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Children's Event-Related Potentials of Auditory Selective Attention Vary With Their Socioeconomic Status

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Past research suggests a link between socioeconomic status (SES) and brain processes in children, but direct evidence from neuroimaging is scarce. The authors investigated the relationships among SES, performance, and the neural correlates of auditory selective attention, by comparing event-related potentials (ERPs) in lower- and higher-SES preadolescent children during a task in which they attended to two types of pure tones but ignored two other types. Our hypothesis was that, at comparable performance levels, higher-SES children ignore distracters (the unattended, irrelevant tones) while lower-SES children attend equally to distracters and to targets (the attended, relevant tones). The authors found that ERP waveform differences between *attended* and *unattended* tones (Nd, *difference negativity*) were significant in the higher-SES but not in the lower-SES group. However, the groups did not differ in reaction times or accuracy. Electroencephalographic power analysis revealed a differential pattern of *theta* activity concomitant with irrelevant tones for the two groups, indicating that although they performed similarly the children from these groups recruited different neural processes. Lower-SES children, the authors suggest, deployed supplementary resources to also attend to irrelevant information.

Keywords: socioeconomic status, auditory selective attention, event-related potentials, theta EEG power, preadolescent children

In the last 30 years, research has established that family income and other indicators of *socioeconomic status of origin* (SES)[1], such as parental occupation or education, are highly associated with cognitive, developmental, and achievement outcomes, whereby children coming from families at the lower end of the SES spectrum, or *lower-SES* children, generally lag behind those at the higher end, or *higher-SES* children (Bradley & Corwyn, 2002; Danziger & Danziger, 1995; Duncan & Brooks-Gunn, 1997). The literature includes reports of performance differences on tests of achievement (e.g., White, 1982; Selcuk, 2005), intelligence (e.g., Neisser et al., 1996), and more recently on executive functions (Farah et al., 2006; Noble, Norman, & Farah, 2005; Farah, Noble & Hurt, 2005; Mezzacappa, 2004).

Being a key specific ability needed at school, at home, or in the community, children's *selective attention* (the ability to attend to relevant information while ignoring distracters) may also be expected to be subject to the potent influences of SES. A few studies (e.g., Ardila & Rosselli, 1994; Lupien, King, Meaney, & McEwen, 2001) have indeed shown a correlation between SES and children's performance on behavioral tests of selective attention. While this body of research has certainly contributed to our understanding of variables influencing attention, it employed measures that were not designed to characterize the underlying neural processes involved in the observed outcomes. Lacking neuroimaging evidence, inferences on the link between SES and brain functions were indirect.

Although reliable brain responses can be recorded from children and particularly in relation to auditory selective attention (Berman & Friedman, 1995), there has been very little investigation of the relationship between SES and the neural responses underlying selective attention in childhood. In a preliminary event-related potential (ERP) study, Lauinger, Sanders, Stevens, and Neville (2006) found that a group of higher-SES children, ages 3 to 8 years, displayed larger *positive* ERPs (between 100 and 300 ms) in response to the attended, rather than the unattended, auditory

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[1] We follow Jensen and Sinha's (1993) distinction between *socioeconomic status of origin*, which is attained by the child's parents, and *attained socioeconomic status*, which is attained by a person in adulthood; throughout this paper, the acronym "SES" refers to the former notion.

information. However, the comparison group of lower-SES children of same age range did not show the differential effect. (Note that in this study maternal education level was used as the measure of SES). The authors suggested that the lower-SES children may not suppress unattended stimuli. Their interpretation implies that, while higher-SES children may filter out distracters, lower-SES children may attend to distracters (the irrelevant information) as much as they attend to targets (the relevant information), and this without apparent differences or consequences in terms of behavior/ performance—their "passive" auditory task did not require response and the accuracy of concurrent story comprehension was equated in the two SES groups.

Thus, ERPs may reveal subtle processing differences in children's selective attention that are not detected through behavioral measures. Using an established selective attention paradigm different from the one used by Lauinger et al. (2006), we adopted a similar rationale to investigate the pattern of relationships between SES, performance and ERP correlates in typically developing preadolescent children, who also had comparable basic academic skills and school performance. We tested the hypothesis that the pattern of ERP correlates of selective auditory attention in lower- and higher-SES preadolescents differs even though the groups perform comparably on the behavioral task. Specifically, we predicted that lower-SES children would show similar ERP activity for both attended and unattended information, whereas higher-SES children would show a differential pattern of ERP activity relative to the two types of information.

