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Socio-economic Status (SES) Affects Infants' Selective Exploration

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Infants change their behaviours in accordance with the objects they are exploring. They also tailor their exploratory actions to the physical context. This selectivity of exploratory actions represents a foundational cognitive skill that underlies higher-level cognitive processes. The present study compared the development of selective exploratory behaviours in high and low socio-economic status (SES) infants. Sixty-one 6–8- and 10–12-month-old infants were presented with rigid and flexible cubes on a tray that was half rigid and half flexible. There were SES effects for each category of exploratory behaviours: object only, surface only and object–surface interactions. Low-SES infants engaged in comparable amounts of exploratory behaviours with high-SES infants, but they exhibited behaviours less conducive to information uptake, compared with high-SES infants. The results suggest difficulty for low-SES infants in transitioning to more mature exploration strategies. Copyright © 2015 John Wiley & Sons, Ltd.

Key words: socio-economic status (SES); selectivity; exploration; affordance

Exploration is any action taken to gain information about the surrounding environment (e.g. Ruff, 1989). These actions must be goal oriented, in that the infant seeks to acquire specific information about the environment (Gibson, 1988). Infants' manipulation of objects shows exploratory purpose from very early on (Ruff, 1984, 1992). By 6 months of age, infants use different kinds of exploratory strategies for different qualities of objects: they rotate objects to investigate larger shape differences, while they finger objects to detect finer details related to the object's surface texture (Ruff, 1984).

The purpose of exploration is not just to detect properties of objects but also to detect the match between the qualities of the objects and environment with the infants' capabilities. This match, or fit, is known as an affordance (e.g. Adolph, Eppler, & Gibson, 1993). The ability to detect affordances is essential

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for exploration because it allows infants to capitalize on potential sources of information (Gibson, 1988). As motor skills develop, the potential variety and sophistication of exploratory actions increases (e.g. Adolph et al., 1993; Bushnell & Boudreau, 1993).

Infants' agentive exploratory actions on objects are linked to advances in perception and cognition. For example, prereaching infants given 'sticky mittens' to assist in obtaining and exploring objects showed advanced reaching and visual exploration behaviours compared with infants without such training (Libertus & Needham, 2010). Active experience with objects also increases infants' interest in the actions of other people with the same object (Hauf, Aschersleben, & Prinz, 2007), sensitivity to others' action goals (Gerson & Woodward, 2014), knowledge about affordances (Yang, Sidman, & Bushnell, 2010) and object individuation (Wilcox, Woods, Chapa, & McCurry, 2007). So infants' active exploration is essential to perceptual, motor and cognitive development.

Selectivity is a critical feature of advanced exploratory behaviour. Infants adjust their exploratory skills when properties of the object change, so a texture change elicits more fingering while a shape change elicits more object rotation (Ruff, 1984). These adaptations become more pronounced as infants develop and allow for greater learning about the properties of the object (Gibson & Walker, 1984; Palmer, 1989). The context in which the object is presented also elicits adaptation. For instance, infants will scoot an object across a hard surface but will not scoot it across a foam surface (Palmer, 1989). The fact that certain behaviours change according to the properties of the object and the context indicates that infants must select which behaviour is best suited for the information they seek to learn.

The opportunities for selectivity are increased when infants explore objects and surfaces together, at the same time. Surfaces add a new dimension to the detection of affordances in that infants need to understand the fit between themselves, objects *and* surfaces instead of just between themselves and objects. For example, playing with a toy on a hard surface allows infants to gain more information about the toy's hardness and ability to produce sound. In order to gain the most information possible, infants must capitalize on this expanded set of affordances. Thus, relating an object to a surface is more cognitively complex than exploring either on its own (Lockman, 2000; Palmer, 1989) and is therefore a good measure of both exploration and selectivity of action.

Recent work by Lockman and colleagues on manual exploration and selectivity has shown that infants can detect these object–surface affordances at 6 months of age but show increasing selectivity over the second half of the first year (Bourgeois, Khawar, Neal, & Lockman, 2005; Fontenelle, Kahrs, Neal, Newton, & Lockman, 2007). Bourgeois et al. (2005) presented 6-, 8- and 10-month-old infants with hard and soft objects on various types of surfaces (liquid, discontinuous, flexible or rigid) presented on a high-chair tray. All infants showed adaptive differences in their exploratory behaviours of the objects alone and the surface alone, but selectivity increased with age on behaviours that involved both the object and surface. In a greater test of selectivity, Fontenelle et al. (2007) presented 8- and 10-month-old infants with a high-chair tray that was half flexible and half rigid. They then gave the infants a cube made of either wood or sponge and found that infants showed selectivity in how they explored the cubes and surfaces of different textures. Most importantly, they showed selectivity in their interactions between the surface and object. For instance, infants rubbed objects more on the rigid surface but pressed objects more into the flexible. They also reported that the younger infants tended to bang the soft object more than the older infants, while both banged the hard object equally. In presenting the different substrates

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simultaneously, the infants' behaviours in this study demonstrate selectivity to a greater extent because the infant must actively make a choice as to which object–surface behaviours will yield the most information.

