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Socioeconomic Predictors of Recognition and Recall Memory in Infants

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Abstract

Relationships between socioeconomic status and recognition and recall memory were explored in a sample of 72 infants at 6-, 9-, and 12-months-of age. Socioeconomic status was disentangled into household annual income, parental education, and parental subjective social status to test their individual associations with recognition and recall memory function. Findings suggest differential effects on recognition memory in 6 month olds, and recall memory in 12 month olds, based on income, education, and subjective social status. Discussion points to a larger sample size with an older age group as next steps in the analyses.

Introduction

Socioeconomic status (SES) is defined as the "social standing of an individual or group" (American Psychological Association, 12/1/2018). It can be examined using a subset of the financial, educational, social, and cultural opportunities and hardships that are disposed to, or possessed by, an individual or group. Lower levels of SES—typically characterized by poverty, low occupational prestige, and low education level—are associated with higher rates of negative psychological health components like depression, anxiety, and attempted suicide (Newacheck *et al.* 2003); aggression, hostility, and perceived threat (Chen & Paterson, 2006); and worsening symptoms for delinquency and attentional problems in school (DeCarlo *et al.* 2011). Additionally, lower levels of SES are associated with higher likelihood of being sedentary (Newacheck *et al.* 2003); higher levels of obesity (Levine, 2011); and higher prevalences of childhood asthma (Mielck *et al.* 1996). Low levels of socioeconomic status has also been linked to aspects of family well-being like child abuse and neglect (Ondersma, 2002), and domestic crowding (Melki *et al.* 2004).

Additionally, socioeconomic status has been linked to academic achievement in a myriad of ways. At the higher ages of childhood, low SES prospective college students are less likely to have access to information about college resources (Brown *et al.* 2016); the highest high school

dropout rate among adolescents aged 16-24 are low income (National Center for Education Statistics); and low SES children begin high school with literacy skills five years behind their high-income peers (Reardon *et al.* 2013). Children in low-income schools are also less likely to have well-qualified teachers (Clotfelter *et al.* 2007) and experiences that develop fundamental skills in reading acquisition (Buckingham *et al.* 2014). Even in the home, these low income children are often exposed to adversity and stress that are linked to decreased educational success (McLaughlin & Sheridan, 2016) and have parents whose socioeconomic statuses are related to their inattention, disinterest, and lack of cooperation in school (Morgan *et al.* 2009).

In summary, socioeconomic status affects us on several levels—including psychological and physical health and the home environment—that intersect with the educational experience. While the majority of the past research on how SES is associated with academic achievement focuses on aspects like attendance, test performance, interest, attitudes in the classroom, and career aspirations, neuroscientists and psychologists have begun to target specific neurocognitive systems, structures, and their specialized functions. For example, among first graders (~6-7 years old), working class children did significantly worse than their middle class peers on two tests of executive functioning (Calvo & Bialystok, 2014) and low SES children performed significantly worse on individual tasks targeting cognitive control of the prefrontal/executive system (Noble *et al* 2005; & Noble *et al* 2007). The low SES participants in Noble and colleagues' 2007 study also scored significantly lower on tasks of visuospatial ability, language, and declarative memory (notably when asked to recall faces). In older populations, high-income adolescents were found to have significantly greater cortical gray-matter volume and greater cortical thickness in all lobes of the brain; both of these measures were associated with better test

performance (Mackey *et al* 2015). Lower SES adolescents additionally have been found to have worse working memory, smaller hippocampal volumes, and smaller DLPFC (dorsal lateral prefrontal cortex) volumes.

Memory-specific associations with SES have been found in previous studies. For example, in Markant and colleagues' 2016 study, SES predicted recognition memory performance in 9 month olds. This specificity is significant because recognition memory is a subset of declarative memory, or the memory of facts and events, which is a component of being able to learn about new things. Other studies have shown that early memory-specific associations with SES may predict future academic and educational success. For example, in Lyu's 2015 study, data were taken from the Health and Retirement Study (HRS) that represented 21,384 participants aged 51 years and above. Childhood SES was operationalized as education and income from both parents. Declarative memory was examined using a scale that equally tested the respondent's immediate free recall and delayed free recall. Childhood SES disadvantage was associated with poor memory, while controlling for adult SES, suggesting that the effects of childhood SES on memory may persist into adulthood. On a similar note, in Smith and colleagues' study (2002), 69 children were recruited from neonative intensive care and completed the Fagan Test of Infant Intelligence (FTII) at 2.4 and 4.6 years old. This test was a paired comparison test of visual novelty preference, measuring the infant's ability to rapidly detect new information and differ it from previously exposed stimuli. The participants' SES was a composite of their parents' occupation and education. Intelligence at 8 years old, using the Stanford-Binet Intelligence scale was significantly predicted by both parental SES and the FTII. Both of these studies illustrate that (1) the association between SES and memory can be

long-lasting and (2) declarative memory ability is a predictor of intelligence and academic achievement measures.

Most studies examining socioeconomic disparities look at objective measures such as income, education, and occupation of the individual (or the parent if the participant is a child). However, whenever someone attempts to correlate typical measures of SES to an outcome, they are missing part of the story because they are not considering how individuals perceive their social standing and make decisions based on that standing. Subjective social status (SSS) tries to "capture individuals' sense of their place in the social ladder which takes into account standing on multiple dimensions of socioeconomic status and social position" (The John D. and Katherine T. MacArthur Foundation). This perspective relates to objective measures, but it considers the other people and social networks that the individual interacts with (social capital) and the individual's possessions, skills, customs, and knowledge that promote social mobility in the environment they live in (cultural capital) (Bourdieu, 1986).

