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Selective attention neutralizes the adverse effects of low 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 demonstrate that engaging spatial selective attention mechanisms may counteract this negative influence of impoverished environments on early learning. We previously used a spatial cueing task to compare target object encoding in the context of basic orienting ("facilitation") versus a spatial selective attention orienting mechanism that engages distractor suppression ("IOR"). This work showed that object encoding in the context of IOR boosted 9-month-old infants' recognition memory relative to facilitation (Markant and Amso, 2013). Here we asked whether this attention-memory link further interacted with SES in infancy. Results indicated that SES was related to memory but not attention orienting efficacy. However, the correlation between SES and memory performance was moderated by the attention mechanism engaged during encoding. SES predicted memory performance when objects were encoded with basic orienting processes, with infants from low-SES environments showing poorer memory than those from high-SES environments. However, SES did not predict memory performance among infants who engaged selective attention during encoding. Spatial selective attention engagement mitigated the effects of SES on memory and may offer an effective mechanism for promoting learning among infants at risk for poor cognitive outcomes related to SES.

1. Introduction

Growing up in poverty negatively impacts children's brain and cognitive development (e.g., Hackman and Farah, 2009; Lipina and Posner, 2012). Socioeconomic status (SES; McLoyd, 1998) is frequently used as a proxy for children's poverty level. Lower SES adversely impacts language, memory, and cognitive control in childhood and adolescence (Amso et al., 2014; Hackman and Farah, 2009; Noble et al., 2005, 2006a,b, 2007) and leads to parallel differences in brain development (Noble et al., 2012a,b, 2015b; Sheridan et al., 2012, 2013). Growing evidence suggests that SES begins to influence both cognitive development (Clearfield and Jedd, 2013; Clearfield and Niman, 2012; Lipina et al., 2005; Noble et al., 2015a) and structural brain development (Hanson et al., 2013) as early as infancy.

The present study examined links between SES and the development of foundational interactions between spatial selective attention and memory among 9-month-old infants who previously completed a spatial cueing/attention orienting and subsequent memory task (data from Markant and Amso, 2013; Markant et al., 2015a). The effects of SES on attention development vary depending on the specific attention mechanisms considered. For example, low SES has been related to less effective auditory selective attention skills in childhood, as measured by increased attention to distracting auditory stimuli (D'Angiulli et al., 2008; Stevens et al., 2009), but was unrelated to spatial attention orienting in childhood (Mezzacappa, 2004). In contrast, there is strong evidence that lower SES is associated with poorer memory performance and reduced volume of the hippocampus during childhood (Hackman and Farah, 2009; Hanson et al., 2011; Levine et al., 2005; Noble et al., 2012a,b, 2015b). A similar association between SES and recognition memory emerges by 21 months of age among typically developing infants (Noble et al., 2015a).

Previous research has shown that spatial selective attention and memory are mechanistically linked early in life (Markant and Amso, 2013), suggesting that it may be important to consider the interactive effects of selective attention, memory, and SES rather than examine the impact of SES on attention and memory separately. Selective attention involves modulation of visual cortex activity, with enhanced processing of attended stimuli and

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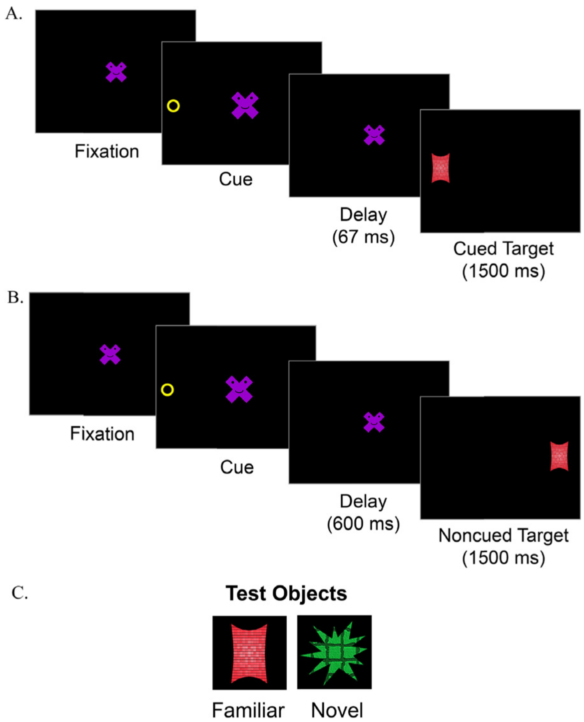