In sum, a key element of haptic exploration is the detection of affordances that enable infants to glean the maximum amount of information from the environment. One particular challenge for infants is detecting affordances between not just their bodies and an object but also a surface. The selectivity in exploratory behaviours required by a multisurface substrate reflects infants' ability to detect the differences, to consider different behaviours and to choose the behaviours that will maximize information. This selectivity of exploratory actions represents a foundational cognitive skill that underlies higher-level cognitive processes. This is a challenging perceptual–motor–cognitive task for 6- to 10-month-old infants, who show increasing selectivity and adaptive behaviours during this time frame.

There is ample reason to believe that exploratory selectivity might differ in an at-risk population, specifically infants from families of low socio-economic status (SES). The well-documented cognitive deficits in low-income children have been found to begin in the first 2 years of life (e.g. Mackner, Black, & Starr, 2003). For example, by age 2, poverty becomes a significant predictor of IQ, and neighbourhood affluence becomes positively correlated with IQ scores at age 3 (Klebanov, Brooks-Gunn, McCarton, & McCormick, 1998). Beyond IQ, recent studies have addressed specific processes that underlie cognition. As young as 6 months, infants in poverty show deficits in attention (Clearfield & Jedd, 2013), cognitive flexibility, which measures an infant's ability to process multiple sources of information simultaneously (Clearfield & Niman, 2012; Lipina, Martelli, Vuelta, & Colombo, 2005), and means-ends behaviour (Stanger, Jenne, & Clearfield, 2013).

In addition to general cognitive deficits, more recent studies report SES differences in infants' exploratory activity. For example, low-SES toddlers spend significantly less time playing, which might provide the opportunity to develop their haptic exploration of objects (Milteer & Ginsburg, 2011). Poor nutrition may also be a factor in exploratory behaviours. Arburto, Ramirez-Zea, Neufeld, and Flores-Ayala (2010) treated malnourished 8- to 12-month-old infants with macronutrient and micronutrient supplements over a 4-month period of daily supplementation (e.g. protein, iron and zinc). The treated infants showed greater exploration in a free-play task than a control group that did not receive the supplements (Arburto et al., 2010).

Socio-economic status does not just affect the amount of haptic exploration; one recent study suggests a different developmental trajectory in object exploration for high-SES and low-SES infants. In a longitudinal study of high-SES and low-SES infants' manual exploration, high-SES infants decreased mouthing and fingering of an object over time and replaced these behaviours with more sophisticated exploratory strategies such as rotating and transferring (Clearfield, Bailey, Jenne, Stanger, & Tacke, 2014). In contrast, low-SES infants did decrease mouthing but failed to replace this behaviour with the more sophisticated strategies, resulting in less overall exploration and less sophisticated strategies.

The purpose of the present study was to examine the impact of SES on the development of selectivity in manual exploration. Because selectivity of exploratory actions represents a foundational cognitive skill and exploratory behaviours are susceptible to SES effects, we believe that a detailed investigation of infants' selectivity might get at the nuances of cognitive differences based on SES. We replicated Fontenelle et al.'s (2007) procedure, presenting 6–8- and 10–12-month-old infants with flexible and rigid cubes on a surface that was half flexible and half rigid, and extended the study to compare low-SES and high-

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SES infants. We included the two age groups because Bourgeois et al. (2005) reported selectivity differences between 6- and 10-month-olds and Fontenelle et al. (2007) reported some selectivity differences between 8 and 10 months. Thus, we predicted that 6–8 months might be a transitional period for selectivity, but by 10 months, infants should demonstrate more sophisticated adaptation. If there are SES differences, comparing behaviour at the transitional period and beyond should yield a better picture of when those differences begin and how stable they are.

Predictions of SES differences are grouped into three categories:

1. Object exploration: We predicted that low-SES infants would show less adaptation in response to the composition of the object compared with their high-SES peers, especially in the younger age group. Specifically, we predicted that high-SES infants would be more likely to mouth and scratch the hard object and squeeze the soft object, because these are the most adaptive behaviours (Bourgeois et al., 2005).
2. Surface exploration: We predicted high-SES infants would pick and press the spongy surface more than the rigid surface, while the low-SES group would show less of a distinction in their exploration of the surfaces, especially in the younger infants (again, because those behaviours will yield the most information given the context, Bourgeois et al., 2005).
3. Object–surface exploration: We predicted that the low-SES group would show less sophisticated selective choices in their object–surface interaction behaviours than their high-SES peers, especially in the younger infants. Specifically, we hypothesized that high-SES infants would be more likely than low-SES infants to rub the objects on the hard surface (which capitalizes on friction and is thus the most adaptive), press the objects more into the soft surface (which capitalizes on pressure) and bang the hard object more on the hard surface (which yields additional auditory information and is thus considered the most informative; Fontenelle et al., 2007).