In the last decade, studies examining the correlation between SES and cognition/the brain have considered the complexity of SES, teasing apart different components and individually testing their effects on brain structure, activity, and function. In one group of these studies, experimenters de-grouped objective measures of socioeconomic status. In these studies, it is suggested that maternal and paternal education, and not income, have significant effects on children's stress hair cortisol (Vaghri *et al.* 2013 & Ursache *et al.* 2017), significant effects on adolescents' levels of anxiety and depression, even after controlling for family history of these traits (Merz *et al.* 2017), and infants' declarative memory (Noble *et al.* 2015). While it would be best examined through qualitative research with the parents in these studies, it could be predicted

that aspects of parental education that enhance the child's cognitive abilities include the quantity and quality of talk at home surrounding specific educational topics like math (Ramani *et al.* 2014) and the linguistic environment at home (Melvin *et al.* 2016; Hoff & Tian, 2005).

In the second group of studies that teased apart different components of SES, experimenters looked at both differential and compounded effects of objective and subjective measures. In Chen and Paterson's (2006) study on adolescents, family SES and neighborhood SES predicted negative psychological characteristics like hostility, threat perception, and discrimination, but only parental subjective social status predicted optimism, control, and self-esteem. Similarly, Whittle and Pantelis's (2017) study of adolescents illustrated that neighborhood (but in this case, not family) socioeconomic disadvantage was associated with altered brain development mainly in the temporal lobes and the amygdala, but positive parenting moderated effects of this disadvantage in the dorsal frontal and lateral orbitofrontal cortices—with lack of development associated with increased rates of school noncompletion—and the amygdala. In a study on children in NYC (Ursache *et al.* 2015), SES and SSS were independently correlated with speed of processing and executive function scores, but were not correlated with each other. Studies such as these, again, illustrate that SES is complex with many components that either differentially, or compoundly, correlate to different aspects of brain structure, activity, and function.

We studied infants at 6, 9, and 12 months old to explore when SES disparities emerge in the development of declarative memory, and even more specifically in the development of recognition and recall memory. With regards to mechanism, we disentangled SES into income, parental education, and parental subjective social status to test their individual associations with

declarative memory function. Lastly, we compare aspects of socioeconomic status to parental responses on a parent child activities and material deprivation survey in order to get closer to the connection between these SES measures and their possible effects on the development of recognition and recall memory.

Methods

Research Questions

1. When do SES disparities emerge in the development of recognition and recall memory? Do different aspects of SES—notably income, education, and subjective social status—have stronger individual associations with either type of these types of declarative memory function?
2. If we find significant associations between SES measures and memory performance, can these associations be strengthened by hypothesized mediators, material deprivation and number of parent child activities?

Design

This study aims to explore the correlations between socioeconomic measures and ability in recognition and recall memory in infants. To do this, we tested three different age groups—6, 9, and 12 months old. For all age groups, we collected information on their parents' household income, income to needs ratio, highest level of education, and subjective social status. Additionally, we asked the families to complete surveys on parent child activities and material deprivation because we hypothesized that these might be mediating factors between the objective and subjective SES measures and their correlation to memory. We conducted a visual paired comparison task to measure recognition memory and a deferred imitation task to measure recall

memory. Lastly we used mixed effects models in Statistical Package for the Social Sciences (SPSS) to allow for attrition and estimate missing data in this ongoing study.

Participants

The sample of this study consists of 72 infants who participated for at least one target age visit (6, 9, or 12 months old). This totalled to a dataset of 27 6-month-olds (mean=6.33, range=5.62-7.17), 37 9-month-olds (mean=9.13, range=8.48-10.06), and 52 12-month-olds (mean=12.32, range=11.34-13.94) for a total of 116 individual entries.

These families were recruited largely through community advertisements in New York City, mostly in the borough of Manhattan. Other families were called because they expressed prior interest in participating in research or because their infant participated in this study for an earlier age. Racial and ethnic demographics are currently only available for a subset of the participants, but we included them to help describe the sample. In this subset of data (n=85), 59% of the respondents race-classified as White, 25% as Black or African American, 2% as asian, 9% as other, 4% as American Indian/Alaska Native, and 1% as Native Hawaiian or other Pacific Islander. These respondents reported the racial makeup of their infants; in a subset of 85 infants, 49% were race-classified as White, 24% as Black or African American, 1% as Asian, 25% as other, 0% as American Indian/Alaska Native, and 1% as Native Hawaiian or other Pacific Islander. Furthermore, 19% of the parents (n=86) and 29% of the infants (n=83) were reported as Hispanic/Latino.

Because of the nature of this study, obtaining a large and socioeconomically diverse sample size was vital. We were able to obtain a sample where the reported household income ranged from $0 to over $300,000/year, the education levels ranged from less than a high school

diploma/GED to graduate school degrees, and the subjective social statuses ranged from 0-10 (the most outer bounds of the measure we used). More descriptives of our sample could be found in our results.

Families were escorted to and from the lab via uber rides paid for by the lab, or given $30 to travel on their own. Once they arrived at the lab, parents provided written informed consent and were paid $30 for participating in the study. Exclusionary criteria included major neurological or developmental deficits, birth before 37 weeks gestation, multiple births, or maternal age under 18 years. Other than that, infants were enrolled in the study without regard to prenatal exposures. Research procedures were approved by the IRB at Teachers College, Columbia University.

Measures and Tasks

Socioeconomic Status

Objective

Parents were asked to fill out a sociodemographic questionnaire written or orally in the lab, or written at home, depending on their preference. Of a subset of 94 data entries, 86% of the parents that completed the survey were mothers, 11% were fathers, and 3% were other. This questionnaire, formulated using Qualtrics, inquired about educational attainment (total years of education for primary care provider and another parent if available), household composition (number of adults and children in the household), and family income (estimated gross annual income). An income-to-needs (ITN) ratio for each family was calculated by dividing reported annual income by the federal poverty level for a family of that size in the year the data were collected. We

asked that the child's primary caregiver provide responses for the entire questionnaire. In single-mother households, only maternal demographic information was obtained.

Subjective

Parental subjective social status (SSS) was captured on the administered MacArthur Network Sociodemographic Questionnaire (2000). This questionnaire asks participants to rank themselves on a 10-rung ladder symbolizing the range of social status in the United States based on education, occupation, and income. The scores represent where each participant views themself in the spectrum of the least educated, lower skilled, and poorest individuals to the most educated, highly skilled, and wealthiest individuals in the country. Because this measure asks participants to think of themselves and report, it attempts to include other forms of capital (social and cultural) that the objective measures may miss.

