Lower socioeconomic status is associated with greater neural responses to deviance in the ambient environment

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Abstract

The early life experience of people varies by socioeconomic status, raising the question of how this difference is reflected in the adult brain. An important aspect of brain function is the ability to focus on a task while maintaining the ability to detect salient changes in the task-irrelevant background. Here we ask whether SES, as measured by perceived social standing, is reflected by the way brain signals, measured with an electroencephalogram, correlate with detecting changes in irrelevant information. We study electrical brain activities in the frontocentral region to a series of auditory tones composed of "standard" (80%) stimuli randomly interspersed by "deviant" (20%) stimuli while subjects were engaged in visual tasks. In study 1, participants focused on a silent documentary movie with captions ($N = 16$); in study 2, participants ($N = 42$) focused on image sequences incorporating neutral or negative content. Both studies showed stronger automatic change detection indexed by mismatch negativity (MMN) in lower SES individuals, regardless of sound features, emotional content, or study types. In addition, a larger MMN was observed despite comparable task performance across SES. Our study indicates low SES participants' higher sensitivity to detect ambient auditory changes.

Keywords: auditory change detection, socioeconomic status, mismatch negativity, adaptation

We often ignore sounds that are irrelevant to a currently pursued goal in order to focus. Nevertheless, automatically detecting changes in ambient sounds is also vital - a sharp noise suddenly standing out in the background may signal threats and require a rapid escape (May et al., 1999). These auditory deviances may be particularly salient to individuals low in socioeconomic status (SES), a construct measuring objective resources (e.g., income, education, neighborhood quality), or subjective social standing (Farah, 2017). Lower-SES (LSES as opposed to HSLS as higher-SES) individuals are more likely to live in chaotic and unsafe environments and feel inferior in their community, both of which can make LSES people more vigilant to unpredicted physical or social threats (Ellis et al., 2017; Evans, 2004; Kraus et al., 2011; Manstead, 2018). In other words, physical and social environments associated with LSES may alter how individuals automatically detect changes in the ambient environment. However, direct evidence concerning automatic change detection in relation to SES remains unavailable.

The current study examines the link between automatic auditory change detection in young adults in relation to their childhood SES. By *automatic*, we mean that the changes are detected without deliberate attention allocation. Prior research on SES effects has mainly focused on effortful attentional control, and most relevant to our current investigation are findings that LSES children appeared to show attenuated selective attention, the ability to enhance relevant signals and manage distraction (Breznitz & Norman, 1998; Hoyer et al., 2022; Norman & Breznitz, 1992). Compared with HSES, LSES children in these studies were more sensitive to task-irrelevant information that they were supposed to ignore. For example, they performed worse when distractors interfered (e.g., incongruent trials in Flanker task, Mezzacappa, 2004), made more impulsive responses to task-irrelevant stimuli (Hoyer et al., 2022), recognized more distracting, irrelevant images in reading materials (Norman & Breznitz, 1992), and chose a lower signal-to-noise ratio when hearing a speaker's voice against noisy background conditions (Evans et al., 1995).

Without obvious performance differences (e.g., reaction time and accuracy), some recent studies further illustrate SES-related differences in auditory selective attention in the brain level (D'Angiulli et al., 2008; D'Angiulli, Weinberg, et al., 2012; Li et al., 2022; Stevens et al., 2009, 2015). In these studies, participants were instructed to attend to sounds in one ear while sound inputs were played binaurally (e.g., Stevens et al., 2009), or to a specific type of tones while ignoring others in a sound sequence (e.g., D'Angiulli et al., 2008). Selective attention is reflected by larger event-related potential (ERP) amplitudes evoked by attended than unattended stimuli. However, the cited studies consistently found that LSES participants demonstrated reduced differences in ERP of attended and unattended stimuli. These studies attributed the reduced selective attention in LSES to a lack of suppression of task-irrelevant information. This is evidenced by the findings that LSES had similar ERP amplitudes with HSES to attended probes but stronger ERP responses to the unattended ones (Stevens et al., 2009), and that LSES showed higher theta power to the unattended than attended tones (D'Angiulli et al., 2008; D'Angiulli, Weinberg, et al., 2012).

Although LSES people are more sensitive to task-irrelevant information, their comparable performance with HSES people warrants alternate interpretation rather than attention

deficits. Alternatively, these SES effects might be viewed as an adaptation to living in chaotic and unpredictable environments (D'Angiulli, Lipina, et al., 2012; Norman & Breznitz, 1992). An overly strong focused attention can result in difficulties in detecting salient changes in the surrounding environment (Rivière et al., 2017), but a more diffuse mode of attention may help LSES allocate attention broadly and detect potential threats in one's surroundings. This adaptive interpretation is congruent with the evolutionary-developmental perspective, which proposes that adverse environments, rather than exclusively impairing cognitive functions, may enhance some aspects of cognition relevant to surviving in harsh environments (see Ellis et al., 2017 for a review of this perspective).