METHOD

Participants

Sixty-one infants participated in this study, divided into two age groups, 6–8 months (31 infants) and 10–12 months (30 infants), further divided by high and low SES. The high-SES 6- to 8-month-olds had a mean age of 7.4 months (range: 6.8–7.9 months; nine boys and six girls; two Hispanic, one biracial and 13 Caucasian), and the high-SES 10- to 12-month-old infants had a mean age of 11.2 months (range: 10.7–12 months; 10 boys and five girls; four biracial (not otherwise specified) and 11 Caucasian). The low-SES 6- to 8-month-olds had a mean age of 7.3 months (range: 6.5–7.9 months; seven boys and nine girls; four Hispanic, one African-American and 11 Caucasian), and the low-SES 10- to 12-month-olds had a mean age of 11.1 months (range: 10.1–11.9 months; eight boys and seven girls; two Hispanic, two biracial and 11 Caucasian). There were no differences in age between the SES groups for either age. Two additional participants were excluded as outliers (exploratory behaviours were more than 3 standard deviations above the mean).

Socio-economic was determined in two ways. A needs assessment survey asked parents to report their ability to meet their families' financial needs (e.g. rent, food and health care). Families who relied on state assistance for food or shelter (185%

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Federal Poverty Line or FPL) or those who qualified for Early Head Start (100% of FPL) were considered low SES. We also asked for maternal education: 'some college' or above (2 years or more) qualified the infant as high SES (e.g. Noble, McCandliss, & Farah, 2007; Stevens, Lauinger, & Neville, 2009). Maternal education was used as a proxy for income because parents are generally more accurate when they report education than when they report income (Stevens et al., 2009). All families classified as low SES met both criteria.

The participants in this study were recruited through ads in the local newspaper, community email LISTSERVs, flyers in town, word of mouth, Early Head Start and the Farm Labor Homes. Families were compensated with a $10 gift card and a book.

Materials

The materials were adapted from Fontenelle et al. (2007). Infants sat in a commercial standard high chair during the task. We constructed a portable high-chair tray measuring 60.96 cm × 27.94 cm. Half of the tray consisted of a green 0.5-in. foam surface, and the other half was simply the standard white hard plastic high-chair surface. Two different trays were constructed, one with the foam surface on the left and one with the foam surface on the right. Half the infants were tested with one tray, and the other half with the other tray. In addition, we used two 2.54-cm yellow cubes, the rigid one made of wood and the other of sponge. A Sony DCR-SR68 digital camera recorded the experiment.

Procedure

The procedure was adapted from Fontenelle et al. (2007). Data collection took place during a single videotaped session in the home (five were tested in the lab by request, 4 = high SES and 1 = low SES). Infants sat in a standard high chair during the task. This task was always first in a series of other tasks as part of a larger study. The experimenter first tapped each side of the tray three times with his or her hand to obtain the infant's attention and then presented one cube in his or her hand over the midline of the tray between the hard and soft surfaces. The task was timed for 45 s beginning immediately after the infant first touched the cube. If the infant did not grab the cube immediately but instead touched the surface, this counted as surface exploration (refer to later discussion) and was part of the 45-s trial. If the infant dropped the cube off the tray, the experimenter retrieved it and held it at the midline. After 45 s, the experimenter removed the cube. This procedure was repeated five more times, alternating between the rigid and flexible cubes. The order of cube presentation (rigid vs flexible) was counterbalanced across infants within the age groups.

Coding

The coding procedure precisely replicated that of Fontenelle et al. (2007). All data were coded from the recordings of the sessions. Two independent observers, blind to the age and SES of the infant, coded the object, surface and object–surface behaviours. Only the infant in the chair was captured on the video, so no other details about the home were in the video frame. Reliability (Pearson's r) for each measure across 20% of the data averaged 0.92 (0.84–0.99) for object

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behaviours, 0.93 (0.89–0.99) for surface behaviours and 0.94 (0.81–0.99) for object–surface interactions.

Object exploration

Based on Fontenelle et al. (2007), object exploration was considered the most basic and easiest type of exploration. We coded for mouthing, scratching and squeezing of the rigid and flexible cubes. Mouthing was coded as a duration in seconds and occurred any time the infant's lips or tongue was touching the cube. Scratching was coded as a frequency where each back and forth scratch was coded as one scratch and was identified as any instance where infants moved the tip of their finger or fingers back and forth across the surface of the cube. Squeezing was coded as a frequency where each application and release of pressure was coded as one squeeze and was defined as whenever infants applied pressure to the cube that resulted in deformation of the object or the infant's skin.

Surface exploration

Based on Fontenelle et al. (2007), surface exploration was considered the next step up in terms of sophistication of exploration. For this category, we coded for pressing, picking and slapping as frequencies. Pressing was coded when infants applied pressure to the tray causing deformation of skin or tray surface. Picking was coded when infants dug their finger(s) into the surface of the tray. Slapping was coded when infants raised their arms and lowered them to make open-handed contact with the tray. Rubbing was coded as a duration in seconds and was defined as any instance where infants rubbed their hands across the surface. Infants received credit for surface exploration if they were not holding a cube at all or if they touched the surface with one hand while holding the cube with the other.

Object–surface exploration

Based on Fontenelle et al. (2007), object–surface exploration was considered the most sophisticated type of exploration. We coded for rubbing (duration), banging (frequency) and pressing (frequency) of a surface with the object. Rubbing was coded whenever the infant had the cube in his or her hand and rubbed the cube across the surface. Banging was coded whenever the infant raised and lowered his or her hand with the object in it and made contact with the tray. Pressing was coded whenever the infant applied pressure to the tray with the object.