Parent Child Activities Survey [See Appendix A]

The Parent Child Activities survey was administered orally to the parent at the end of the visit or completed by the parent online in their home. We instructed parents to think about some of the activities on the survey (ex. singing songs, watching TV) that they do with their child and how often they did those things. The survey consisted of 11 questions with answers on a likert type scale capturing the frequency of each activity that was done. The survey answers used in this study only describe the activities that the survey respondent does with their child, but we also asked the respondent to fill out another survey for their partner, or co-caretaker, if that was applicable. We scored an answer of "unknown" as 0, "rarely or not at all" as 1, "few times a

month" as 2, "few times a week" as 3, and "everyday" as 4. The final score for each participant entry was a sum of their scores.

Material Deprivation Survey [See Appendix B]

The Material Deprivation survey was administered orally to the parent at the end of the visit or completed by the parent online in their home. Parents were instructed to answer whether they did specific actions that we provided if they were deprived of basic needs like food, money, and shelter and state whether they did these actions if they didn't have enough money. The survey consisted of 14 yes/no questions. We coded an answer of "yes" as 1 and an answer of "no" as 0, and added these values to get a final score for each data entry, so a higher score indicated that a family was more materially deprived. We used these values for our correlations, but reversed each score for our mixed effects models.

Memory

Declarative Memory was measured using the Visual Paired Comparison (VPC) and the Deferred Imitation (DI) tasks. More specifically, these tasks are a measure of recognition and recall memory respectively.

Visual Paired Comparison Task

The Visual Paired Comparison task is a nonverbal measure of visual recognition memory and, in infants, an early measure of declarative memory. The task compares looking time between a familiar and novel visual stimulus to assess how well individuals recognize and remember a stimulus that they were previously exposed to. If the individual remembers the previous stimulus, they should preferentially look at the novel stimulus for a longer time (Rose et al., 2004; Morgan & Hayne, 2010).

Conducting the task: In this task, infants were seated on their parents' laps 40 inches away from two 20 inch monitors that were 33 inches apart at their centers. A video camera was placed between the monitors to capture the infant's gaze and parents were told to close their eyes or look directly between the monitors to avoid influencing the infant's response. To orient the infant toward the monitors, each screen displayed an identical spinning ball for 13 seconds. During the 10 second familiarization phase, each screen showed an identical blue, mailbox shaped face. Following, in the first 10 second novelty preference phase, one of the blue faces was replaced by a novel circular yellow face. In the second 10 second novelty preference phase, the yellow face was replaced by the previously shown blue face and the other screen displayed a novel square red face.

Coding the task: Coders reviewed videos of the task frame-by-frame (at a 200ms interval) on Datavyu to establish total looking time of the left and right screens for each phase. This allowed the coders to calculate the ratio of novel looking time to total looking time. Ratios above 0.5 indicate novel preference. Reliability checks were run on 20% of the scores and inter-rater reliability was greater than 95%.

Deferred Imitation Task

The Deferred Imitation task is a nonverbal measure of recall memory and, in infants, an early measure of declarative memory. The task requires an adult to complete a set of actions and examines the participant's ability to imitate those actions (Meltzoff & Moore, 1994; McDonough et al., 1995; Barr et al., 1996; Klein & Meltzoff, 1999; Hayne et al., 2000).

Conducting the task: The stimuli for this task was a handheld puppet 12 inches in height. The puppet was accessorized with a removable felt mitten that was worn on the right hand of the puppet and matched in color. For the demonstration phase, this removable felt mitten was attached to a jingle bell that created noise when shaken, but for the test phase, this bell was absent. For 6 month olds, the demonstration and test puppets were both pink rabbits. For 9 month olds, the demonstration and test puppets were both grey mice. For 12 month olds, the demonstration puppet was a pink rabbit and the test puppet was a grey mouse, allowing for the test of memory generalization in addition to recall (Barnat et al., 1996). Additionally, because this is an 'observation-only' procedure, memory cannot be based on re-accessing a motor habit (Klein & Meltzoff, 1999).

Parents were asked to sit on a bench and seat their child on their lap. Parents were also asked to abstain from touching, pointing to, or speaking about the stimuli in order not to direct or influence the child's attention or behavior in any fashion. The experimenter knelt on the floor approximately 32 inches away in front of the infant and held the puppet at the infant's eye level. After the child oriented to the puppet, the experimenter removed the mitten from the puppet's right hand, shook the mitten 3 times, and put the mitten back on the puppet's right hand. This demonstration was done three times and then the puppet was replaced to storage for approximately 35 minutes until the test phase. In this waiting time period, the infant completed other neurocognitive tasks and activities.

The DI test phase was done in the same place as the demonstration phase with identical conditions. However, this time, the experimenter held the puppet in reach of the

infant and encouraged the infant to interact with the puppet if the infant didn't already do so. After the infant touched the puppet, they were given 90 seconds to imitate the previously demonstrated actions, and the task was done. Both the demonstration and test phases were recorded by another experimenter in the room with a video camera.

Coding the task: Coders reviewed videos of the task frame-by-frame (at a 200ms interval) on Datavyu to score participants' attention in the demonstration and test phases. Memory scores were determined by the number of individual target behaviors that the infant imitated during the test session. One point was awarded for removing the mitten from the puppet's hand, another point was awarded for shaking the mitten, and a final point was awarded for attempting to replace the mitten on either hand, for a total possible score of three points. Reliability checks were run on 20% of the scores and inter-rater reliability was greater than 95%.

Analysis Strategies

To interpret our findings in this exploratory study, we initially looked at the descriptives to get a sense of the range of the data. We then looked at bivariate pearson correlations, and finally used mixed effects models to isolate predictors of memory outcomes for the total sample and individual age groups. Using mixed effects models allowed us to (1) look at the data cross-sectionally and longitudinally, (2) handle uncorrelated data and unequal variances, and (3) allow for attrition and estimate missing data. In conducting our correlations, we entered the values for objective and subjective SES measures as the respondents reported them. However, for our mixed models, we aggregated these continuous data into bins (Table 1).

