Selective Attention As A Mechanism of Resilience: Attention Neutralizes the Adverse Effects of Socioeconomic Status On Memory in 9 Month-old Infants

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Abstract

Socioeconomic status (SES) has a documented impact on brain and cognitive development. We provide evidence that early engagement of attention mechanisms may rescue this negative influence of impoverished environments on cognition. This study examined the effect of SES on attention and memory in 9 month-old infants. By varying a single parameter, the spatial cueing task can elicit either a simple orienting mechanism (i.e., facilitation) or one that involves both target selection and simultaneous suppression of competing information (i.e., IOR). We modified this paradigm to include images of common objects in target locations for encoding. Following the cueing task, participants completed a recognition memory test. In previous work, results confirmed that target object encoding with simultaneous interference suppression (IOR) promoted better memory among 9 month-old infants than target enhancement via facilitation of orienting alone (Markant & Amso, 2013). Here we found that SES predicted memory, but not attention orienting, performance in 9 month-old infants. Furthermore, engaging selective attention at object encoding diminished the effects of SES on memory performance. SES predicted memory performance when target objects were encoded with simple orienting processes. When selective attention was engaged during encoding, SES no longer predicted memory performance in 9 month-old infants. Engaging selective attention mitigated the effects of SES on learning and memory and may function as an internal mechanism of resilience in infants at risk for poor cognitive outcomes related to SES.

Keywords: selective attention, infancy, socioeconomic status, memory, resilience
Growing up in poverty has a negative impact on children’s brain and cognitive development (e.g., Hackman & Farah, 2009; Lipina & Posner, 2012). Socioeconomic status (SES, McLoyd, 1998) is frequently used as a proxy for children’s poverty level. While the majority of studies examining the effects of SES on cognitive development focus on childhood and adolescence, recent work suggests SES effects may begin as early as infancy (Clearfield & Jedd, 2013; Hanson et al., 2013; Lipina, Martelli, Vuelta, & Colombo, 2005). The present study examined the influence of SES on the development of foundational interactions between attention and memory skills in a group of 9 month-old infants.

SES theoretically indexes two interacting lower-level variables, namely stress and enrichment. Stress in low SES homes may derive from malnourishment, parental emotional stress, or abuse and neglect (Bradley & Corwyn, 2002; Evans, 2004). These circumstances have been shown to increase risk for atypical developmental profiles and pathology (Barajas, Philipsen, Brooks-Gunn, 2007; Evans & Kim, 2010). Enrichment varies as a function of the availability of stimulation in the home, as well as financial resources that allow exposure to variable experiences including museum visits, travel, and access to age-appropriate toys and books. (Dahl & Lochner, 2012; Duncan, Morris, & Rodrigues, 2011; Hart & Risley, 1995). Low levels of enrichment in otherwise psychologically healthy homes is unlikely to result in pathology but may contribute to the achievement gap between children raised in lower relative to higher SES environments (Duncan & Murnane, 2011; Hart & Risley, 1995; Lee & Burkam 2002; Ramey & Ramey, 2004).

The influences of SES on cognitive and brain development are well documented. Data from young children and adolescents show that lower SES environments adversely impact language, memory, and cognitive control processes (Amso, Haas, McShane, & Badre, 2014;
Farah & McCandliss, 2006; Hackman & Farah, 2009; Noble, McCandliss, & Farah, 2007; Noble, Norman, & Farah, 2005; Noble, Wolmetz, Ochs, Farah, & McCandliss, 2006), and also lead to parallel differences in structural brain development (Kishiyama, Boyce, Jimenez, Perry, & Knight, 2009; Noble, Houston, Kan, Bookheimer, & Sowell, 2012; Sheridan, Sarsour, Jutte, D’Esposito, & Boyce, 2012). Growing evidence suggests that SES begins to exert these influences on both cognitive (Clearfield & Niman, 2012; Clearfield & Jedd, 2013) and structural (Hanson et al., 2013) development as early as infancy. Perhaps the best data in favor of this early influence comes from studies that consistently show that SES has a moderating effect on health and cognitive outcomes in infants born preterm (Beaino et al., 2011; Voss, Jungmann, Wachtendorf, & Neubauer, 2012; Wolke & Meyer, 1999).