RESULTS

We conducted a series of 2 (age: 6–8 and 10–12 months) × 2 (SES: high and low) × 2 (object or surface category: rigid and flexible) mixed ANOVAs. The between-subjects independent variables were age and SES. The object and surface categories were within-subjects independent variables. The dependent variables were sorted into three categories, each with several behaviours: (1) object exploration (mouthing, scratching and squeezing); (2) surface exploration (pressing, picking, slapping and rubbing); and (3) object–surface interactions (rubbing, pressing and banging). Statistical significance was set at $p < 0.05$, and marginal significance was set at $p = 0.06$–0.09.

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Object Exploration

Mouthing

The means and standard error for the duration of mouthing the object are presented in the top rows of Table 1. There was a marginal main effect of type of object on mouthing, $F(1, 59) = 3.49$, $p = 0.06$, $\eta^2 = 0.06$; infants mouthed the rigid object more than the flexible object, which is an indication of selectivity. There were no other effects or interactions.

Scratching

The means and standard error for the frequency of object scratching are presented in the middle rows of Table 1. As predicted, there was a significant interaction between type of object and SES, $F(1, 1) = 4.80$, $p = 0.03$, $\eta^2 = 0.02$ (Figure 1). High-SES infants showed a distinction between their rigid and flexible object scratching, where they scratched the rigid object more than the flexible object, while the low-SES infants showed no such distinction, $F(1, 59) = 4.87$, $p = 0.03$, $\eta^2 = 0.02$. There was also a main effect of age for scratching, $F(1, 59) = 10.41$, $p = 0.002$, $\eta^2 = 0.17$ (the younger infants scratched more than the older infants),

Table 1. Mean object exploration behaviours (with standard error)

	6–8 months		10–12 months	
	Low SES	High SES	Low SES	High SES
Mouthing (s)				
Flexible object	28.81 (7.30)	28.32 (8.78)	18.48 (8.95)	20.65 (6.03)
Rigid object	35.30 (7.45)	34.66 (8.54)	31.06 (8.28)	18.24 (4.74)
Scratching (frequency)				
Flexible object	12.81 (2.02)	10.22 (1.18)	6.25 (1.24)	6.20 (1.44)
Rigid object	12.16 (2.19)	14.00 (1.69)	7.81 (1.27)	10.27 (1.84)
Squeezing (frequency)				
Flexible object	5.88 (1.34)	4.09 (1.06)	6.12 (1.67)	8.93 (2.34)
Rigid object	0.50 (0.39)	0.06 (0.06)	0.12 (0.12)	0.13 (0.13)

SES, socio-economic status.

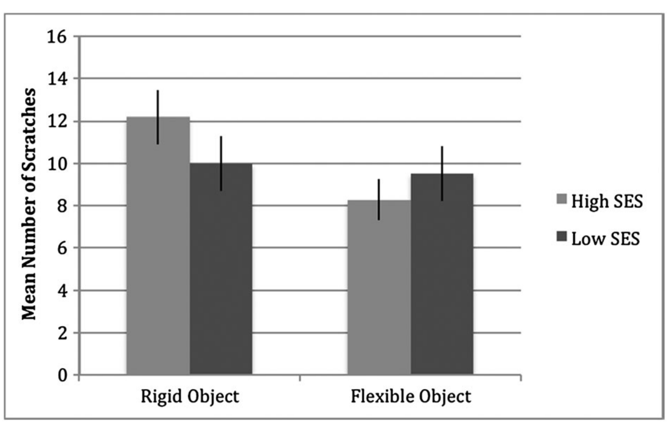

Figure 1. Object exploration: socio-economic status (SES) breakdown of the mean number of scratches by object type.

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and a main effect for type of object (infants scratched the rigid object more than the flexible object, $F(1, 59) = 7.63$, $p = 0.007$, $\eta^2 = 0.04$).

Squeezing

The means and standard error for the frequency of object squeezing are presented in the bottom rows of Table 1. There was a main effect for type of object on squeezing, $F(1, 59) = 56.74$, $p < 0.001$, $\eta^2 = 0.84$; infants squeezed the flexible object more than the rigid object. There was also a marginally significant interaction between age and type of object: infants in the older age group squeezed the flexible object more than the infants in the younger age group did, $F(1, 59) = 2.82$, $p = 0.09$, $\eta^2 = 0.04$. There were no other main effects or interactions.

In sum, as predicted with respect to object exploration, infants did show differences in selectivity based on SES for scratching, with high-SES infants scratching the rigid object more than the flexible object, while the low-SES infants showed no such distinction. For both mouthing and squeezing, all infants (both ages and SES groups) showed some signs of selectivity, mouthing the rigid object and squeezing the soft one.

Surface Exploration

Pressing

The means and standard error for the frequency of surface pressing are presented in the top rows of Table 2. There was a statistically significant main effect for type of surface, $F(1, 59) = 9.94$, $p = 0.002$, $\eta^2 = 0.09$; infants pressed the flexible surface more than the rigid surface. There were no other main effects or interactions.