Table 1. Data Bins for Socioeconomic Measures

	Low	Medium	High
Household Annual Income	<39,000 (n=38, 34.9%)	40,000-99,000 (n=28, 25.7%)	>100,000 (n=43, 39.4%)
Income to Needs Ratio	<1 (n=30, 29.4%)	1-5 (n=33, 32.4%)	>5 (n=39, 38.2%)
Parental Education	High school diploma and less (n=42, 37.5%)	Some college education to bachelors degree (n=28, 25%)	Graduate degree (Masters and above) (n=42, 37.5%)
Subjective Social Status	1-4 (n=25, 24%)	5-6 (n=36, 34.6%)	7-10 (n=43, 41.3%)

Results

Descriptive Statistics

72 infants (27 6-month-olds, 37 9-month-olds, and 52 12-month-olds) participated in at least one visit for this study. Participant's mean household income was $88,223.96 (SD=77,113.40, range=0-360,000) and the average income-to-needs (ITN) ratio was 4.1090 (SD=3.7118, range=0-18.6355). The median values for household income and ITN ratio were 65,000 and 3.0304 respectively, illustrating that our dataset skewed towards higher incomes (Table 2). Using our data bins, 34.9% of our respondents reported a household income of less than 40,000, 25.7% reported 40,000-99,000, and 39.4% reported greater than 100,000. Additionally, 29.4% of our respondents reported an ITN less than 1 (indicating poverty). For comparison, according to the United States Census Bureau (2016), the median household income was 60,741 and 14.7% of people lived in poverty.

Descriptive analyses showed an average parental education of 15.786 years (SD=3.7953, range=6-22) (Table 2). Using our data bins, 37.5% of respondents had a high school diploma or less, 25% had some college or a bachelor's degree, 37.5% had a graduate degree. For comparison, according to the United States Census Bureau (2016), for individuals 18 years and

older, 41% had a high school diploma or less, 48% had some college or a bachelor's degree, and 11% had a graduate degree. Lastly, for our SES measures, the average subjective social status was 5.889 (SD=1.9371, range=1-10) (Table 2). Missing entries from SES measures are due to respondent incompleteness of the survey or inconsistent results in need of clarification (i.e. if the participant stated they had a household income of 52,000/year, but then clicked "30,000-39,000" as the interval). Researchers of this study are still contacting respondents to clarify the latter reason for future publications.

The mean score for parent child activities was 33.557 (SD=11.2381, range=4-55) and 1.298 for material deprivation (SD=1.9111, range=0-10) (Table 2). Missing entries from these survey measures are due to respondent incompleteness of the survey or data exportation mistakes.

Lastly, the mean VPC ratio was 0.7623 (SD=0.5004, range=0-2.9231) and the mean DI score was 0.713 (SD=0.9574, range=0-3) (Table 2). The majority of infants, in each age group, showed novel preference in our visual paired comparison task. Performance on this task also increased with age, most notably between 6 and 9 months of age (Table 3). This relationship between recognition memory performance and age is also supported by our correlations (Bivariate Correlations, Table 4, r=.302, p=.014). On the other hand, there was more variability in the performance on the deferred imitation task with no obvious increase in performance with age (Table 3). Missing entries from these memory measures are due to a number of reasons, but primarily because; one, the infant became too fussy to complete the task; two, the parent directed the infant's attention in some physical or vocal way; three, the researcher made an error in conducting the task; four, the video of the task was improperly documented; five, the family and

researchers ran out of time to complete the study; and six, the video was not coded before the publication of this paper.

Predictors of Recognition Memory

None of our socioeconomic measures correlated to recognition memory performance for the total sample or each of the individual age groups (Tables 4 and 5). According to our linear mixed effects models, income and education only predicted recognition memory performance in 6 month olds with moderate significances (F=3.604, d.f.=2, p=.063; F=3.383, d.f.=2, p=.066 respectively) (Table 6). Subjective social status was a moderate predictor of recognition memory for the whole sample (F=2.663, d.f.=2, p=.078) and for the 6 month olds (F=3.830, d.f.=2, p=.052) (Table 6). These relationships were not linear; recognition memory performance increased from low to medium values, but then decreased from medium to high values (Table 6). It should be noted that the sample size for this age group was lower than all other groups. The best predictor of recognition memory in this age range was age (Table 3, χ^2=5.661, df=2, p=.060; Table 4, r=.302, p=.014).

Predictors of Recall Memory

None of our socioeconomic measures correlated to recall memory performance for the total sample (Table 4). However, income (r=.498, p=.021), ITN (r=.504, p=.023), and parental education (r=.407, p=.054) was positively linked to recall memory performance for 6 month olds. These correlations are only loosely supported by results from our linear mixed effects model where all of these associations warranted a p value of less than .22, but greater than our cut-off of .1.

Parental Education was negatively correlated to recall memory performance for 12 month olds (r=-.260, p=.054). On the other hand, the number and frequency of parent child activities was positively correlated to recall memory performance for this age group (r=.376, p=.037). Additionally, even though recall memory performance was not correlated to SSS for 12 month olds (r=-.052, p=.749), our linear mixed effects model found SSS to be a moderate predictor of recall memory performance (F=2.692, d.f.=2, p=.081) with performance increasing from the low to medium groups, and then decreasing with the high group (Table 7).