Here we examined the role of SES in domain general selective attention and memory processes in a large sample of 9 month-old infants who previously completed versions of a spatial cueing and subsequent memory task (data from Markant & Amso, 2013; Markant, Oakes, & Amso, in review). Selective attention orienting involves two core processes – enhanced processing of attended stimuli and concurrent suppression of irrelevant/unattended information (e.g., Desimone & Duncan, 1995). This concurrent enhancement and suppression ensures that attended information benefits while interference is simultaneously minimized. We capitalized on the classic spatial cueing task (Posner & Cohen, 1980) where brief peripheral cues are followed by targets at one of two onscreen locations (Figure 1). When the cue-target delay is short (67 ms), attention orienting is facilitated to the previously cued location. When the delay is long (600 ms), the cued location becomes suppressed and attention orienting becomes biased to the noncued location. This inhibition of return (IOR) condition reflects a selective attention process during encoding of target objects presented in the noncued location, as it involves attending to an
object while residual information from the previously attended cue has become suppressed. In previous work, we modified this paradigm to include images of multiple objects in target locations. Following the cueing task, we measured infants’ looking times to novel objects relative to objects presented during the spatial cueing encoding phase of the task. Results showed that target object selection coupled with concurrent suppression (IOR) promoted better memory encoding for subsequent recognition than did simple orienting (facilitation) or no cue baseline conditions in both 9 month-old infants (Markant & Amso, 2013; Markant, Oaks, & Amso, in review), as well as in children and adolescents (Markant & Amso, 2014). These findings show that attention and memory are deeply intertwined. Simply stated, better attention helps us remember what we have learned.

There is strong evidence that medial temporal lobe memory functions are negatively affected by family SES in childhood (Hackman & Farah, 2009; Levine, Vasilyeva, Lourenco, Newcombe, & Huttenlocher, 2005); however, to our knowledge, there are no data on the role of SES in either memory encoding or recognition in infancy. Visual attention is a multi-dimensional mechanism encompassing aspects of executive attention, orienting, and alerting (Fan, McCandliss, Sommer, Raz, & Posner 2002). Mezzacapa (2004) showed that lower SES negatively impacted both alerting and executive attention networks in children (see also Lipina & Colombo, 2005; Noble et al., 2006; 2007; Amso et al., 2014), but had no effects on spatial orienting of attention in a cueing paradigm similar to the one used here (see also Hackman & Farah, 2009).

We examined the effects of SES on attention orienting and memory in infancy. Based on reviewed literature in children, our prediction is that memory, but not attention orienting, processes will be adversely affected by lower SES. We also asked whether there are interactive
effects between SES, memory, and attention orienting in infancy. In a version of the spatial cueing/memory paradigm adapted for children and adolescents (Markant & Amso, 2014), engaging a selective attention orienting mechanism during encoding not only supported better performance, but also mitigated the effects of poorer IQ on subsequent recognition memory. Specifically, when cueing elicited basic orienting (i.e., facilitation) to target objects during encoding, IQ was the only predictor of subsequent memory for the attended objects. In contrast, engaging selection with concurrent suppression (i.e., IOR) during target object encoding counteracted individual differences in intelligence on memory performance, effectively improving memory performance among children with lower IQs (Markant & Amso, 2014). These findings raise the possibility that selective attention orienting processes may serve as a mechanism of resilience in infancy as well, protecting memory from the adverse effects of low SES. As such, we undertook an analysis of our combined visual attention orienting and memory data in a large group of 9 month-old infants, with a specific focus on the role of SES in the isolated and interactive functions of attention and memory.

**Method**

**Participants**

The final sample comprised a total of $N = 136$ 9 month-old infants ($M = 276$ days, $SD = 13$ days, 65 Male). According to parent report, 91.9% of participants were Caucasian, 2.9% were Asian, 5.1% were Black, and .07% were Pacific Islander. All participants were recruited from the community through advertisements and public birth records. Infants were excluded from the study if they had been born early (< 36 weeks), had low birth weight (< 5 lbs), or had any history of serious health problems. All families received compensation for participating.

**Eye tracking apparatus**
The general procedure was the same across all infants. We recorded eye movements using a remote eye tracker (SensoMotoric Instruments 60 Hz RED system). Infants sat on their parent’s lap 70 cm from a 22” monitor. A digital video camera (Canon ZR960) recorded infants’ head movements and allowed for online coding during the test phase. The video output was also recorded as a digital file.

Stimuli were presented using the SMI Experiment Center software. We used a 2-point calibration and 4-point calibration accuracy check as described in Markant and Amso (2013). Average deviation was 2.4° ($SD = 1.9°$). The digital eye recording was used for offline coding of left/right eye movements if an accurate calibration/stable point of gaze (POG) was not obtained. To confirm the accuracy of these data, reliability between coded and POG data was calculated for a subset of videos for infants who had successful eye movement recordings, $r > .90, p < .05$.

