverty already is negatively associated with cognitive functioning (e.g., Klebanov, Brooks-Gunn, McCarton, & McCormick, 1998). Two-year-old children living below the poverty line score lower than do high-SES children on the Bayley Scales of Infant Development (Smith, Brooks-Gunn, & Klebanov, 1997). This correlation remains stable, as family income is a powerful predictor of IQ at age 5 (Duncan, Brooks-Gunn, & Klebanov, 1994). The longer the exposure to poverty, the lower childrens' scores are on vocabulary, reading recognition, and mathematics assessments (Smith et al., 1997).

Even by 6 months of age, low-SES infants show signs of cognitive deficits across a variety of tasks. For example, Lipina, Martelli, Vuelta, and Colombo (2005) found that poor infants made more errors (both perseverative and nonperseverative) as compared to their higher income peers on a perseverative reaching task. Similarly, Clearfield and Niman (2012) found that low-income infants lagged behind higher income peers in the developmental trajectory of perseverative reaching errors. In addition, low-SES infants showed less focused attention and more inattention to objects from 6 to 12 months of age, as compared to high-income peers (Clearfield & Jedd, 2013).

The purpose of the present study was to track the developmental trajectory of object exploration in a low-income sample. Despite links between exploration and cognition in other high-risk infants, there have been no studies to date that have investigated the detailed developmental path of object exploration in this population. Thus, this project should expand the knowledge base to include diverse and potentially divergent developmental pathways. We longitudinally tracked low- and high-SES infants at 6, 9, and 12 months of age and measured their mouthing and manual examining behaviors. We predicted that high-SES infants would replicate the literature, that low-SES infants would show lower levels of exploration as compared to their high-SES peers, and that low-SES infants would be slower to switch from the less mature oral exploration to the more sophisticated forms of haptic exploration.

METHOD

These data were collected as part of larger study (Clearfield & Jedd, 2013).

Participants

Thirty-four infants with a mean age of 6.29 months at the first visit, 9.16 months at the second visit, and 12.15 months at the third visit participated. Eighteen of the infants (9 males, 9 females) came from families of middle- to high-SES, and 16 (10 males, 6 females) were from families of low-SES. Of the high-SES group, 14 infants were Caucasian, 3 were Hispanic, and 1 was Other. The low-SES cohort included 11 Caucasian infants and 5 Hispanic infants. Two low-SES infants missed the 12-month session, but there was no other attrition. Participants were recruited via an ad in the local newspaper (with no mention of SES in the ad), by word of mouth, and from a migrant farm labor child-development center.

SES was primarily evaluated using maternal education, with some college or more (i.e., $\geq$1 year) designating high-SES and less than 1 year of college designating low-SES (Clearfield & Niman, 2012; Noble et al., 2007; Stevens, Lauinger, & Neville, 2009). This proxy was used because parents generally report their education levels more accurately than they do their income and because maternal education is strongly correlated with both income and SES (Noble et al., 2007; Stevens et al., 2009). To confirm SES, the caregivers also were asked to complete a needs-assessment survey, rating their ability to meet the family's financial needs, including rent, food, and healthcare. Families were considered to be low-SES if they qualified for state aid for food or housing (i.e., they were at or below 100% of the federal poverty line); all families in our low-SES sample qualified for aid. Participants received a $20 gift card to Wal-Mart and a book at each session.

Materials

A Sony DCR-SR68 digital camera recorded all the tasks. The same commercially available, multicolored plastic rattle was used for all infants at all sessions.

Procedure

Visits took place at 6, 9, and 12 months either in the participant's home ($n = 31$) or in the lab (by parent request; $n = 3$ infants: 2 high-SES and 1 low-SES; there were no differences between data from these participants and those tested in the home). After a few minutes of acclimatization, infants were seated on a caregiver's lap at a table, and an experimenter sat diagonally from the infant. The rattle was shaken in front of the infant to gain his or her attention and then placed on the table in front of the infant and within easy reach. Infants were given 2 min to play with the rattle. Caregivers were asked not to instruct their children, and the experimenter retrieved the toy if it was thrown or dropped. A second researcher was present to record the session and to time each task.

Dependent Measures

All data were coded from the recordings of the sessions. The coding procedures were adapted from Ruff (1984, 1986) and colleagues (Ruff & Lawson, 1990; Ruff et al., 1992). This coding procedure requires frame-by-frame coding of the video, with detailed definitions of active and passive mouthing (measured in seconds) as well as fingering, rotations, and transfer of the object (measured in frequencies).