Table 2. Descriptive Statistics

	N	Minimum	Maximum	Mean	Standard Deviation
Household Annual Income	109	0	360,000	88,223.96 (median=65,000)	77,113.40
Income to Needs Ratio	102	0	18.6355	4.1090 (median=3.0304)	3.7118
Parental Education	112	6	22	15.786	3.7953
Subjective Social Status	104	1	10	5.889	1.9371
Parent Child Activities	88	4	55	33.557	11.2381
Material Deprivation	94	0	10	1.298	1.9111
Visual Paired Comparison [Recognition Memory]	66	0	2.9231	0.7623	0.5004
Deferred Imitation [Recall Memory]	94	0	3	0.713	0.9574

Table 3. Memory Outcomes by Age

Visual Paired Comparison—Recognition Memory χ^2=5.661, df=2, p=.060			
	6 months	**9 months**	**12 months**
Novel Preference	10 (63%)	21 (91%)	23 (85%)
Non-Novel Preference	6 (37%)	2 (9%)	4 (15%)

	16 (100%)	23 (100%)	27 (100%)

Deferred Imitation—Recall Memory χ^2=4.161, df=6, p=.655			
	6 months	**9 months**	**12 months**
0 acts imitated	11 (48%)	15 (54%)	27 (63%)
1 act imitated	6 (26%)	5 (18%)	11 (26%)
2 acts imitated	4 (17%)	5 (18%)	3 (7%)
3 acts imitated	2 (9%)	3 (10%)	2 (4%)
	23 (100%)	28 (100%)	43 (100%)

Table 4. Bivariate Correlations of Total Population

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1. Visit Age	Correlation Sig. N	------- ------- 116								
2. Household Income	Correlation Sig. N	-.023 .812 109	------- ------- 109							
3. Income to Needs Ratio	Correlation Sig. N	.035 .729 102	**.922**** **.000** **102**	------- ------- 102						
4. Parental Education	Correlation Sig. N	-.018 .852 112	**.657**** **.000** **105**	**.674**** **.000** **99**	------- ------- 112					
5. Subjective Social Status	Correlation Sig. N	-.041 .677 104	**.595**** **.000** **100**	**.593**** **.000** **93**	**.648**** **.000** **100**	------- ------- 104				
6. Parent Child Activities	Correlation Sig. N	**.235*** **.027** **88**	-.110 .320 83	-.091 .430 77	-.161 .133 88	-.016 .892 77	------- ------- 88			
7. Material Deprivation	Correlation Sig.	-.150 .148	**-.446**** **.000**	**-.473**** **.000**	**-.456**** **.000**	**-.365**** **.001**	**.239*** **.025**	------- -------		

	N	94	**88**	**81**	**91**	**83**	**88**	94		
8. Visual Paired Comparison	Correlation Sig. N	**.302**[*] **.014** **66**	-.095 .462 62	-.063 .639 58	-.002 .989 64	-.097 .444 64	.013 .927 52	.081 .555 55	------- ------- 66	
9. Deferred Imitation	Correlation Sig. N	-.155 .135 94	-.019 .859 88	-.033 .769 84	-.026 .806 91	-.047 .663 89	.100 .418 68	.086 .467 73	-.025 .851 58	------- ------- 94

[Δ] Correlation is significant at the 0.10 level (2-tailed)

[*] Correlation is significant at the 0.05 level (2-tailed)

[**] Correlation is significant at the 0.01 level (2 tailed)

Table 5. Bivariate Correlations by Age

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1. Household Income 6mo	Correlation Sig. N	------ ------ 24							
9mo	Correlation Sig. N	------ ------ 36							
12mo	Correlation Sig. N	------ ------ 49							
2. Income to Needs Ratio 6mo	Correlation Sig. N	**.945**[**] **.000** **22**	------ ------ 22						
9mo	Correlation Sig. N	**.842**[**] **.000** **33**	------ ------ 33						
12mo	Correlation Sig. N	**.991**[**] **.000** **47**	------ ------ 47						
3. Parental Education 6mo	Correlation Sig. N	**.749**[**] **.000** **24**	**.794**[**] **.000** **22**	------ ------ 27					
9mo	Correlation Sig. N	**.717**[**] **.000** **34**	**.754**[**] **.000** **32**	------ ------ 35					
	Correlation Sig.	**.554**[**] **.000**	**.569**[**] **.000**	------ ------					

12mo	N	**47**	**45**						
4. Subjective Social Status 6mo	Correlation Sig. N	**.562**** **.005** **23**	**.571**** **.007** **21**	**.684**** **.000** **24**	------ ------ 24				
9mo	Correlation Sig. N	**.697**** **.000** **34**	**.710**** **000** **31**	**.587**** **.000** **32**	------ ------ 34				
12mo	Correlation Sig. N	**.522**** **.000** **43**	**.543**** **.000** **41**	**.674**** **.000** **44**	------ ------				
5. Parent Child Activities 6mo	Correlation Sig. N	-.072 .776 18	-.099 .716 16	-.261 .254 21	-.290 .243 18	------ ------ 21			
9mo	Correlation Sig. N	.114 .562 28	.206 .312 26	.094 .635 28	.199 .329 26	------ ------ 28			
12mo	Correlation Sig. N	**-.380*** **.020** **37**	**-.388*** **.021** **35**	**-.374*** **.019** **39**	-.015 .932 33	------ ------			
6. Material Deprivation 6mo	Correlation Sig. N	**-.504*** **.023** **20**	**-.636**** **.005** **18**	**-.552**** **.006** **23**	**-.471*** **.036** **20**	**.441*** **.045** **21**	------ ------ 23		
9mo	Correlation Sig. N	**-.481**** **.008** **29**	**-.497**** **.010** **26**	**-.499**** **.007** **28**	**-.325**$^{\Delta}$ **.098** **27**	.261 .179 28	------ ------ 29		
12mo	Correlation Sig. N	**-.411** **.009**** **39**	**-.400** **.014*** **37**	**-.336** **.034*** **40**	**-.336** **.045*** **36**	.112 .497 39	------ ------		
7. Visual Paired Comparison 6mo	Correlation Sig. N	-.336 .241 14	-.278 .381 12	-.234 .382 16	-.207 .460 15	-.344 .250 13	.112 .702 14	------ ------ 16	
9mo	Correlation Sig. N	.033 .880 23	.032 .890 21	-.018 .936 23	.121 .584 23	-.102 .677 19	-.187 .444 19	------ ------ 23	
12mo	Correlation Sig. N	-.122 .562 25	-.112 .594 25	.086 .683 25	-.172 .400 26	.066 .782 20	.342 .120 22	------ ------	
8. Deferred	Correlation	**.498***	**.504***	**.407**$^{\Delta}$	.238	-.087	-.124	-.106	------