Picking

The means and standard error for the frequency of surface picking are presented in the middle rows of Table 2. There was a main effect for type of surface on picking; infants picked the flexible surface more than the rigid surface, $F(1, 59) = 8.39$, $p = 0.005$, $\eta^2 = 0.04$. There were no other main effects or interactions.

Table 2. Mean surface exploration behaviours (with standard error)

	6–8 months		10–12 months	
	Low SES	High SES	Low SES	High SES
Pressing (frequency)				
Flexible surface	1.34 (0.36)	1.31 (0.70)	1.88 (0.55)	1.53 (0.49)
Rigid surface	0.94 (0.38)	0.19 (0.19)	1.19 (0.46)	0.40 (0.16)
Picking (frequency)				
Flexible surface	4.94 (2.54)	2.81 (1.17)	6.02 (2.34)	3.73 (1.12)
Rigid surface	3.34 (1.94)	1.63 (0.68)	0.62 (0.62)	2.87 (1.05)
Slapping (frequency)				
Flexible surface	6.25 (2.57)	3.62 (1.62)	11.06 (2.90)	9.40 (3.65)
Rigid surface	8.75 (2.81)	9.56 (3.96)	3.69 (1.90)	3.80 (1.23)
Rubbing (s)				
Flexible surface	3.26 (1.18)	1.15 (0.35)	2.54 (0.83)	0.97 (0.36)
Rigid surface	1.43 (0.56)	0.58 (0.26)	0.73 (0.28)	0.51 (0.28)

SES, socio-economic status.

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Slapping

The means and standard error for the frequency of surface slapping are presented in the middle rows of Table 2. There was an interaction between type of surface and age; infants in the older age group slapped the flexible surface more than the rigid surface, while the younger infants slapped the rigid surface more, $F(1, 59) = 10.96$, $p = 0.001$, $\eta^2 = 0.10$. There were no other main effects or interactions.

Rubbing

The means and standard error for the frequency of surface rubbing are presented in the bottom rows of Table 2. There was a main effect of SES on rubbing, $F(1, 59) = 5.69$, $p = 0.02$, $\eta^2 = 0.10$; low-SES infants rubbed on the surfaces more than high-SES infants. There was an effect of type of surface on rubbing as well; infants rubbed more on the flexible surface than the rigid surface, $F(1, 59) = 10.69$, $p = 0.001$, $\eta^2 = 0.09$. There was also a marginally significant interaction between type of surface and SES, $F(1, 59) = 3.35$, $p = 0.07$, $\eta^2 = 0.03$ (Figure 2). Low-SES infants showed a bigger difference between their rigid and flexible surface rubbing, where they rubbed the flexible surface more. High-SES infants did not show as large of a difference in their rubbing of the two surfaces. There were no other main effects or interactions.

In sum, for surface exploration, as predicted, infants demonstrated SES differences in selectivity for rubbing. Low-SES infants rubbed the surfaces more than high-SES infants and tended to rub the flexible surface more than the rigid. All infants showed some selectivity in exploring the surfaces, by pressing and picking the flexible surface more than the rigid, but age differences in selectivity appeared only for slapping.

Object–Surface Exploration

The last series of dependent variables were analysed slightly differently. Age and SES were again between-subjects independent variables, but the within-subjects independent variable had four levels to account for each object–surface combination (flexible object–flexible surface, flexible object–rigid surface, rigid object–flexible surface and rigid object–rigid surface). We thus conducted a series of 2

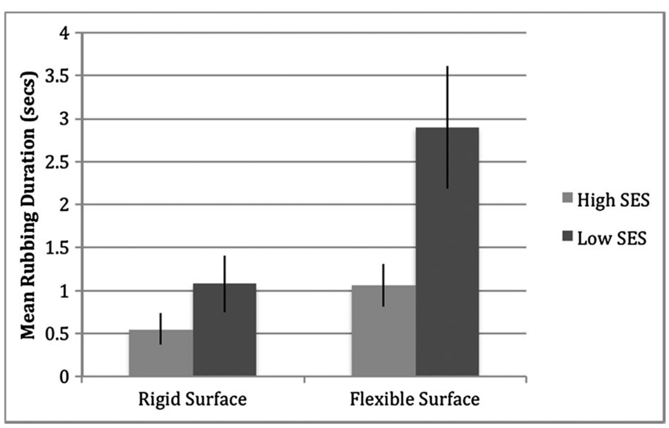

Figure 2. Surface exploration: socio-economic status (SES) breakdown of the mean duration of rubbing by surface type.

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(age) × 2 (SES) × 4 (object and surface category) mixed ANOVAs on the three dependent measures: rubbing, pressing and banging.

Rubbing

There was a main effect of object and surface category, $F(3,\ 177) = 9.69$, $p < 0.0001$, $\eta^2 = 0.30$. Infants rubbed the rigid object on the rigid surface significantly more ($M = 1.17$, $SE = 0.28$) than all other combinations (rigid object–flexible surface: $M = 0.24$, $SE = 0.08$; flexible object–rigid surface: $M = 0.30$, $SE = 0.10$; flexible object–flexible surface: $M = 0.15$, $SE = 0.10$). There were no other main effects or interactions.