Mouthing. Mouthing was defined as the object touching any part of the inside or outside of the infant's mouth, including the lips, tongue, teeth, and gums. Mouthing was separated into two categories: active and passive. Active mouthing occurred when the object touched the mouth and was moved around by the hand or held in place while the lips of tongue moved around the object (Ruff et al., 1992). Passive mouthing occurred when the object was in contact with the infant's mouth, but not moving. Unless active mouthing behaviors were clearly visible, we categorized the mouthing as passive. Both the frequency and duration of active and passive mouthing were coded. Looks after active mouthing also was coded, as this is an exploratory act linked to mouthing (Ruff et al., 1992). It was defined as the infant looking at the object within 1 s after removing the object from the mouth from an episode of active mouthing.

Fingering

Fingering was the frequency with which the infant touched or scanned the object's surface with the fingertips (Ruff, 1984; Ruff & Lawson, 1990). Different episodes of fingering were coded when there was a pause in the motion of the fingers for more than one second. Fingering was further subdivided based on whether it occurred alone, with looking or with mouthing (It never occurred during both looking and mouthing.) Fingering while looking was defined as the infant's eyes being directed at the object while the fingers moved on it. Fingering while mouthing was defined as the infant's mouth or tongue touching the object while the fingers moved on it.

Rotating. Rotating was defined as the frequency with which the infant used his or her wrist to move the object in space (Ruff, 1984; Ruff & Lawson, 1990). Each change in direction made by the infant counted as a new rotation. If a rotation was executed in spurts where the toy stopped moving for more than a half-second, then an additional instance of a rotation was counted; pauses of less than a half-second were considered one smooth rotation. Rotations were exploratory; goal-directed movements (e.g., moving the object from the table directly to the mouth) and random movements (batting the object around or pushing it with one or two fingers) were not counted. Rotations were further divided into three categories: alone, with looking, or with mouthing (It never occurred during both looking and mouthing.) Rotating while looking required that the infant be intently gazing at the toy, and rotating while mouthing required that the rattle be in the infant's mouth while the rotation occurred.

Transferring. Transferring was defined as the frequency of the infant moving the toy from one hand to another, where the new hand was able to support the weight of the toy (Ruff, 1984; Ruff & Lawson, 1990). The original hand did not have to let go of the toy for it to be considered a transfer. Transferring was further subdivided based on whether it occurred alone, with looking, or with mouthing.

Each dependent variable was coded by a single coder blind to the experimental condition across all sessions, and a second coder (also blind to the experimental conditions) coded 20% of the data (Seven infants were randomly selected for each age tested.) The coders were highly reliable, $r = 0.97$ for passive mouthing; $r = 0.99$ for active mouthing; $r = 0.93$, .94, and .98 for fingering alone, fingering while looking, and fingering while mouthing, respectively; $r = 0.95$, .98, and .99 for rotating alone, rotating while looking, and rotating while mouthing, respectively; and $r = 0.94$, .96, and .99 for transferring alone, transferring while looking, and transferring while mouthing, respectively; all ps $< .001$.

RESULTS

Mouthing

Data were analyzed with a series of repeated measures analyses of variance (ANOVAs). The independent variables were SES (high or low) and age (6, 9, and 12 months). Mouthing was separated into two categories: passive and active. We analyzed both frequencies and durations and found exactly the same pattern of results, so only results for frequencies are reported here. There were no effects

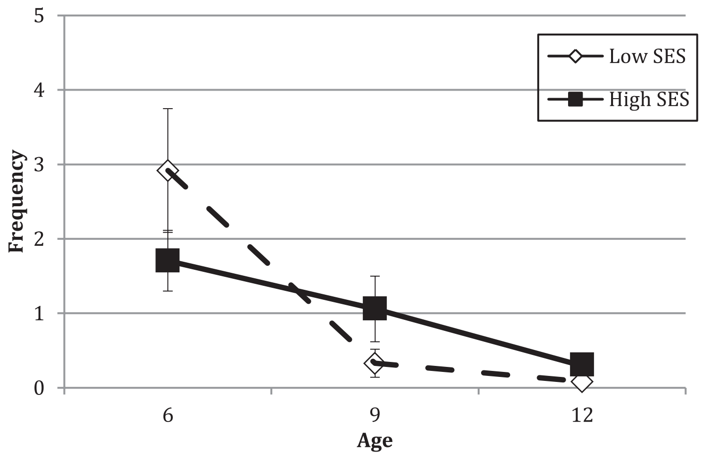

FIGURE 1. Frequency of looks after active mouthing, by socioeconomic status (SES).