Imitation 6mo	Sig. N	**.021** **21**	**.023** **20**	**.054** **23**	.286 22	.741 17	.614 19	.707 15	------ 23
9mo	Correlation Sig. N	-.145 .471 27	-.123 .558 25	-.106 .607 26	-.297 .141 26	.211 .371 20	.172 .455 21	.045 .859 18	------ ------ 28
12mo	Correlation Sig. N	-.143 .378 40	-.176 .284 39	**-.260**[Δ] **.097** **42**	-.052 .749 41	**.376**[*] **.037** **31**	.104 .565 33	.102 .629 25	------ ------

[Δ] Correlation is significant at the 0.10 level (2-tailed)

[*] Correlation is significant at the 0.05 level (2-tailed)

[**] Correlation is significant at the 0.01 level (2 tailed)

Table 6.1. Results of the Linear Mixed-Effects Model [Income] of Recognition Memory Performance

All	F=.536, d.f.=2, p=.588			**9mo**	F=.578, d.f.=2, p=.570		
	Count	Mean	SD		Count	Mean	SD
Low	20	.815	.462	Low	8	.678	.199
Medium	18	.854	.631	Medium	4	.575	.078
High	24	.700	.437	High	11	.672	.166
6mo	**F=3.604, d.f.=2, p=.063**[Δ]			**12mo**	F=.536, d.f.=2, p=.588		
	Count	Mean	SD		Count	Mean	SD
Low	5	.648	.150	Low	7	1.090	.692
Medium	5	.858	.370	Medium	9	.976	.848
High	4	.394	.175	High	9	.869	.652

Table 6.2. Results of the Linear Mixed-Effects Model [Income to Needs Ratio] of Recognition Memory Performance

All	F=.266, d.f.=2, p=.767			**9mo**	F=.036, d.f.=2, p=.965		
	Count	Mean	SD		Count	Mean	SD
Low	16	.848	.513	Low	7	.664	.211
Medium	21	.801	.598	Medium	6	.641	.119
High	21	.724	.460	High	8	.664	.190
6mo	F=.876, d.f.=2, p=.449			**12mo**	F=.501, d.f.=2, p=.612		

		Count	Mean	SD			Count	Mean	SD
	Low	4	.661	.170		Low	5	1.254	.774
	Medium	5	.725	.432		Medium	10	.936	.809
	High	3	.423	.202		High	10	.861	.615

Table 6.3. Results of the Linear Mixed-Effects Model [Parental Education] of Recognition Memory Performance

All	F=.242, d.f.=2, p=.786				**9mo**	F=.573, d.f.=2, p=.573			
		Count	Mean	SD			Count	Mean	SD
	Low	27	.776	.491		Low	9	.676	.186
	Medium	16	.679	.263		Medium	5	.586	.217
	High	21	.786	.643		High	9	.679	.114
6mo	**F=3.383, d.f.=2, p=.066**$^{\Delta}$				**12mo**	F=1.368, d.f.=2, p=.275			
		Count	Mean	SD			Count	Mean	SD
	Low	9	.599	.293		Low	9	1.053	.727
	Medium	2	1.034	.550		Medium	9	.652	.175
	High	5	.406	.153		High	7	1.195	1.006

Table 6.4. Results of the Linear Mixed-Effects Model [Subjective Social Status] of Recognition Memory Performance

All	**F=2.663, d.f.=2, p=.078**$^{\Delta}$				**9mo**	F=.112, d.f.=2, p=.895			
		Count	Mean	SD			Count	Mean	SD
	Low	13	.743	.372		Low	5	.627	.253
	Medium	23	.956	.713		Medium	6	.674	.095
	High	28	.642	.241		High	12	.662	.164
6mo	**F=3.830, d.f.=2, p=.052**$^{\Delta}$				**12mo**	F=.692, d.f.=2, p=.511			
		Count	Mean	SD			Count	Mean	SD
	Low	4	.602	.258		Low	4	1.028	.495
	Medium	4	.923	.354		Medium	13	1.096	.914
	High	7	.484	.184		High	9	.740	.317

△Correlation is significant at the 0.10 level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2 tailed)

Table 7.1. Results of the Linear Mixed-Effects Model [Income] of Recall Memory Performance

All	F=.1.807, d.f.=2, p=.170				**9mo**	F=1.826, d.f.=2, p=.183			
		Count	Mean	SD			Count	Mean	SD
	Low	32	.563	.948		Low	12	.917	1.165
	Medium	25	1.000	1.118		Medium	5	1.600	1.140
	High	31	.581	.8072		High	10	.500	.850
6mo	F=2.176, d.f.=2, p=.142				**12mo**	F=.747, d.f.=2, p=.481			
		Count	Mean	SD			Count	Mean	SD
	Low	6	.167	.408		Low	14	.429	.852
	Medium	7	1.143	1.215		Medium	13	.692	1.032
	High	8	1.125	.991		High	13	.308	.480

Table 7.2. Results of the Linear Mixed-Effects Model [Income to Needs Ratio] of Recall Memory Performance

All	F=1.140, d.f.=2, p=.325				**9mo**	F=2.008, d.f.=2, p=.158			
		Count	Mean	SD			Count	Mean	SD
	Low	26	.615	1.023		Low	10	1.100	1.197
	Medium	30	.900	1.062		Medium	7	1.429	1.134
	High	28	.536	.793		High	8	.375	.744
6mo	F=2.305, d.f.=2, p=.130				**12mo**	F=.577, d.f.=2, p=.567			
		Count	Mean	SD			Count	Mean	SD
	Low	6	.167	.408		Low	10	.400	.966
	Medium	8	1.000	1.195		Medium	15	.600	.910
	High	6	1.333	1.033		High	14	.286	.469