If our hypothesis was correct, one possible explanation would be that the lower- and higher-SES children may modulate the same underlying process differently by varying the amount of attentional resources allocated to irrelevant information. To verify this possibility, we conducted a follow-up exploratory power analysis on the electroencephalographic (EEG) recordings of our participants. In previous research on adults, power analysis on EEG activity measured concurrently with heightened attention has shown that a significant increase in the occurrence of a specific EEG frequency band, *theta*, is a reliable correlate of the process of allocating supplementary attentional resources (Onton, Delorme & Makeig, 2005). Consequently, detecting a differential pattern for theta could offer a possible explanation for processing differences between higher- and lower-SES groups in the context of the present study.

Method

Participants. Twenty-eight children with no hearing impairments were recruited from two very different schools: one attended predominantly by students with higher SES and the other attended predominantly by students with lower SES. All children recruited were Caucasian; while fortuitous, this eliminated confounds between SES and ethnicity, since ethnic minorities are overrepresented in lower-SES samples (Wilson, 1997; see also Selcuk, 2005). Given little prior research specifically on SES and ERPs in children and the effort involved in data collection, it appeared suitable to use the extreme groups approach (EGA) to enhance the detectability of plausible effects (Preacher, Rucker, MacCallum & Nicewander, 2005)[2]. Such use of EGA does not require the assumption that the compared groups must be at the *most* extreme ends of the underlying SES distribution, thus, it applied particularly well here given the samples we attained.

To recruit participants, an information package was distributed to all parents whose children attended Grade 6 and mixed-grade classes (6–7 and 8–9) at the two schools. Parents signed a consent form and completed a brief questionnaire on demographic and socioeconomic information about their family. Children were provided with \$5 for their participation, and also received a book of stickers at the end of the study. Written informed consent was obtained from a parent according to a protocol approved by research ethics boards at two universities and at the local school district. Children's active assent was also a requirement for participation. Table 1 summarizes the characteristics of the two groups of participants.

The final sample of 28 was obtained after exclusion of six participants from an original sample of 34 children: two children with pediatric diagnoses of Attention Deficit/ Hyperactivity Disorder (one with lower and one with higher SES) who were under medical treatment, one with Fetal Alcohol Syndrome (lower SES), and one with a diagnosed reading disorder (lower SES). The exclusion of these participants was done by linking anonymously our participants' codes to records about them stored in the school district database. This administrative repository collects information concerning special needs students, such as medical records and reports from the team of school psychologists and other professionals working for the district; the definitions of disorders were based on the Diagnostic and Statistical Manual of Mental Disorders (*DSM–IV*, American Psychiatric Association, 1994). In addition, one child was excluded because of an insufficient number (31%) of artifact-free or artifact-corrected usable EEG data (low SES), and another one due to the daily use of anti-inflammatory medications which are known to alter attention and working memory functions in children (Belanoff, Gross, Yager & Schatzberg, 2001).

By parents' and teachers' indications and according to the schools' records, all the participants included in the study were typically developing children with no history of medication or referral to disability assessment or services.

Group school performance and academic skills. In both SES groups, the median of the combined average grades in arithmetic, reading comprehension, and written composition was B (i.e., a score between 73% and 85%), with no difference in their rank distributions (Mann–Whitney $U = 73.0, p > .80$). Accordingly, all children in the two groups met expectations on the cut off pass performance scores of the standard provincial exams assessing their levels of numeracy, reading comprehension and writing skills (Foundation Skills Assessment [FSA] British Columbia Ministry of Education, 2002a, 2002b, 2002c). The FSA is a battery of criterion referenced achievement tests administered annually in Grades 4, 7, and 10 across British Columbia. To compare our two groups on basic academic skills, we used the continuous FSA scores based on identical tests administered in Grade 7 (thus, for

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[2] For the most salient results, throughout this paper we report effect sizes in unstandardized units (i.e., *r*), as only this class of effect sizes is known to remain unbiased after the extreme group approach is used (see Preacher et al., 2005).