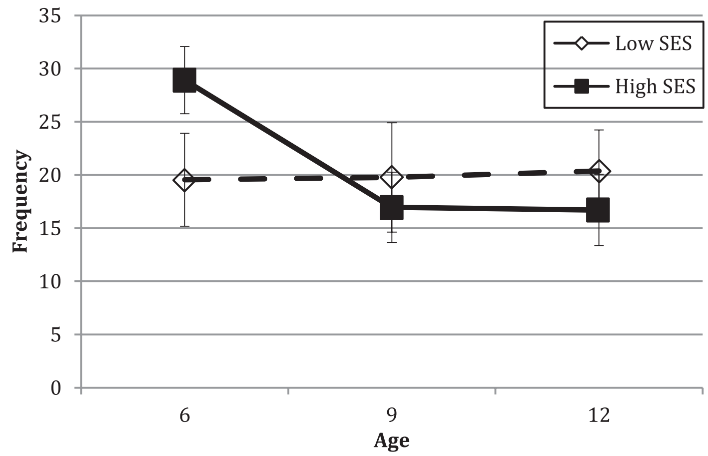

FIGURE 2. Frequency of fingering while looking, by socioeconomic status (SES).

for passive mouthing, and for active mouthing, there was only a significant age effect, $F(1, 1) = 23.281$, $p < .0001$, $\eta^2 = .862$, with decreasing active mouthing as infants got older.

As a further indicator of exploratory mouthing, we analyzed the frequency of looks after active mouthing. An ANOVA on the frequency of looks after active mouthing revealed a significant Age × SES interaction, $F(1, 1) = 3.167$, $p = .05$, $\eta^2 = .117$ (see Figure 1). Low-SES infants had more looks after mouthing than did high-SES infants at 6 months, but this decreased sharply so that by 9 and 12 months, high-SES infants had more looks after mouthing. Over time, high-SES infants showed a linear decrease in looks after whereas low-SES infants showed a steep decline between 6 and 9 months, and then a tapering off at 12 months. We also found a significant age effect, $F(1, 1) = 15.475$, $p < .0001$, $\eta^2 = .573$, with all infants decreasing active mouthing with age.

Fingering

Separate 2 (SES: low or high) × 3 (Age: 6, 9, and 12 months) repeated measures ANOVAs were conducted on each measure of fingering (fingering alone, fingering while looking, and fingering while mouthing). There was a significant Age × SES interaction for fingering while looking, $F(1, 27) = 3.212$, $p = .048$, $\eta^2 = .119$ (see Figure 2). High-SES infants decreased the amount of fingering while looking with age while low-SES infants showed no change in the amount of fingering while looking across all sessions. There were no other significant interactions.

While there were no main effects of SES for any type of fingering, there were several age effects. Overall, the total amount of fingering decreased with age, $F(1, 27) = 5.432$, $p = .006$, $\eta^2 = .175$. Fingering alone increased from 6 to 12 months, $F(1, 27) = 5.154$, $p = .008$, $\eta^2 = .19$, but fingering while mouthing decreased with age, $F(1, 27) = 10.77$, $p = .0001$, $\eta^2 = .399$.

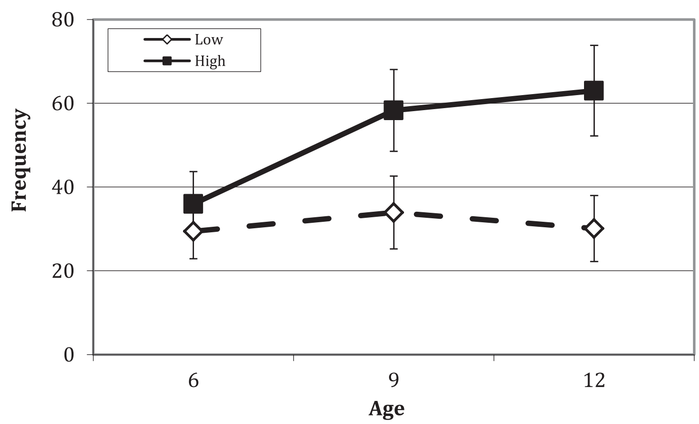

FIGURE 3. Frequency of rotations, by socioeconomic status (SES).

Rotations

Separate 2 (SES: low or high) × 3 (Age: 6, 9, and 12 months) repeated measures ANOVAs were conducted on each measure of rotations (rotating alone, rotating while looking, and rotating while mouthing). There was a main effect of SES for rotations alone, $F(1) = 5.135$, $p = .0317$, $\eta^2 = .20$; high-SES infants rotated significantly more than did low-SES infants (see Figure 3). There also was a main age effect for mouthing while rotating, $F(2) = 8.992$, $p = .0004$, $\eta^2 = .33$; mouthing decreased over time for both high- and low-SES infants. There were no other effects or interactions.