Pressing

There was a significant main effect of SES for pressing, $F(1,\ 58) = 5.79$, $p = 0.02$, $\eta^2 = 0.10$ (Figure 3); the high-SES infants pressed more ($M = 1.68$, $SE = 0.67$) than the low-SES infants ($M = 0.73$, $SE = 0.24$). There was also a significant effect of age, $F(1,\ 58) = 4.73$, $p = 0.03$, $\eta^2 = 0.08$, where older infants pressed more ($M = 1.63$, $SE = 0.43$) than younger infants ($M = .78$, $SE = 0.58$). There were no other main effects or interactions.

Banging

There was a significant interaction between SES and object and surface category, $F(3,\ 177) = 5.92$, $p < 0.001$, $\eta^2 = 0.07$ (Figure 4). *Post hoc t*-tests revealed that the high-SES infants banged the rigid object into the rigid surface more than low-SES infants, $t(61) = 2.07$, $p = 0.04$, and the low-SES infants banged the flexible object into the flexible surface more, $t(61) = 2.17$, $p = 0.03$. There were no SES differences in the other two categories, nor were there any other main effects or interactions.

In sum, for the object–surface exploration, two of the three behaviours showed significant SES differences in selectivity, as predicted. High-SES infants pressed the objects into the surfaces more than low-SES infants. High-SES infants also banged the rigid objects into the rigid surface more, whereas low-SES infants banged the flexible object into the flexible surface more.

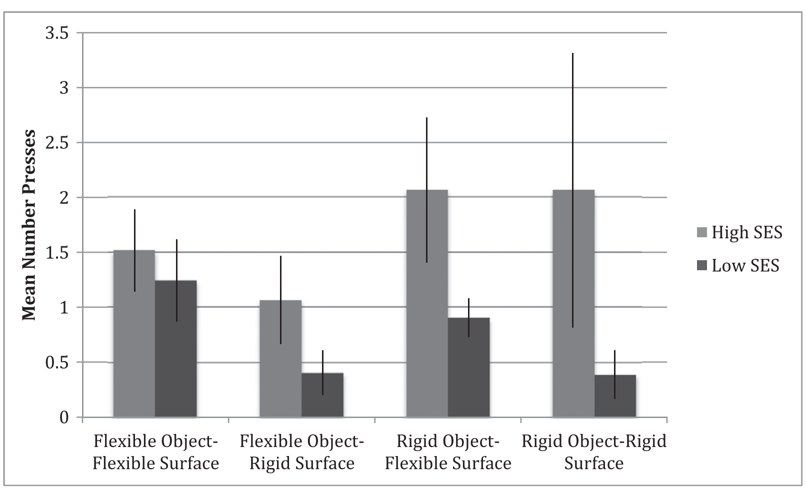

Figure 3. Object–surface behaviour: socio-economic status (SES) breakdown of the mean number of presses by object and surface type.

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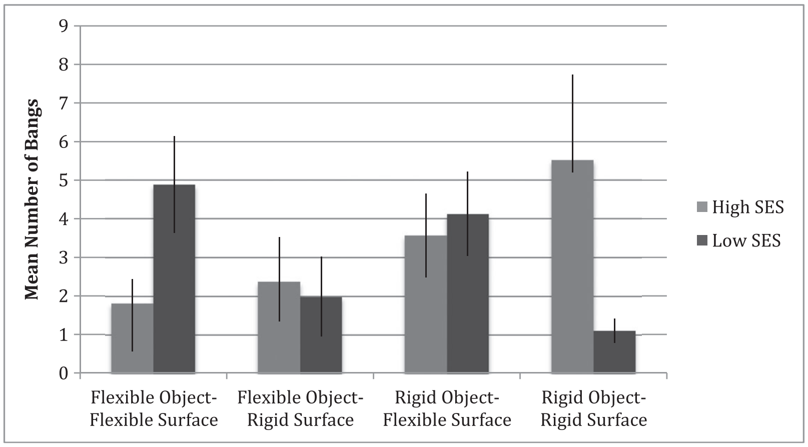

Figure 4. Object–surface behaviour: socio-economic status (SES) breakdown of the mean number of bangs by object and surface type.

DISCUSSION

The purpose of the current study was to examine selective exploration in low-SES and high-SES infants. We hypothesized that high-SES infants would show more selectivity than low-SES infants in their object exploration, in their surface exploration and, more importantly, in their object–surface exploration. All hypotheses were supported.

For object exploration, infants did show differences in selectivity based on SES for scratching, with high-SES infants scratching the rigid object more than the flexible object, while the low-SES infants showed no such distinction. Fontenelle et al. (2007) suggested that the rigid object affords scratching more than the flexible object, so the lack of distinction in the low-SES infants could be considered less selective. However, it is worth noting that all infants (both ages and SES groups) showed some signs of selectivity for both mouthing and squeezing (mouthing the rigid object and squeezing the flexible one). So low-SES infants did show selectivity in some aspects of object exploration, but also differences. It is worth noting that in Fontenelle et al.'s (2007) original study, they reported selectivity in mouthing across both ages, but age differences in squeezing and scratching, with younger infants squeezing the objects more and older infants scratching the objects more. They concluded that scratching was the most sophisticated exploratory behaviour of the three behaviours coded, and that is the behaviour where we found SES effects.