The current research, which also investigates the SES effects on processing task-irrelevant, unattended auditory information, nevertheless concentrates on a different type of cognitive processing. It has been argued that more effortful control might compensate for the lack of suppression of irrelevant stimuli on performance (D'Angiulli, Weinberg, et al., 2012), and training on self-regulation of attention could also improve selective attention effects in LSES (Neville et al., 2013). In contrast, automatic change detection, the focus of our current research, can take place without effortful attention (Näätänen et al., 2007; Näätänen & Kreegipuu, 2011; Sussman et al., 2014) and thus, may rely on different neural mechanisms from selective attention. Therefore, examining SES and automatic change detection could reveal unique aspects of how the SES-cognition relation is represented in the brain, and provide further evidence regarding the adaptive interpretation of the SES differences in cognitive functions.

To test our hypothesis that automatic change detection and its neural representations vary as a function of SES, we assessed mismatch negativity (MMN), an ERP component evoked by small deviations in a sequence of regular auditory stimuli that usually peaks at around 100 - 250 ms from change onset (Näätänen et al., 2007; Näätänen & Kreegipuu, 2011). Because MMN can be elicited during passive listening situations and is to a large extent unaffected by top-down information processing, it reflects a more bottom-up influence and how the brain represents a violation of regularity in sensory inputs (Näätänen et al., 2007; Näätänen & Kreegipuu, 2011; Sussman et al., 2014). MMN has been extensively used to study mental disorders (meta-analysis for MMN relation to autism, depression, and schizophrenia: Schwartz et al., 2018; Tseng et al., 2021; Umbricht & Krljes, 2005) and individual differences in healthy adults regarding personality, impulsivity, and psychosocial functioning (Franken et al., 2005; Hansenne et al., 2003; Light et al., 2007).

In the current study, we recorded MMN in a cohort of young adults who reported their childhood SES retrospectively. During ERP recording, participants were asked to pay attention to visual tasks while ignoring irrelevant sound streams. We predicted that young adults with lower childhood SES would have greater brain responses to auditory change detection reflected by greater MMN amplitude. In addition to this main hypothesis, we performed an exploratory examination of the MMN relation to SES across different contexts with varying attentional load and stimuli salience.

Methods

Participants

As no study has previously investigated electroencephalogram (EEG) MMN and SES in an adult sample, we conducted a simulation-based power analysis (Kumle et al., 2021) for Study 2 based on the effect size of Study 1 with a small sample size (N = 16). The result from 1,000 simulations suggested that at the significance level of 0.05, a sample size of 40 is needed to reach the power of 95.9% (95% *CI* = 94.48 to 97.04)

Participants were recruited from Cornell University. Exclusion criteria were medication use that could affect the nervous system and any neurological or psychiatric illness history. Data collection for Study 1 took place with 20 participants for another study aim ((Hao, Yao, Sun, et al., 2019), among whom four did not report SES. Study 2 collected data from 50 participants, among whom one fell asleep right after the recording started, and four did not report SES. Three additional people did not show clear MMN waveform. Thus, the final valid sample size is 16 for Study 1, and 42 for Study 2. All participants are right-handed. See Table 1 for demographic information for both studies. The Cornell University Institutional Review Board approved the study. Informed consent was obtained, and participants were compensated with either course credits or $20.

Table 1. Participants' demographics.

Sample	**Study 1** (N = 16)	**Study 2** (N=42)
Gender (women)	81.3%	66.7%
Age	M = 19.94 SD = 2.32	M = 21.93 SD = 3.79
Race	Asian: 8 or 50% White: 6 or 37.5% African American: 2 or 12.5%	Asian: 33 or 78.6% White: 9 or 21/4% African American: 0 or 0%
SES	Range: 3-9 Median = 7 Mean = 6.63 SD = 1.39	Range: 3-9 Median = 6.5 Mean = 6.07 SD = 1.44

SES measurement

Subjective SES was measured by the MacArthur Scale of Subjective Social Status, which assesses a person's perceived rank relative to others in their group (Adler et al., 2000). It has been found by a large body of interdisciplinary literature to have an important role in affecting

later health outcomes and psychological and brain functioning, above and beyond those of objective measures such as income, job prestige, or education (e.g., Adler et al., 2000; Anwyl-Irvine et al., 2021; Hoebel et al., 2017; Singh-Manoux et al., 2005). Participants used a nine-rung 'social ladder' to rank their family social standing during childhood compared with the community they lived in since it is more salient for the immediate community they compare themselves to rather than the general concept of their whole country, as it reflects the immediate environment and social interactions (Cundiff et al., 2013). Higher scores indicate higher childhood family social standing, ranging from 1 to 9.