Table 1
Family and Demographic Characteristics of the Two Groups of Children Studied

	Socioeconomic status		
	Higher	Lower	
N	16	12	
Mean age (*SD*)	12.7 (1.7)	13.8 (1.2)*	
Gender (% female)[a]	65	42	
Mean of median household income[b]	70,507.88* (15,369.58)	38,366.83 (21,290.96)	
			Max-Min
Mean parent occupation[c]	3.25 (1.10)	5.32 (1.38)*	1–7
Mean parent education[c]	2.47 (0.87)	4.21 (1.40)*	1–6
% Single parents	16	40*	
% Parent unemployment	0	35*	
% Vulnerable children in neighborhood[d]	7.41	42.57*	
Neighborhood rank[d]	14	1	14–1
Composite parent social position class[c]	II	IV	I–V

[a] Comparison of aggregate ERP data between females and males within the same SES group did not yield significant differences (see text for details).
[b] Canadian Dollars (taken from Statistics Canada, 2001).
[c] Computed using a revised version of Hollingshead four factor index of SES (Hollingshead, 1975) which uses reversed scale (see "Max-Min" column).
[d] Quality of residential area (neighborhood) as reflected by developmental vulnerability on the Early Development Instrument in 1,125 students across fourteen residential boundaries in the North Thompson and Gold Trail regions of Southern British Columbia; these data were converted from maps published in Kershaw, Irwin, Trafford, & Hertzman (2005).
* $t(26) < 2.04$ or $\chi^2(1) < 3.84$; $p < .05$, two-tailed.

some of our participants FSA scores were available after the ERP data). There were no differences between mean FSA scores in the higher- and lower-SES group for numeracy (68.71 [*SD* = 6.17] vs. 57.88 [*SD* = 17.24]), reading (76.20 [*SD* = 10.11] vs. 67.35 [*SD* = 12.67]) or writing (53.47 [*SD* = 5.73] vs. 48.59 [*SD* = 10.87]).

SES measurement. For each student, SES scores were computed using an adapted version of Hollingshead (1975) four-factor index of social status (Bornstein, Hahn, Suwalsky, & Haynes, 2003), a composite index based on measures of residential area quality, as well as parents' occupation and education, which are the most frequently used indices of SES (Ensminger & Fothergill, 2003). These can be considered global proxies for the many other environmental factors that vary systematically with SES and are likely to influence child development, including physical health, home environment, early education, parenting, and neighborhood characteristics (Bornstein & Bradley, 2002). Although the Hollingshead SES index has been criticized for being too crude a measure (Duncan & Magnuson, 2003), it is nevertheless the best known and most widely used measure available (Bornstein et al., 2003), and therefore suitable for the aim of this study—that is, establishing direct evidence of the link between children's SES and brain processes.

The SES characteristics of the two groups of children are provided in Table 1. The highest occupation and education level of either parent was rated using the Hollingshead categories 1–4, ranging from "higher executives" to 'laborers/menial workers.' On the composite SES scale (highest = I, lowest = V; note that by convention the original Hollingshead index used reversed scales), the higher-SES parents ranked II (corresponding to high school graduates and skilled workers), whereas the lower-SES parents ranked IV (corresponding to college graduates and managers/professionals). The percentage of single parents was 40% in the lower-SES group versus 16% in the higher-SES group. We used a definition of long-term unemployment adapted from Statistics Canada (2001), according to which "unemployed parents" were defined as parents who did not have a job any time during the year current or previous to the year of our study, but who were available to start work in the week prior to the study and looked for work in the past 4 weeks; this definition included parents on social welfare or receiving government subsidies, but it excluded homemakers. The percentage of unemployed parents was 35% in the lower-SES group versus 0% in the higher-SES group; neither SES groups included families with two homemakers, with single parents who were homemakers, or with both parents receiving some kind of pension. Individual occupation, education, and income data were all within the 99% confidence interval of the means for the respective neighborhood data from the most recent available Census data (Statistics Canada, 2001). Therefore, our samples appeared to be representative. In addition, because paternal and maternal education levels were highly correlated ($r_s = .81$) and because the higher parental income was highly correlated with household income ($r = .69$), using a different algorithm for taking into account information about both parents did not have any impact on group characterization, as the assignments of the participants into the two SES groups remained unchanged.