For surface exploration, low-SES infants rubbed more, especially on the flexible surface. This was contrary to our hypotheses given that low-SES infants generally show less exploration (Clearfield et al., 2014). Although the low-SES infants demonstrated selectivity in rubbing the surface, rubbing the flexible surface may not be as conducive to learning about the surface as all of the other possible surface behaviours (pressing, picking and banging). Indeed, the original study did not even report results for rubbing because so few infants did it. And both high-SES and low-SES infants did show selectivity in pressing and picking the flexible surface more than the rigid surface (as did both age groups in the original Fontenelle et al., 2007). One might question whether this differential behaviour in the low-SES infants is a sign of different but equally effective selectivity. It certainly seems as though the low-SES infants explored the flexible surface more, indicating

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perhaps that it was more novel to them or interesting in some way. While that may well be the case, what matters here is that the low-SES infants differentially explored the surface, *at the expense of* the more sophisticated object–surface exploration. Because trials were a fixed length, more time spent exploring the surface alone meant less time exploring the object–surface interactions, which is the most advanced form of exploration.

The critical finding is that the low-SES infants did not use the information gleaned from object or surface exploration to recognize new opportunities for exploration through object–surface interactions. Only the high-SES infants pressed the object into a surface, meaning that the high-SES infants were using the properties of the surface to enhance exploration. The low-SES infants did not seem to capitalize on the properties of the surface and object to render new opportunities for exploration, which is the critical cognitive component of exploration. In failing to capitalize on what Fontenelle et al. (2007) argue are advanced object–surface combinations, the low-SES infants appear less selective than their high-SES peers.

Similar SES differences were seen in the infants' banging behaviour, where the high-SES infants made a more sophisticated choice. Fontenelle et al. (2007) found that infants at both ages bang the rigid object equally, but flexible object banging decreases as infants mature. They argue that by 8–10 months of age, infants have had enough experiences with objects of different consistencies that they appear to have learned that banging the flexible object is not the best way to capitalize on its properties. Banging a rigid object more than a flexible object, then, is indicative of greater sensitivity to affordances, and this is the pattern we saw for the high-SES infants. The high-SES infants made a sophisticated selective choice because the presupposed goal of object/surface banging is to gain information about the sound-producing potential of the object and surface (Bushnell & Boudreau, 1993; Gibson & Walker, 1984; Lockman, 2000; Palmer, 1989; Ruff, 1984).

The low-SES infants, on the other hand, showed a preference for banging the flexible object on the flexible surface. Again, one might wonder whether the low-SES infants' choice was a different but equally effective exploratory behaviour. The low-SES infants did show great interest in the flexible surface, more than the high-SES infants. So perhaps their preference for banging the flexible object into the flexible surface reflects a preference for the flexible materials. However, exploratory behaviour is supposed to have the goal of gaining information. If infants were banging the flexible object into the flexible surface because it was fun or more interesting, then they were not capitalizing on information intake, they were playing, which is not goal oriented. If, on the other hand, they were actively seeking information, consider the kinds of information one can glean from exploring the object and surface together, above and beyond what can be gleaned from exploring each separately. For the flexible object and flexible surface, infants do not gain any additional visual or tactile information by exploring them together. Because banging a flexible object on a flexible surface gives little auditory information, there is no additional information gained, in contrast to a rigid object or rigid surface. Thus, either way, their behaviour may be considered a less advanced choice.

It is worth noting that low-SES infants did not differ from the high-SES infants in every behaviour, or even most behaviours. If we consider exploring the object alone and the surface alone as less mature forms of exploration (because infants are only exploring one dimension), low-SES infants only differ in two of the seven behaviours. So for the majority of simple exploratory behaviours, low-SES infants demonstrated the typical developmental trajectory. However, when considering the more advanced object–surface exploratory behaviours, low-SES infants

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showed less selective choices in two of the three behaviours. And it was not the case that the low-SES infants simply explored less overall; the critical SES differences were in their choices of behaviours that were less selective, producing less information for guiding actions. That notion held even for the simpler exploratory behaviours (object only and surface only).

Not only did the low-SES infants show less selectivity, but they did so consistently over time. Bourgeois et al. (2005) reported a number of selectivity differences between 6- and 10-month-olds, and Fontenelle et al. (2007) reported some selectivity differences between 8 and 10 months. We thought that testing 6–8- and 10–12-month-old infants might capture a transitional period, where SES effects might be less pronounced early on but strengthen over time. However, this was not the case. We found few age differences (the ones we found were consistent with the findings of Bourgeois et al., 2005, and Fontenelle et al., 2007) and no interactions between age and SES. This suggests that whatever SES differences we found are stable across the second half of the first year.