Table 7.3. Results of the Linear Mixed-Effects Model [Parental Education] of Recall Memory Performance

All	F=.323, d.f.=2, p=.725				**9mo**	F=1.728, d.f.=2, p=.200			
		Count	Mean	SD			Count	Mean	SD
	Low	37	.730	.990		Low	11	.909	1.0445
	Medium	21	.810	.873		Medium	4	1.500	1.2910
	High	33	.606	.933		High	11	.455	.8202
6mo	F=1.658, d.f.=2, p=.216				**12mo**	F=1.437, d.f.=2, p=.250			
		Count	Mean	SD			Count	Mean	SD
	Low	11	.545	.820		Low	15	.733	1.100
	Medium	3	.667	1.155		Medium	14	.643	.633
	High	9	1.333	1.118		High	13	.231	.599

Table 7.4. Results of the Linear Mixed-Effects Model [Subjective Social Status] of Recall Memory Performance

All	F=.983, d.f.=2, p=.378				**9mo**	F=2.058, d.f.=2, p=.151			
		Count	Mean	SD			Count	Mean	SD
	Low	21	.714	1.007		Low	7	1.429	1.272
	Medium	32	.938	1.014		Medium	8	1.125	1.126
	High	36	.611	.903		High	11	.455	.820
6mo	F=.898, d.f.=2, p=.424				**12mo**	**F=2.692, d.f.=2, p=.081**[Δ]			
		Count	Mean	SD			Count	Mean	SD
	Low	6	.500	.837		Low	8	.250	.463
	Medium	6	.833	.983		Medium	18	.889	1.023
	High	10	1.200	1.135		High	15	.333	.617

[Δ] Correlation is significant at the 0.10 level (2-tailed)

[*] Correlation is significant at the 0.05 level (2-tailed)

[**] Correlation is significant at the 0.01 level (2 tailed)

Discussion

This study examined the timing and mechanism by which an individual's socioeconomic status relates and possibly predicts their infant's performance in recognition and recall memory. The first research question addressed the timing of socioeconomic disparities in participants' memory performance and the individual associations from different SES components. The question of timing is difficult; for recognition memory, we saw a linear progression of performance with age, but we only found socioeconomic effects in 6 month olds. Even though the majority of 6 month infants showed novel preference in this task, 9 month old infants showed significant progress (Table 3). However, while accounting for age, recognition memory did not correlate to any of our SES measures or our predicted mediators (parent child activities or material deprivation) (Table 5). Income, parental education, and subjective social status did predict recognition memory performance in 6 month olds, but this did not hold for the two older age groups (Table 6). An initial interpretation of this might be that SES disparities exist for recognition memory for 6 month olds and then dissipate, but this data is not consistent with other studies that suggest that the disparities grow larger with age. This finding might be due to our small sample size of 6 month olds, so we suggest duplicating the study.

On the other hand, for the timing of SES differences in recall memory, we did not see a linear progression of performance with age, and we only found effects for 12-month-olds based on subjective social status. We found that most of the infants of all ages did not imitate any of the three key actions. This floor effect may be hiding the sensitive differences potentially caused by socioeconomic disparities. Still, we found some socioeconomic differences. Performance on the deferred imitation task was positively correlated with household income, the income to needs ratio, and parental education for 6 month olds (Table 5). These correlations are only loosely

supported by results from our linear mixed effects model where all of these associations warranted a p value of less than .22, but greater than our cut-off of .1 (Table 7). For 12 month olds, performance on the deferred imitation task was negatively correlated with parental education and positively correlated with parent child activities (Table 5). Neither of those statements are supported by our linear mixed effects model (Table 7). All in all, we were not able to pinpoint the age when socioeconomic disparities emerged in the development of recognition and recall memory.

Our discussion concerning different effects on infant memory from different components of SES is partly embedded in the discussion of timing. As said before, income, parental education, and subjective social status predicted recognition memory performance in 6-month-olds and subjective social status predicted recall memory performance in 12-month-olds. These findings support two recommendations. For one, household income, income to needs ratio, educational attainment, and subjective social status should not be considered together as a composite for future studies exploring socioeconomic disparities in infant memory. Secondly, subjective social status should be used in more studies exploring socioeconomic disparities. We are unable to state why this is important using our methods, but in accordance with the literature, we propose that the parents' perspective of their own socioeconomic status may be different than their objective measures of SES and may differentially impact their children's memory development.

The second research question concerned the roles of material deprivations and number of parent child activities in the association between socioeconomic measures and memory. Interestingly, in all of our significant associations, memory performance increased from low to

medium SES, and then dropped from medium to high SES (Tables 5 and 6). The first part of that finding is in agreement with the existing literature, but we think the second part is due to the quantity and quality of activities done by the infant and parent. Parent child activities was correlated to material deprivation, but only for 6-month-olds (r=.441, p=.045). This means that the most deprived parents reported a higher amount and frequency of activities that they did with their infants. Material deprivation was not linked to any of our socioeconomic measures, but we suggest that high socioeconomic parents were not doing as many activities with their infants as the medium socioeconomic parents. Maybe these infants were spending time with babysitters or other caretakers who didn't have the same income or educational attainment as the infant's parents. In order to test this hypothesis, we will need to look at who is doing activities with the infants.

Limitations

As said throughout the paper, the data used is part of an ongoing study. Therefore, it is not complete, and that serves as an obvious limitation. Other than the size, another limitation of our sample was the socioeconomic diversity. We were able to obtain a sample where the reported household income ranged from $0 to over $300,000/year, the education levels ranged from less than a high school diploma/GED to graduate school degrees, and the subjective social statuses ranged from 0-10 (the most outer bounds of the measure we used) (Table 2). However, this sample was skewed right towards higher household annual incomes, larger ITN ratios, more years of parental educational attainment, and higher values for subjective social status. More than a third of the sample had a household annual income of more than $100,000, had more five times the poverty level for their family size, and had at least one parent with a graduate degree.