**Procedure and Design**

See Markant & Amso (2013) for design details. The task included a spatial cueing/encoding phase and a subsequent memory test (see Figure 1). In the spatial cueing phase, each trial began with a purple X that loomed in and out (2.5 - 5.67 cm²) to engage infants’ fixation in the center of the display. The fixation was presented alone for 1100 ms and then a cue (a yellow ring, 2.5 cm diameter; see Figure 1) was presented 16° (19.4 cm) to the left/right of the central fixation, for 100 ms. This was followed by either a 67 ms or a 600 ms delay period in which only the fixation stimulus was visible. Then the target image was presented in either the cued or noncued location. A 67 ms delay between cue offset and target onset elicits a basic orienting response (i.e., facilitation) whereas a 600 ms delay elicits suppression at the cued location and selectively biases attention to targets in the noncued location (i.e., IOR) (Markant & Amso, 2013; Markant & Amso, 2014). After this delay the fixation disappeared and a target
object appeared in the cued or noncued location for 1500 ms. Infants participated in a 67 ms facilitation encoding cueing condition \((n = 20)\), a 600 ms IOR encoding cueing condition \((n = 75)\), or in a baseline encoding condition where targets were learned in the absence of cues \((n = 41)\).

After the incidental encoding in the spatial cueing phase, infants saw a series of memory test trials including familiar objects from encoding and a completely novel object (Figure 1C). All objects were presented in isolation while duration of looking was recorded. Order of test trial type (novel, familiar) was counterbalanced in all cases. The majority of infants’ data \((n = 95)\) was drawn from Markant & Amso (2013) where abstract objects were used (Figure 1C). An additional \(n = 41\) infants participated in an identical paradigm but with face rather than abstract object stimuli (Markant et al., in review). As this is a combined analysis across experiments, we focused our memory measure on infants’ responses to completely novel objects presented at test across all tasks.

**Eye tracking measures**

Our primary variables for the spatial cueing phase were eye movement reaction times and duration of looking to the targets. Initial processing of the eye movement data utilized the SMI BeGaze analysis software. Three areas of interest (AOIs) were identified based on the central, left, and right stimulus locations. These AOIs were equivalent 14.2-cm\(^2\) regions over each of these locations. Usable looks were defined as segments of the data in which the POG remained within 7.1 cm\(^2\) (5.8°) for at least 100 ms. Reaction times were based on the time when a look first entered the AOI. Individual trials were discarded for the reaction time analysis if the infant looked at the cue prior to target onset, looked away from the screen before looking at a target, or if eye movement data was unavailable.
Calculation of Variables

**SES Variable.** Parents were asked to fill out a demographic questionnaire indicating parental education, occupation, income, and family size. Education was coded as number of years of school completed. We coded occupation on a scale of 1 to 5 using the O*Net rankings of job zones (Amso et al., 2014). O*Net, developed by the US Department of Labor/Employment and Training Administration, is a nationally recognized current database on occupational information. Job zones are groups of occupations requiring similar levels of education and training. Parent 1 and parent 2 education and occupation were averaged to yield a single value. Household income was used to generate an income-to-needs ratio (family income divided by the poverty threshold of a family of that size).

Of the 136 families who provided demographic information, \( n = 112 \) provided all three data points and \( n = 24 \) provided education and occupation but not income information, consistent with rates of omission of this variable in previous literature (Amso et al., 2014; Bornstein & Bradley, 2003; Noble et al., 2007). We followed the example of previous literature to impute income-to-needs for these participants. We calculated a regression equation with the parental occupation and education metrics as predictors of income-to-needs. The regression was significant, \( R^2 = .392, F(2,109) = 35.100, p = .000 \). Both education and occupation were reliable predictors of income-to-needs (all \( ps < .005 \)). The regression equation derived from this analysis were used to impute the income-to-needs ratio of the participants whose parents had reported education and occupation but not household income. Table 1 provides full SES statistics on the sample. Nineteen families were living below an income-to-needs of 2, with a value of 1 being equivalent to living at the national poverty line. All three SES variables were highly correlated (all \( ps = .000 \)) posing a multicollinearity threat to statistical models. In addition, the imputation
of income-to-needs raises interpretation concerns of this variable where it was generated from the two others. As such, we extracted a single SES variable. We entered average parent education, occupation, and income-to-needs into a factor analysis, using the principal components method of extraction on a covariance matrix. The extracted factor was used as the SES score and explained 80% of the variance across the three variables.