In our sample (combined $N = 58$), SES is not related to age ($p = 0.737$), gender ($p = 0.680$), or race ($p = 0.200$). Perceived Stress Scale (Cohen, Kamarck, & Mermelstein, 1984) was administered in Study 2 because it has been shown to be related to SES (Steen et al., 2020). Indeed, in our sample, lower SES is associated with greater perceived stress ($r = -0.36$, $p = 0.012$).

Experiment

In Study 1, we instructed participants to watch muted movies of their own choice (details see: Hao, Yao, Sun, et al., 2019) while the stream of task-irrelevant auditory tones was playing; in Study 2, we asked participants to watch a series of images and press the space bar as soon as each image appeared. In both studies, the presentation of the auditory stimuli was the same, as described below in detail. The participants were also told to focus on the information on the screen and ignore the background sound. In Study 2, prior to the experiment, participants did a flanker task indexing inhibitory control (Eriksen & Eriksen, 1979). Because there is no SES effect on flanker performance (all $p > 0.226$), the analyses are reported in supplementary materials (Table S1).

Auditory stimuli. Participants were immersed in auditory oddball streams 55 *dBA* via speakers that contained standard or deviant tones either in a pitch ascending or descending condition. The sound pressure level was measured with a sound meter at the location of the subject's head. The stimulus in ascending stream was the rapidly ascending pitch in frequency from 600 to 1400 Hz, i.e., 600 Hz, 800 Hz, 1000 Hz, 1200 Hz, and 1400 Hz. The stimulus in descending stream was the rapidly descending pitch in frequency from 1400 to 600 Hz, i.e., 1400 Hz, 1200 Hz, 1000 Hz, 800 Hz, and 600 Hz. Each tone lasted 50 ms. The inter-trial interval is 600 ms. The deviant in each stream was the last pitch: 1,600 Hz instead of 1,400 Hz in an ascending stream and 400 Hz instead of 600 Hz in a descending stream. Each block consisted of 144 standards and 36 deviants (80/20 ratio), roughly 2.5 minutes in duration. Ascending stream and descending stream, each repeated 9 blocks. In total, there were $36 \times 18 = 324$ deviants in each sound condition and 648 deviants in total for each participant. The first 10 trials in each block were standards (to establish the expectation), followed by a pseudorandom distribution of standards and deviants, avoiding consecutive deviants.

Visual stimuli. In Study 1, the visual stimuli were muted movies based on participants' choices, following the standard auditory MMN paradigm. In Study 2, visual stimuli were images selected from the IAPS database (Lang et al., 1997). We included emotional images to

manipulate visual attention (Schupp et al., 2006). All selected images were within 2.2 standard deviations of the standard ratings for both valence and arousal levels. In addition, the valence ratings ranged from 1 to 3.8 for the selected negative images and from 4.5 to 5.5 for the selected neutral images. Each image presentation duration was 5000 ms (± 100 ms jittered) with an inter-stimulus interval of 1000 ms (± 100 ms jittered). Twenty images formed a block with different conditions: 1) all neutral image condition, 2) all negative image condition, and 3) dynamic image condition that randomly mixed 10 negative and 10 neutral images. Dynamic image condition was included based on our prior study showing that it taxes more executive functioning (Hao, Yao, Smith, et al., 2019). Each image sequence condition was repeated 3 blocks, and no one image was repeated. Therefore, this is a repeated within-subject 3 image sequence condition (neutral vs. negative vs. dynamic) by 2 sound condition (ascending vs. descending) by 3 repeated blocks design. In total, 18 blocks were presented in pseudorandom order with the constraint that no same combination of image and sound conditions appeared sequentially (Figure 1 depicts the study procedure).