Transfers

A series of 3 (Age: 6, 9, and 12 months) × 2 (SES: low or high) repeated measures ANOVAs was run on all the measures of transfers. In addition, we analyzed the proportion of transferring alone of total transfers, the proportion of transferring while looking, and the proportion of transferring while mouthing. There was a significant Age × SES interaction for the proportion of transferring

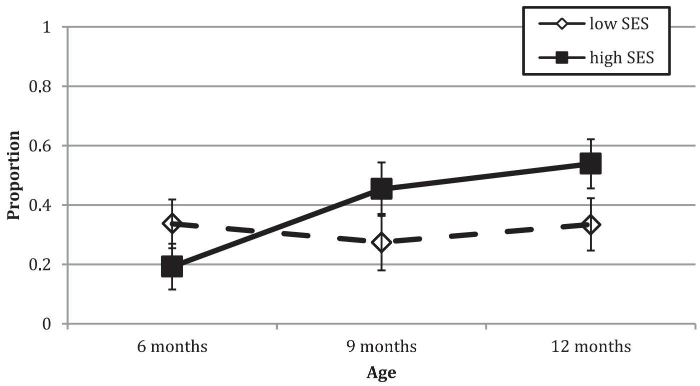

FIGURE 4. Proportion of transfers while looking of total transfers, by socioeconomic status (SES).

while looking, $F(1) = 3.231$, $p = .046$, $\eta^2 = .10$. High-SES infants increased in the proportion of transfers in which they were looking at the toy over time while low-SES infants stayed constant in the proportion of transfers in which they were looking at the toy. There were no other significant interactions.

Again, we found a number of age effects. Transferring while looking increased from 6 to 12 months, $F(1) = 7.052$, $p = .0003$, $\eta^2 = .32$, and transferring while mouthing decreased with age, $F(1) = 5.214$, $p = .0073$, $\eta^2 = .184$, as did the proportion of transferring while mouthing, $F(1) = 7.614$, $p < .01$. There were no other significant effects.

DISCUSSION

The goal of this study was to track the developmental trajectory of exploratory behaviors in low- and high-SES infants. We predicted that high-SES infants would replicate the trajectory that has been previously reported in the literature, with mouthing and fingering decreasing over time and the more sophisticated behaviors of rotations and transfers increasing. This hypothesis was confirmed. The pattern demonstrated by the high-SES infants in our sample matches that reported in the literature (Belsky & Most, 1980; Palmer, 1989; Ruff, 1984, 1986). Since the literature has focused nearly exclusively on White, middle-class infants, it is not surprising that our similar sample showed the same pattern. This confirms that our high-SES sample is not atypical and that our procedure and coding scheme were effective replications.

In contrast, low-SES infants did not show this same developmental pattern. We predicted that low-SES infants would show reduced exploration, as compared to their high-SES peers, and that they would be delayed in their transition to the more sophisticated behaviors. This hypothesis was only partially confirmed; low-SES infants did show less exploration overall by the end of the study, but not exactly in the way that we had predicted. Low-SES infants showed a remarkably different developmental trajectory than did both high-SES infants and the literature reports. While low-SES infants did show the predicted drop in mouthing, it was not replaced with manual exploration. Instead, the frequency of all manual forms of exploration remained the same over the course of the year. At 6 months, low-SES infants had more looks after active mouthing, but the same levels of the other measures as did high-SES infants. The low-SES infants then showed a significant drop-off in looks after active mouthing at 9 months, with no accompanying changes in any form of manual exploration, and by 12 months, they rotated and transferred the object significantly less than did high-SES infants. Thus, over the course of the study, low-SES infants showed fewer exploratory behaviors.

The fact that low-SES infants did not show the expected increases in rotations and transfers could support our prediction of a delay. It is possible that we did not track the infants long enough to see those increases; had we tested them again at 15 or 18 months, we might have seen those more sophisticated exploratory behaviors. It also is possible that low-SES infants never catch up, and that their reduced levels of exploration contribute to, or are related to, the cognitive deficits that are robust in the literature (e.g., Brooks-Gunn & Duncan, 1997; Clearfield & Niman, 2012; D.I.K. Evans, 1985). If either of these is correct, we would predict a close interaction between these differences in exploratory behaviors and attention. The behaviors we measured comprise what is known as “examining,” which reflects a process of gathering information about an object (e.g., Ruff, 1986). The ability and motivation to attend to that object in the course of gathering information seems critical to the process of examining. Indeed, Ruff (1986) found that infants’ examining behaviors predicted later attention. In addition, Clearfield and Jedd (2013) reported that low-SES infants already show decreased attention and increased inattention, leading us to suspect attention as a potential cause for the exploration effects. However, it is unclear which comes first. Infants with attention problems might have more difficulty focusing on an object and less interest in gathering information about it, thus leading to reduced exploratory behaviors. On the other hand, infants with less developed fine motor skills or less opportunity for object manipulation might have weaker exploratory behaviors, resulting in decreased attention to novel objects. Determining the directionality of this relationship is an important next step.