Data bins were largely created around simply cutting the sample into thirds, but we may be covering data differences by grouping the participants, particularly for the medium group.

A limitation and strength of this study is the sample age. Markant and colleagues (2016) was able to find that SES predicted recognition memory performance in 9 month olds, so choosing 6-, 9-, and 12-month olds to find the emergence of SES disparities in recognition and recall memory performance was strategic. However, that meant that we had to be intentional in choosing tasks that this age range can show their memory performance in and create the study protocol with their age in mind. Tasks had to be nonverbal, short, and engaging enough to sustain the infant's attention. Still, with this intentionality, we lost the most data in our memory measures.

Recommendations

For future studies, we suggest a larger sample size. More specifically, we suggest that experimenters find a sample with a normal distribution according to SES in order to find a significant enough number of participants from low, middle, and high socioeconomic backgrounds. We also suggest that future studies look at 6-, 9-, 12-, and 15- month infants. A study by Markant and colleagues (2016) suggests that the disparities emerge for recognition memory at 9 months of age, but the disparities in recall memory performance might emerge later. For example, in Barr and colleagues' study (1996), the same three actions on a puppet were used as the task (removing, shaking, and replacing the mitten), and the biggest jump in completion of those three actions occurred between 12 and 18 months old. A natural progression of performance with age would need to be identified in order to isolate socioeconomic disparity. With regards to tasks, we recommend that there should be a method to

record the attention that the infant is giving the task. The floor effect seen in our DI task may have developed because infants at this age didn't have the minimal attention span necessary in order to complete the task. This method could be some sort of eye tracking.

In the beginning of this paper, we intended on using the EEG data from the study, but these results were not ready by the time of publication. The association between SES and brain structure has been found in children as early as 1 month old. In a cohort of healthy African American female infants (4-6 weeks old), MRI results have shown that lower SES (indicated by income and maternal education) was associated with smaller cortical gray and deep gray matter volumes (Betancourt *et al.* 2015). Additionally, Tomalski and colleagues (2013) found significantly lower frontal gamma power in awake 6-9 month olds from low income homes and whose mothers has lower occupational status. Studies that combine findings in both brain structure/activity and functional output are rare for this age group, but would be noteworthy to the field of knowledge.

Lastly, we recommend that future experimenters include a qualitative piece like an interview or home visit, particularly for the data on subjective social status and parent child activities. One purpose of this type of study is to provide evidence to governmental programs and the greater society that SES measures can have a strong impact on memory and future academic achievement even at the age of infancy. Another purpose is to provide low SES parents and childcare providers with resources that are in their grasp to do what they can to alleviate some of these disadvantages. If there is a patterned activity among low SES parents whose infants do not show these memory disadvantages, we want to share that they are doing.

Concluding Thoughts

The findings from this study are inconclusive. They suggest that socioeconomic disparities in recognition and recall memory might be identified among 6- to 12- months old, and also that memory performance might be differentially correlated to income, income to needs ratio, education, and subjective social status as components of SES. Focusing in on the socioeconomic disparities found in the development of specific neurocognitive systems, structures, and their specialized functions allows us to focus on more targeted intervention. Such information could be essential for parents, other childcare providers, and policymakers who want to better understand neural mechanisms underlying socioeconomic disadvantages and inform the practices and policies that will aid in closing the cognitive gap introduced by SES. With regards to our specific research questions, further study is needed, and a larger sample size with an older age group are suggested.

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Appendix A. Parent Child Activities Survey

Instructions: We would like to ask about some of the activities that you and your child do together, as well as about how often you do these things. The same questions will be asked about the baby's other parent as well.

Please fill out the following for the activities that YOU do with your baby:

	Frequency				
	Everyday	Few times a week	Few times a month	Rarely or not at all	Unknown
Sing songs with baby?	○	○	○	○	○
Watch TV together?	○	○	○	○	○
Watch children's videos with baby?	○	○	○	○	○
Read books or look at pictures in a book with baby?	○	○	○	○	○
Tell stories to baby?	○	○	○	○	○
Listen or dance to music with baby?	○	○	○	○	○
Play games that do NOT involve toys? (hand games, peek-a-boo, where is baby?)	○	○	○	○	○
Turn upside down or toss him/her in the air, give child a ride on your shoulders?	○	○	○	○	○
Play together with toys for building things? (blocks, Tinkertoys, Lincoln Logs, or Duplos)	○	○	○	○	○
Roll a ball, toss a ball, or play games with a bat?	○	○	○	○	○
Go to special programs? (Mommy & Me, library story times, play groups)	○	○	○	○	○

Appendix B. Material Deprivation Survey

Instructions: We are interested in some of the problems that families face. In the past year, did you do any of the following because there wasn't enough money?

1. Did you receive free food or meals?

   ◯ Yes ◯ No

2. Did your child/children go hungry?

   ◯ Yes ◯ No

3. Did you go hungry?

   ◯ Yes ◯ No

4. Did you not pay the full amount of rent or mortgage payments?

   ◯ Yes ◯ No

5. Were you evicted from your home or apartment for not paying rent or mortgage?

   ◯ Yes ◯ No

6. Did you not pay the full amount of gas, oil, or electricity bill?

   ◯ Yes ◯ No

7. Was service turned off by the gas or electric company, or did the oil company not deliver oil?

   ◯ Yes ◯ No

8. Was service disconnected by the telephone company because payments were not made?

   ◯ Yes ◯ No

9. Did you borrow money from friends or family to pay bills?

   ◯ Yes ◯ No

10. Did you move in with other people, even for a little while, because of financial problems?

    ◯ Yes ◯ No

11. Did you stay at a shelter, in an abandoned building, in an automobile, or any other place not meant for regular housing, even for one night?

Yes No

12. Was there anyone in your household who needed to see a doctor or go to the hospital but couldn't go because of the cost?

Yes No

13. Have you cut back on buying clothes for yourself?

Yes No

14. Have you worked overtime or taken a second job?

Yes No