Quality of residential area (neighborhood) as reflected by developmental vulnerability was taken from Kershaw, Irwin, Trafford, and Hertzman (2005). The percentage of vulnerable children in the lower-SES neighborhood was 43% versus 7% in the higher-SES neighborhood. Among 14 geographically incorporated city neighborhoods (population ~65,000), the lower-SES neighborhood ranked 1st for vulnerability, whereas the higher-SES neighborhood ranked 14th; the school attended mainly by lower-SES children was granted *inner-city* school status and as a result received government funding for various basic intervention programs (e.g., lunch program).

EEG/ERP Data Collection

Stimuli. The stimuli were four pure tones, two frequencies (800 Hz and 1200 Hz) by two durations (100 ms and 250 ms) generated through STIM^2 sound editor function program from Compumedics Neuroscan. Each tone was framed within a Hanning window of 250 ms with 10% (rise/fall of 5 ms) taper at beginning and end of the tone. The EEG was recorded during two blocks in which both 800- and 1200-Hz tones and durations were presented. In a block, the child was instructed to attend to tones of either 800 or the 1200 Hz, which defined the "attended channel," and to ignore tones with the other frequency, that is, the "unattended channel." They were to respond to the rare tones (deviants) with longer (target) duration in the attended channel but to withhold response to all other tones whether these were in the attended or in the unattended channel (see Figure 1A and below). Specifically, each block consisted of an intermixed sequence of 30 rare (10% occurrence) attended target-duration (250 ms) tones—*attended deviants*; 30 rare (10% occurrence) unattended target-duration tones with same the duration and probability of occurrence as attended deviants but the other frequency—*unattended deviants*; 120 recurrent (40% occurrence) attended nontarget duration (150 ms) tones with the same frequency as the attended deviants but the other duration—*attended standards*; and, 120 recurrent (40% occurrence) unattended nontarget duration tones with frequency and duration other than those of attended deviants—*unattended standards*.

The four types of tones were presented binaurally through insert earphones at 84 dB SPL, with an interstimulus interval of 1 s. The delivery of the tones was controlled via an Audio System interfaced with the STIM^2 program. Stimulus presentation followed different random orders for each block of trials and for each child; the different orders were randomly assigned to a given block and child, except that they were preselected so that an attended deviant tone would not appear immediately after the next in the presentation sequence. Children were asked to press a button as fast and as accurately as possible to the attended deviant tones of one of the two presented frequencies, which was designated as the attended channel at the beginning of each recording block. For half of the children within each SES group, in the first block the attended channel was 800 Hz whereas in the second block it was 1200 Hz. For the other half, the order was reversed.

Correct trials required *withholding* manual responses for three types of tones: the attended standards, the unattended standards, and the unattended deviants. In contrast, manual responses defined correct trials for attended deviants (i.e., reaction times were measured only for these tones). Reaction times and accuracy (in trials with attended deviants) were measured from thumb press on a single button situated in the center of a hand-held response pad. Based on previous data (Bartgis, Lilly, Thomas, 2003; Berman & Friedman, 1995) and on our own pilot work, under these conditions we expected overall accuracy to be around 75%, which for cost-efficiency eliminated the need for extra individual adaptive testing.

Data acquisition and recording procedures. EEGs were recorded with "quick-caps" with silver chloride electrodes (Neurosoft, Inc., Sterling, U.S.A.). EEG recordings were made at F3, F4, Fz, FC3, FC4, Cz, and Pz sites during a modified version of a standard selective attention task (Hillyard, Hink, Schwent & Picton, 1973; see Figure 1A). All electrodes were referenced to nose tip. Impedances were kept below 5 kOhms. Vertical electrooculogram (VEOG) was recorded from a split bipolar electrode on the left supraorbital ridge (VEOGU) and the left zygomatic arch (VEOGL).

The signal from the electrodes was amplified and digitized by a SynAmps^2 and a SCAN™ 4.3 EEG system (Neuroscan) with filter settings at 0.15 Hz (high pass) and 100 Hz (low pass). The data from all channels were digitized online at a sampling rate of 1,000 Hz. Children were seen between 1:15 and 1:45 p.m. The EEG recordings were conducted in a sound-proof, shielded EEG mobile lab.

EEG data reduction. Ocular artifact reduction was based on the eye movement reduction algorithm devised by Semlitsch, Anderer, Schuster and Presslich (1986). This algorithm consists in constructing an average artifact response and then subtracting it from the EEG channels on a sweep-by-sweep, point-by-point basis.