**Dependent Variables.** We used separate multiple linear regressions to examine the impact of predictor variables on the dependent variables of Attention Orienting and Memory. The dependent variable in the Attention Orienting analysis was the classic spatial cueing difference score, computed as each infant’s RT to cued – RT to noncued locations during the spatial cueing task. This RT difference score variable was standardized (z-scored) within infant to account for baseline differences in eye movement times across infants. Positive difference scores reflect faster responses/an attention bias to the noncued location (i.e., IOR) whereas negative difference scores reflect faster responses/an attention bias to the cued location (i.e., facilitation).

The dependent variable for the Memory analysis was each infant’s duration of looking to novel objects during the memory test phase of the experiment. Looking times were first averaged across familiar and novel test trial types to generate a mean value per infant. This value was used to standardize (z-score) duration of looking to novel objects at test. This standardization ensures that the duration of looking to novel objects measure used is relative to looking times to familiar objects. Response to novelty is commonly used as an index of learning and memory in infancy.

**Predictor Variables.** Predictors included infants’ Age in Days, Sex, SES, Encoding Cueing Condition, and Encoding Cueing Condition x SES. Refer to SES Measures above for calculation of the SES variable. The Encoding Cueing Condition variable was a categorical
grouping based on the attention orienting mechanism engaged at target encoding. We have previously shown that infants and children had enhanced memory for objects encoded under selective attention (IOR) conditions and that, memory performance in facilitation and baseline (no cue) conditions was equivalent (Markant & Amso, 2013). For the Memory regression analyses, we grouped infants based on whether they participated in an IOR \( (n = 75, 600 \text{ ms delay between cue and target}) \) or a combined baseline/facilitation \( (n = 61, \text{ no cue or 67 ms delay between cue and target}) \) spatial cueing task during encoding. For the Attention Orienting analysis, the baseline data were not included as there were no cues presented. We verified that there were no differences in SES across these encoding cueing condition groups, \( F(2,133) = .436, p = .648. \)

**Results**

We conducted separate multiple regression models to examine predictors of the dependent variables Attention Orienting and Memory.

We first tested the effects of predictors Age in Days, SES, Encoding Cueing Condition, and SES x Encoding Cueing Condition on the dependent variable Attention Orienting. The model explained a significant amount of the variance in Attention Orienting, \( R^2 = .32, F(4,89) = 10.33, p = .000. \) The only reliable predictor of Attention Orienting was Encoding Cueing Condition, \( \beta = .46, SE = 0.08; t = 6.22, p = .000. \) This expected result reflects the success of the cueing manipulation in biasing attention to the noncued location \( (M = 11.54 \text{ ms}, SD = 53.44 \text{ ms}) \) in the IOR condition and to the cued location in the facilitation condition \( (M = -67.29, SD = 70.80) \). Relevant to this investigation, there were no significant effects of SES, \( \beta = .13, SE = 0.10; t = 1.27, p = .209, \) or Encoding Cueing Condition x SES, \( \beta = -0.95, SE = 0.09; t = -1.06, p = .294, \) on our measure of Attention Orienting. We further correlated the spatial cueing...
difference score with SES in the IOR and facilitation groups separately, and found that SES did not correlate with performance in either condition (all $p$s > .26).

We next examined the influence of SES on Memory performance at test. Again, predictors were Age in Days, SES, Encoding Cueing Condition (coded as either IOR, $n = 75$, or combined facilitation/baseline conditions, $n = 61$), and Encoding Cueing Condition x SES. The model explained a significant amount of variance in memory performance, $R^2 = .09, F(4,131) = 3.18, p = .016$. Socioeconomic status, was a reliable predictor of memory performance, $\beta = .71, SE = 0.26; t = 2.73, p = .007$, with higher SES associated with larger relative responses to novelty (i.e., better recognition memory). Encoding Cueing Condition was a marginally significant predictor of memory performance, $\beta = .26, SE = 0.15; t = 1.77, p = .079$, with memory performance better for objects encoded under selective attention conditions (Figure 2A) as seen in previous work. Finally, SES x Encoding Cueing Condition significantly predicted memory performance, $\beta = - .35, SE = 0.15; t = -2.36, p = .02$.

We investigated the SES x Encoding Cueing Condition interaction effect further with separate regression models per Encoding Cueing Condition. The dependent variable was Memory score as before. The predictors were SES and Age in Days. SES was a significant predictor of memory only when objects were encoded under facilitation/baseline cueing conditions, $\beta = .37, SE = 0.12; t = 3.09, p = .003$ Figure 2B). Higher SES predicted relatively longer looking times to novel objects, an index of better memory performance at test. However, SES did not predict memory when objects were encoded in the context of a selective attention orienting mechanism (IOR cueing condition, $\beta = .003, SE = 0.09; t = .03, p = .973$; Figure 2C). Figure 2B & 2C shows the correlation between SES and memory performance when target objects were encoded in the facilitation/baseline condition, $r(61) = .35, p = .006$ , versus in the
IOR condition, $r(75) = .003$, $p = .979$. Taken together, these data suggest that attention at encoding may act to moderate the relation between SES and memory in infancy.