These findings are consistent with recent research on cognitive development in low-SES infants and children. Low-SES infants appear to deviate from what have been considered 'typical' developmental trajectories (Lipina et al., 2005; Clearfield & Jedd, 2013; Clearfield & Niman, 2012; Clearfield et al., 2014). These infants show deficits in attention by 6 months and in the developmental trajectory of cognitive flexibility (Clearfield & Jedd, 2013; Lipina et al., 2005). Most relevant, low-SES infants explored less and used less sophisticated exploratory behaviours than high-SES infants by 12 months (Clearfield et al., 2014). In that longitudinal study of object exploration, low-SES infants exhibited a reduction in the simple behaviour of mouthing across the first year but failed to replace that with other, more sophisticated exploratory behaviours, like rotating the object or transferring it from hand to hand. Both that study and the present results suggest difficulty for low-SES infants in transitioning from simple behaviours to more complex exploratory behaviours.

These deficits in cognitive development are almost certainly interrelated, and we hypothesize that the nature of the relationships among the cognitive delays of low-SES infants is likely multidirectional. For example, attention may aid selective exploration by allowing infants to focus on particular object or surface properties, which may make objects and surfaces more interesting to them and encourage further exploration. At the same time, the reward of discovery through exploration may provide more motivation for attending to the objects and surfaces around them. Moreover, cognitive flexibility might allow infants to better adapt actions that could help them gain new information about their surroundings. Because high-SES infants generally explore more than low-SES infants, high-SES infants' greater amount of experience with exploration might help explain why they show more sophisticated behaviour through their object–surface interactions (Clearfield et al., 2014). Seeing the benefit of these object–surface interactions could encourage the infants to explore more. We believe that our results regarding high-SES infants' greater selectivity of exploration may be attributed to the fact that high-SES infants are benefitting from the positive feedback loop among these cognitive processes. This is an empirical question that future research should explore, perhaps by initiating this type of positive feedback loop among attention, interest and the reward of discovery in a group of low-SES infants.

Past studies on the adverse effects of poverty on child development may offer additional clues into other factors that contribute to this feedback loop. For example, low-SES children have much less playtime that would give them the opportunity to develop their haptic exploration of objects (Milteer & Ginsburg, 2011).

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Indeed, the opportunity to move around and explore one's space is linked to increasing motor skills (Adolph et al., 2012). Parents can be important models for these exploratory behaviours, and we know that low-SES parents generally have less energy and time to play with their infants because of the stressful nature of living in poverty (Milteer & Ginsburg, 2011). Fewer opportunities to play with parents may then have negative effects on the capacity for selective exploration. Parents might thus be critical to developing selectivity because they can direct attention and demonstrate rewarding exploratory behaviours. This theoretical link could be tested by investigating the link between parent-guided play and selective exploration.

Malnutrition, another result of growing up in poverty, could also impact cognitive factors that might relate to selectivity. Children in poverty, both prenatal and postnatal, are more likely to be undernourished with key nutrients like protein and iron (Tanner & Finn-Stevenson, 2002; Wachs, 1995). Deficits in iron specifically have been found to be linked to decreased attention, which we propose may be tied to selectivity (Tanner & Finn-Stevenson, 2002). Poor nutrition has also been linked to decreased motor functioning, which could impact the infant's abilities to engage in advanced exploratory behaviours (Levitsky & Strupp, 1995). In fact, a direct link between malnutrition and general exploration in infants has already been reported (Arburto et al., 2010).

The major limitation of the present study is that it was not designed to identify the causes for the differences in exploration that we discovered. But establishing exploratory differences is a critical first step before investigating their causes. We believe that the spate of recent studies on cognitive processes in low-SES infants is helping to describe the landscape of deficits and abilities; once this landscape is established, only then can investigations into mechanism be fruitful.

These findings may also have implications for interventions that may then help future cognitive development. The theoretical framework behind this study emphasizes the process of cognitive development rather than its outcome. Identifying those processes offers a practical and tangible way to intervene. Numerous recent studies point to the importance of early agentive experience on infants' understanding of objects (e.g. Gerson & Woodward, 2014; Hauf et al., 2007; Wilcox et al., 2007). That agentive experience could be shaped into different kinds of interventions. For example, Lobo and Galloway (2008) studied the effect of postural and object-oriented experience on early reaching, object exploration and means-end behaviour. Parents were asked to participate for 3 weeks in activities that gave their infant either postural experiences (e.g. helping the infant to sit up from a prone or supine position) or object-oriented experiences (e.g. teaching the infant to reach for an object at midline). Infants demonstrated more advanced development in the targeted areas: reaching, object exploration and developing means-end behaviour. Future studies modelled after the work of Lobo and Galloway (2008) could verify whether such interventions could help enhance low-SES children's performance and perhaps also affect selectivity by extension (or more directly through a selectivity intervention). These intervention studies could in turn provide insight into the causal directions among the cognitive deficits of children in poverty.

In sum, the current study identified ways in which low-SES infants' selective exploration deviates from the exploratory trajectory established by previous studies. When interacting with objects and surfaces of different consistencies, low-SES infants do not maximally tailor their exploratory behaviours to the affordances that those objects and surfaces provide. Detection of affordances is a key part of the foundation for later cognitive outcomes, so future research on selectivity of

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affordances may be critical in preventing the persistent SES gaps in cognitive ability.

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