ERP processing. Each participant's EEG was epoched (100 ms prestimulus and 900 ms poststimulus) and averaged with respect to the onset of each tone. Averages were computed to both relevant (i.e., attended) and irrelevant (i.e., unattended) standard tones, separately for 800 Hz and 1200 Hz. Analyses showed no significant differences as a function of type of pure tone, therefore, the ERPs were averaged across the two types of tones to yield relevant and irrelevant pure-tone averages for each subject.

The effect of selective attention was operationalized by computing negative difference waveforms as in previous work in children of comparable ages (Bartgis et al., 2003; Berman & Friedman, 1995; Brooker, 1980; Loiselle, Stamm, Maitinsky, & Whipple, 1980). ERP differences were calculated between *attended standards* and *unattended standards*. That is, we subtracted averaged ERP responses to 800 Hz (1,200 Hz) tones when unattended from averaged ERP responses to 800 Hz (1,200 Hz) tones when attended. Therefore, ERP analysis included only data corresponding to correct trials with the attended and unattended standards (namely, the types of tones used for determining the Nd waveforms); accuracy analysis included data corresponding to all tones; reaction times analysis included just the data corresponding to correct trials with the attended deviants (requiring manual response).

Amplitudes of the attention-related *Nd* (*difference negativity*) wave were calculated as the maximum negative deflection at two intervals: 100–400 ms (classified as the *early* Nd) and 500–800 ms (classified as the *late* Nd) in the ERP difference waveforms between attended and unattended standards. Analyses of variance and contrasts were used to determine significant differences of the early and late Nd peak amplitudes and latencies between low- and high-SES groups. Additionally, to test for significant response differences between attended and unattended conditions, we applied the basic bootstrap percentile method (Efron & Tibshirani, 1993) with 1,024 bootstrap samples to compute the 99% confidence interval for the latency and amplitude difference between the conditions averaged across the baseline interval. The difference in the poststimulus waveform was considered significant when the difference waveform exceeded the confidence interval (therefore, when $p_{crit} < 0.001$).