**Discussion**

This investigation adds several novel insights into the role of SES in attention and memory processes in infancy. First, SES has little influence on mechanisms of attention orienting in infancy, consistent with results from a similar investigation in children (Mezzacapa, 2004). Second, SES plays a role in memory performance such that infants from lower SES environments perform more poorly than those from higher SES environments. Third, the impact of SES on memory can be diminished with the engagement of selective attention orienting strategies at encoding. When lower SES infants engage selective attention at encoding, their learning and memory is equivalent to that of infants from higher SES backgrounds.

The critical finding here is that SES is exerting an influence on memory systems very early in life. Our data suggest that this effect of SES is specific to memory encoding processes. The negative effects of lower SES on memory were counteracted by the engagement of selective attention orienting mechanisms *at encoding*. This is the second such demonstration of this type of interaction. In previous work, we showed that the same mechanism counteracts individual differences of IQ on memory in children and adolescents (Markant & Amso, 2014). Taken together, selective attention at encoding may be a candidate mechanism of resilience for learning and memory in at-risk groups.

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1 We verified that the grouping of facilitation and baseline did not drive our SES effects. SES correlated similarly with memory performance, controlling for age, in both the facilitation, $r(17)=.53$, $p = .019$, and baseline Encoding Cueing Conditions, $r(38)= .33$, $p = .038$. We also verified that our combination of two different object types across IOR did not swamp any effect of SES on Memory in that condition. SES did not correlate with Memory performance in the IOR condition when either face, $r(27) = -.19$, $p = .316$, or abstract object, $r(42) = -.13$, $p = .389$, stimuli were used.
There are strong mechanistic reasons for the observed interaction between attention and memory at encoding. The brain sees objects better when selective attention is engaged. Previous work shows that attention enhancement paired with concurrent suppression influences the visual quality of object representations in cortical visual regions (Carrasco, 2011, 2013; Zhang, Meyers, Bichot, Serre, Poggio, & Desimone, 2011). We suggest that this elimination of competing neural interference results in a stronger higher fidelity signal for downstream medial temporal lobe memory encoding. In this case, the competing neural interference derives from activation from the previous cue. In natural settings it may result from data carried over from the previously attended location or from distractors concurrently in the surround while an object is being encoded. In any case, the suppression process eliminates noise, reducing the burden on weaker encoding mechanisms in infants from lower SES environments, and thus may override differences in target object encoding and subsequent recognition.

We report here that the trajectory of learning and memory development and its influence by SES begins in infancy. SES is a proxy variable, accounting for both stress and enrichment opportunities in infants’ environments. Stress during development is known to impact the hypothalamic-pituitary-adrenal (HPA) axis and specifically MTL memory operations (e.g., Gunnar & Quevedo, 2007). Lack of enrichment may also provide fewer opportunities for memory systems to engage and strengthen. There is a great deal of focus on alleviating achievement gaps in SES by providing resources in the preschool period. These data highlight the need for more focus and resources as early as infancy.

These data additionally speak to the plasticity and promise of interactive systems in the human brain. Hackman & Farah (2009) argue that SES impacts neurocognitive systems in a graded fashion. We argue here that it is imperative to understand which cognitive architectures
are shaped by SES, which systems are resilient, and how they interact with each other. This understanding will guide the formulation of basic learning and educational strategies that are designed to counteract and ultimately reverse poorer outcomes in lower SES communities as early as in infancy.
References


Figure Legends

**Figure 1.** An example of task trials presented to infants. A. In the Facilitation spatial cueing condition, target objects were presented in the cued location. B. In the IOR condition, the cued location is suppressed and the attention bias shifts to the noncued location. C. Test trials included objects that were familiar to encoding objects along color and texture dimensions as well as completely novel objects for comparison. Object examples taken from Markant & Amso (2013).

**Figure 2.** A) Memory performance is better when targets are encoded under selective attention (IOR) conditions. B) SES predicts memory when targets are encoded with simple orienting mechanisms (Facilitation/Baseline). C) SES is unrelated to memory performance when targets are encoded in the selective attention IOR condition.
Table 1  
*Sample SES Parent Education, Occupation, and Income-to-Needs Ratio Statistics*

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<th>SES Family Income-to-Needs Ratio</th>
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Figure 1
Figure 2