On the other hand, it also is possible that the exploratory behaviors described here are not causally linked to attention, and instead, both are markers of some other process or child characteristic. Even if they are causally linked, there may be alternative developmental pathways to strong attention at 3.5 years of age that do not rely on oral and manual exploration. For example, the reduced exploration in low-SES sample may be adaptive for these infants at present, leading them to build up focused attention through other means. The only way to know for certain what the relation is among SES, exploration, and attention is further longitudinal investigation, following infants through at least 3.5 years. Documenting the link among those and the achievement gap would require following the same low-SES sample through secondary school. Although that is far beyond the scope of the present study, we believe our results pave the way for this kind of detailed, long-term investigation.

Limitations of the current study include a relatively small sample size. A larger sample would increase the statistical power and strengthen the conclusions. In addition, following the infants into their second year might have revealed if and when low-SES infants catch up to the high-SES infants for levels of haptic exploration. Knowing whether these infants catch up could be important in designing effective interventions. Finally, our measure of SES could have been more precise. Although this measure is commonly used in research on SES (e.g., Stevens et al., 2009), with only two categories the potential for variability within the groups is high. We tried to address this with the needs assessment to get a sense of how well parents were able to meet their families' needs, but some families may have been close to the boundary line. However, the pattern of results along with the statistically significant findings suggest that the group differences were robust.

The present study clearly demonstrates a different developmental pathway for low- and high-SES infants. This prompts the critical question of what *exactly* it is about SES that impacts cognitive development. It is certainly possible that the significance of low SES in the present study is related to nutritional and health differences that have adversely affected brain development. Children in poverty begin experiencing deficiencies in many important nutrients such as iron and protein while still in the womb (e.g., Black, 1998; Lia-Hoagberg et al., 1990; Tanner & Finn-Stevenson, 2002; Wachs, 1995). Tanner and Finn-Stevenson (2002) found that a lack of iron results in a decreased attention span and that deficiencies in protein cause decreased motor skills, which could contribute to decreased haptic exploration. The differences also could be related to affordances and the physical environment, where SES impacts the amount of time and/or space that infants have to explore and move on the floor (Adolph et al., 2012). There also may be maternal factors related to SES that influence exploration. For example, Valenzuela (1997) tested poor Chilean mothers, half of whom accessed free nutritional supplements and half of whom did not access those available supplements. She found significant differences in maternal sensitivity and attachment classifications between the two groups of mothers. Infant factors also may contribute. Luster, Boger, and Hannan (1993) found that infant affect was associated with quality of maternal caregiving, but only in low-SES homes. All of these factors, alone and in combination, warrant further detailed study to understand what it is about SES that contributes to different developmental trajectories.

The present study may have important implications for clinical interventions for infants in poverty. In particular, the kinds of exploratory behaviors noted here are thought to form the basis of later problem solving and tool use (Lockman, 2000). When infants rotate an object while looking at it or transfer it from hand to hand, they are learning to manipulate objects to maximize information intake. During this process, infants learn how to exploit the physical properties of the object and their own developing motor skills. This is an early form of problem solving, one that is likely linked to older children's more complex object relational skills (Bourgeouis, Khawar, Neal, & Lockman, 2005; Lockman, 2000). It is thus possible that early mouthing and manual exploration could serve as a marker for developmental delay that might benefit from early intervention efforts. Certainly, additional studies on the link between exploration and later deficits are needed to confirm this hypothesis, ideally longitudinal studies across diverse samples. If this link were confirmed, such an early marker could be an important contribution to preventing long-term differences.

This study represents a first step in understanding the effects of SES on oral and manual exploration in infants before 1 year of age. The fact that low-SES infants show a different developmental trajectory from that in the literature warrants both deeper research and interventions. It is critical that more research be done to investigate potential physiological mechanisms and further our understanding of the connection between attention and exploration. With more extensive knowledge of poverty's effects on infants' early exploration and cognitive development, we will be able to design effective early intervention programs to close the cognitive gap between high- and low-SES children.

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