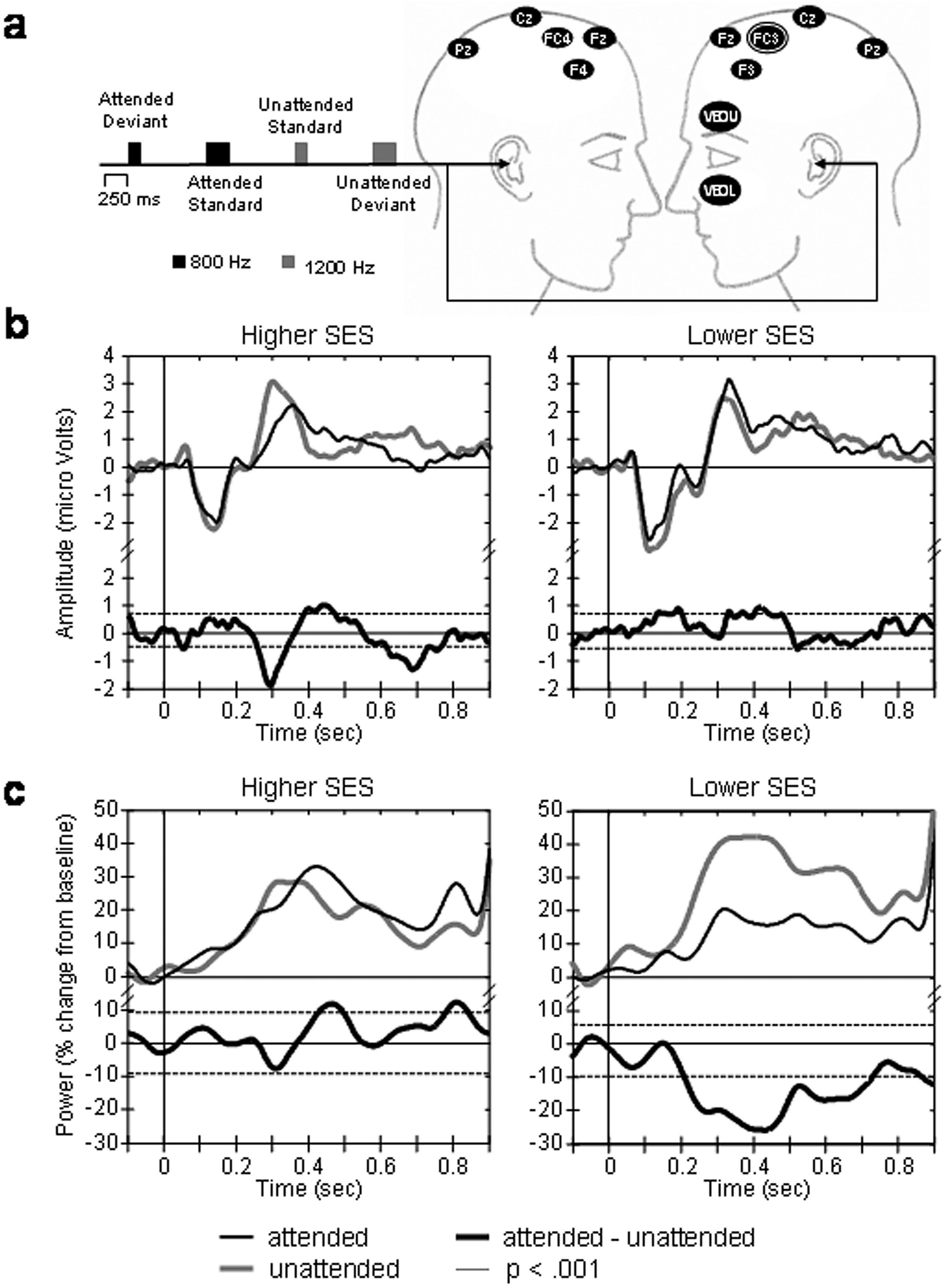

Figure 1. [Panel A] Layout of the auditory selective attention task and electrode positions (adapted from the international 10–20 system of electrode placement) shown from the right side (left picture) and the left side (right picture) of head. As an example, this figure represents a child asked to press a button to the 800-Hz, 250 ms tone (*attended deviant*). Thus, the *attended* tone was 800-Hz, 100 ms tone (black) and the *unattended* tone was the 1200-Hz, 100ms tone (gray). [Panel B] Group-mean event-related potentials (0-30Hz) averaged with respect to attended (black) and unattended (gray) tones are shown for higher- and lower-SES children at FC3 electrode site (marked with inner white ellipse in Panel A). Difference evoked waveforms (attended minus unattended) are shown below the standard waveforms (thick black lines). The 99% confidence limits based on bootstrap sampling of the baseline difference waveform (calculated from prestimulus difference waveforms) are shown as dashed black lines. [Panel C] Group-mean event-related theta (4–8 Hz) power of single trial data averaged with respect to attended (black) and unattended (gray) tones are shown for higher- and lower-SES children. Difference theta power waveforms (attended minus unattended) are shown below the standard waveforms (thick black lines). The 99% confidence limits calculated from prestimulus difference waveforms are shown as dashed black lines.

Results and Discussion

Accuracies and false alarms for all types of tones did not differ significantly between lower- and higher-SES children; reaction times to the attended deviants also did not show any differences (see Table 2). In contrast, the early Nd amplitudes were more negative for higher- than lower-SES children (based on bootstrap sampling of the baseline difference waveform, $p < .001$; $r = .62$). The effects were similarly evident bilaterally in centro-frontal electrodes but were best seen at site FC3 (see Figure 1B) with a mean difference at maximum peak of ~1.1 μV, $t(26) = -2.17$, $p < .05$. No significant effect was found at Pz ($t < 1$, for maximum peak). There were no ERP latency differences between the two groups (*median* $t(26) = 1.11$, $p = .28$). In sum, the Nd brain response, which reflects selective attention, differed in the two groups of children. This differential pattern of ERP activity was associated with a gross midfrontal cortical location with no significant laterality differences.

Female and male participants within the two SES groups exhibited similar Nds when the ERP data from these subgroups were inspected separately. Mean Nd amplitude did not yield significant differences associated with gender within either SES group (lower-SES: $Z = .24$, $p = .88$; higher-SES: $Z = .64$, $p = .52$) or when the two SES groups were collapsed ($Z = .98$, $p = .33$). Furthermore, there were no significant interactions between gender and SES ($F < 1$). These results suggest that the observed Nd effects were not attributable to gender.