Fig. 1. An example of task trials presented to infants. (A) In the Facilitation spatial cueing condition, target objects were presented in the cued location. (B) In the IOR condition, the cued location is suppressed and the attention bias shifts to the noncued location. (C) Test trials included objects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

concurrent suppression of competing information (Desimone and Duncan, 1995; Gandhi et al., 1999; Kastner et al., 1999). This coupled target enhancement and distractor suppression improves the quality of attended object representations in visual cortical regions and supports enhanced visual processing (Carrasco, 2011, 2013; Zhang et al., 2011). Our work is based on the hypothesis that this reduced noise in the signal for the attended object in visual cortex (Zhang et al., 2011) also improves memory encoding for the target object.

We capitalized on the spatial cueing task (Posner, 1980) to study the role of these spatial selective attention dynamics in early learning and memory. In this task, attention is engaged at a central location while a cue appears in the periphery. After a delay, a target appears in the cued location or in the opposite, noncued location (Fig. 1). When the cue-target delay is short (<250 ms), orienting is facilitated to the previously cued location (Posner and Cohen, 1984; Posner, 1980). However, a longer cue-target delay (>250 ms) elicits suppression at the cued location and biases orienting to the noncued location, an effect known as inhibition of return (IOR; Posner et al., 1985). This task can thus be used to compare orienting mechanisms that differentially engage the suppression component of selective attention. Both facilitation and IOR elicit attention at a target location, but only IOR involves both attention at the target location and suppression at the previously cued location.

We previously asked whether engaging facilitation versus IOR orienting mechanisms during encoding supported differential learning during infancy. Infants viewed objects in the cued or noncued locations during an initial spatial cueing/encoding phase. We assessed infants' subsequent memory for these objects based on looking times to novel objects relative to the familiar target objects. Infants' memory was enhanced in the context of IOR orienting involving distractor suppression relative to basic orienting (facilitation) or a baseline condition with no attention manipulation (Markant and Amso, 2013). An adult fMRI study using a similar IOR design further demonstrated that suppression of visual cortex activity associated with the previously cued location predicted enhanced recognition memory performance (Markant et al., 2015b).

This work demonstrated that engaging spatial selective attention supported enhanced memory across development. However, we were unable to examine interactive effects of selective attention, memory, and SES during infancy due to relatively small sample sizes in each study. As such, in the present study we re-analyzed data from these studies with a focus on relating SES and recognition memory in the contexts of facilitation versus IOR orienting mechanisms. In a similar paradigm adapted for children and adolescents (Markant and Amso, 2014), engaging selective attention (IOR) during encoding boosted recognition memory performance and mitigated the effects of lower IQ on recognition memory. When cueing elicited basic orienting (facilitation) during encoding, IQ was the only predictor of recognition memory. In contrast, engaging selection with concurrent suppression (IOR) during encoding improved memory performance among children with lower IQs (Markant and Amso, 2014). These findings raise the possibility that engaging spatial selective attention during encoding may similarly buffer memory from the adverse effects of low SES during infancy. Distractor suppression may support a higher-quality signal in the IOR condition (Markant et al., 2015b; Zhang et al., 2011), which in turn may reduce the load on weaker learning and memory skills among infants from lower SES environments.

To address this question, we re-analyzed our combined samples of 9-month-old attention and memory data to examine main effects of SES on early attention orienting and memory as well as interactions between attention, memory, and SES. We predicted that recognition memory, but not attention orienting, would be adversely affected by lower SES, consistent with previous work in children. However, we also predicted that these adverse effects of low SES on infants' memory performance would not be observed among infants who engaged selective attention mechanisms (IOR) during target encoding.

2. Material and methods

2.1. Participants

The final sample included 136 9-month-old infants (M_{Age} = 276 days, SD = 13 days, 65 Male). According to parental report, 91.9% of participants were Caucasian, 2.9% were Asian, 5.1% were Black, and 0.1% were Pacific Islander. 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.

2.2. Eye tracking apparatus

The general procedure was the same for all infants. We recorded eye movements using a remote eye tracker (SMI 60 Hz RED system; SensoMotoric Instruments, Boston, MA). Infants sat on their parent's lap 70 cm from a 22 in. 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