A late Nd was also present at 600–800 ms, and was more negative in higher-SES than lower-SES children (see Figure 1B) with similar scalp distribution as the early Nd. The late Nd is thought to reflect differences in subsidiary processes associated with maintaining the attentional trace in working memory to monitor response (Naatanen, 1990) and as such it is collinear to the early Nd.

As reported in Table 1, lower-SES children were significantly older than the higher-SES children, thus the Nd effects were actually *opposite* to what one would expect from the substantial knowledge base in literature (see especially Berman & Friedman, 1995). Namely, one would have expected to find absence or reduction of Nd in the younger (higher-SES) group, but we actually found this in the older (lower-SES) group. Nevertheless, we did have some age variability and a small sample. Hence, given that group ages are "nested," to evaluate the presumed role of the "individual ages" (as a covariate) in the abovementioned results we conducted further analyses using a simple hierarchical regression model that emulates analysis of variance (ANOVA) contrasts, and relative levels of between-subjects and repeated-measure factors, with adjusted degrees of freedom (Sackett & Shortt, 1995). When we controlled for age, the effect of SES on the Nds at electrode FC3 did not change: $t(25) = 2.15$, $SE = 2.56$, $p < .05$. Conversely, regression of age onto the Nds, controlling for SES level did not yield a significant effect, $t(25) = 1.11$, $SE = 5.55$, $p = .27$, whereby the variance accounted by age was less than 5%. In addition, there were no significant effects of age on accuracy $t(25) = 0.16$, $SE = 2.74$, $p = .87$; or reaction times $t(25) = 0.62$, $SE = 13.8$, $p = .54$; and across participants age was weakly correlated with accuracy, $r(28) = .06$; or reaction times $r(28) = -.04$. Based on these results, it seems unlikely that a substantial part of our findings may be due to age.

The small or absent Nd in the lower-SES children functionally implies that attentional resources reflected by evoked responses may have been allocated about equally to both the unattended and the attended channel. However, because these children performed similarly to children with higher SES, they must have used neurocognitive processes other than those used by their higher-SES counterparts. To investigate this possibility, we conducted an exhaustive spectral power analysis of the single-trial EEG recordings for the gamma (>30 Hz), beta (13–30 Hz), alpha (8–12 Hz), and theta (4–8 Hz) bands in the frontal and central electrodes. As mentioned in the Introduction, frontal midline theta seems to be a distinctive marker of resource allocation during heightened selective attention (Ishii et al., 1999). Thus, the results of the power analysis may provide some support for our hypothesis that, as compared with higher-SES children, lower-SES children allocated more attentional resources to irrelevant information. This analysis revealed non-phase-locked activity concurrent with Nd (encompassing a latency region that includes both early and late negative waveform differences). The results showed that lower-SES children had significantly greater event-related theta power to the unattended than attended tones between 200 and 700 ms ($p < .001$, $r = .59$; see Figure 1C), whereas higher-SES children showed very small or no differences in theta power between the tones. An important finding was no significant power difference between attended and unattended channels for all other EEG bands in both groups. Thus, the results from the power analysis provide

Table 2

Behavioral Profiles (and Statistical Comparisons) of the Two Groups of Children in Relation to the Auditory Selective Attention Task

	Socioeconomic status				
	Higher	Lower	$t(26)$	P	r
	(Accuracy)				
Hits	72.67 (26.46)	76.46 (18.87)	−0.65	.52	.12
False alarms	3.13 (3.76)	2.76 (3.81)	0.38	.69	.07
	(Reaction times[a])				
Hits	579.08 (64.78)	616.06 (183.66)	−1.09	.28	.19
False alarms	584.79 (179.45)	590.86 (214.37)	−0.11	.91	.02

Note. Values represent group means (values in parentheses represent standard deviations) collapsed across tone frequency conditions, which did not reveal significant differences on preliminary analyses. Accuracy is in percentage; reaction times are in milliseconds.

[a] These data were based only on trials with attended deviant tones, which required manual response.

some support to the conjecture that lower- and higher-SES children could have used different processes to attend and respond selectively, meaning that they could have heightened their level of attention to irrelevant information.

Conclusions

The major and novel finding in this study is that we observed two different patterns of Nd brain response, which reflects selective attention, in two groups of children with different SES. The Nd effect was present in the higher-SES children but absent in the lower-SES children, which suggests that in the latter group, attentional resources, as reflected by ERPs, were allocated about equally to both the unattended and the attended channel. That is, lower-SES children attended to irrelevant information about as much as they attended to relevant information.

One interpretation of the Nd differences between lower- and higher-SES children is that lower-SES children did not use the selective attention mechanisms that are customarily associated with the evoked Nd waveform in the same way that higher-SES children did. This conclusion is supported by the finding of a different pattern of theta activity in the two groups of children. Lower-SES children had significantly greater event-related theta power to the unattended (irrelevant) than the attended (relevant) tones, whereas higher-SES children showed very small or no differences in theta power between the two types of information. Consistent with previous data on theta activity (Ishii et al., 1999), these findings suggest that lower-SES children may have allocated additional resources to also attend to irrelevant information, as compared with the higher-SES children.

An alternative explanation may be formulated in terms of theories of selective attention that postulate multiple resources (Navon & Gopher, 1979; Wickens, 1984). When confronted with tasks such as ours, the higher-SES children may have developed a preference to use *early selection* and may filter out distracters at the level of sensory registration in the stream of auditory information processing. Therefore, resource allocation would reflect control processes specifically related to the auditory modality. On the other hand, in the same type of informational situation, our lower-SES children may have developed the preference to use *late selection*, which may be attributable to the deployment of additional control processes that monitor inputs from the various channels within a modality or from various modalities, thereby putting the filter at the level of cognitive resources that control access to the response.

The present findings appear to challenge the view that low SES should necessarily have a negative influence on children's performance, as the group differences of ERP activity observed in lower- and higher-SES children did not entail a performance gap. Given that lower- and higher-SES children live in very different environments (e.g., Evans, 2004), from a neural selectionist-constructivistic perspective (Quartz & Sejnowski, 1997) it is plausible that these two groups may develop experience-dependent patterns of neural activity differentially and preferentially associated with selective variations in attention (and presumably related executive functions) in response to the different types of information-processing challenges they most frequently encounter (see Mezzacappa, 2004). On the other hand, our findings (and the selectionist-constructivistic interpretation of them) are compatible with the implication that lower-SES children may need to exert more effort (resources) to perform like their higher-SES counterparts. In more complex tasks, where these children may be unable to deploy early selection to single out appropriate features (presumably more automatically), resources deployed for late selection may compromise the ability to manage information load and higher-order processing, resulting in more prominent differences in performance on these more complex tasks.[3]

It is important to note we did not assess the most extreme tails of the SES spectrum. Rather, we compared two SES groups that were located in the "midextremes" on both sides of the distribution assumed by the particular SES measure we used. In spite of this and the relatively low statistical power in our analyses, we found a striking relationship between ERPs and SES measures, which suggests that it should be possible to detect even larger ERP differences between lower- and higher-SES children if these two samples came from the two "real" most extreme tails of the SES distribution. In fact, although Lauinger et al. (2006) used only one measure of SES and studied different selective attention tasks (as well as different age groups), they used a similar sampling strategy obtaining a similar sample size to ours, and their findings appear to be consistent with those reported here. This consistency seems to further bolster what might be observed if the sampling limitations of the present study were overcome. Opportunities for improvement in future research include a sampling strategy that could lead to secure larger samples cutting across the entire SES spectrum, including children with different ethnic backgrounds (e.g., minorities), since our sample size was too small to systematically address the critical role of individual and cultural differences in modulating the effects of SES. A step further would be to extend this study by investigating fundamental variables, such as family dynamics and children's SES-related experiential aspects, which may enable us to explain at a deeper level the relationships we found.

In conclusion, we have reported evidence of the brain's event-related potential differences (i.e., Nd) between lower- and higher-SES children *without* differences in their concurrent performance. EEG power analysis suggests that children from the two groups recruited different neural processes to obtain similar performance levels. Moreover, the behavioral data and the time course of the brain responses support the hypothesis that, relative to higher-SES children, lower-SES children engaged other supplementary neural mechanisms to also attend to irrelevant auditory information. Although preliminary, the present findings represent a first important step to understand the complex social environmental factors that shape neural and cognitive processes in children.

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[3] We thank one reviewer for suggesting the ideas behind and also suggesting text to develop this final sentence.

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