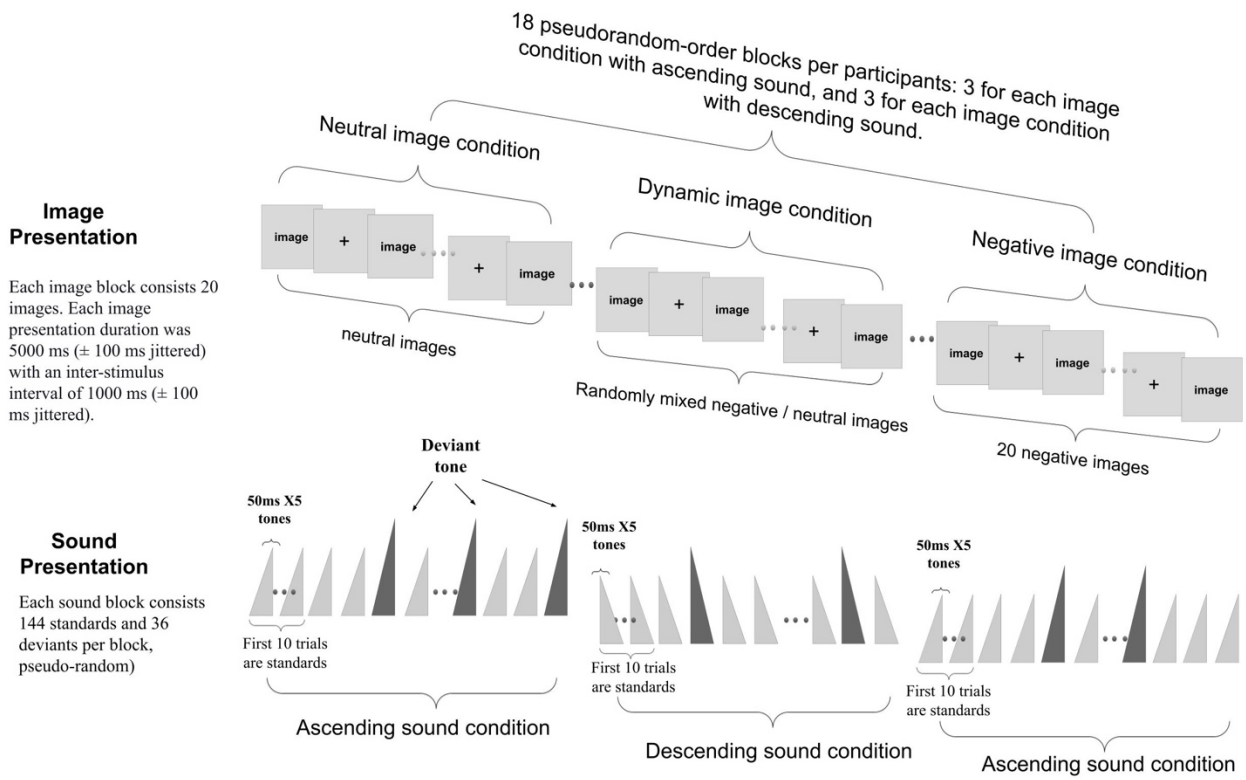


Figure 1. Study diagram

EEG recording and processing

EEG was recorded using a 128-channel BioSemi system at a sampling rate of 512 Hz. The audio and visual presentations and button presses were also collected and synchronized with EEG.

All EEG channels were referenced offline to the algebraic average of left and right mastoids and notch filtered (55~65 Hz) to remove power-line noise. ICA algorithm from EEGlab

(Delorme & Makeig, 2004) was utilized to detect and remove segments contaminated by eye movements, muscle, and cardiac artifacts. After removing the artifact components, the ICA source signals were transferred back to the original signal space, which was then used for the subsequent analysis.

For MMN analysis, the preprocessed EEG signal was further filtered within [0.5 20] Hz. Data were epoched into –100 ms to 350 ms trials, where time 0 was time-locked at the last tone of ascending or descending stimulus, which was 200 ms after the start of the complex tone pattern. The -300 ms to -200 ms period before the first tone of the trial was used for baseline correction.

If the signal surpassed ±75 μV, the trial was excluded for further analysis. The MMN waveform was calculated as the difference between the ERP evoked by the deviant stimuli and the standard stimuli. Based on the previous literature on MMN, the MMN waveforms of 100 ms to 250 ms time window at the frontocentral electrodes were selected and averaged (Biosemi labeling: A1, C23, C21, C2, C11, D2, C24, see Figure 2A) to form a single MMN for subsequent analysis. We used the mean amplitude measures in this time window (Luck, 2014). We repeated the analyses with a single electrode located at the Fz site (Biosemi labeling: C21) and reported the results in the supplementary materials.

Statistical Analyses

Analysis of ERP. We assessed the strength of the relation between SES and MMN using mixed effect models with each experimental condition nested in each participant as a random effect. Gender, age, and race were covaried in all models. Mixed effect modeling was carried out with the package "lme4" (https://github.com/lme4/lme4/) in R. All coefficients reported were standardized to make effect sizes comparable across measures.

First, SES main effect on MMN was reported for Study 1 and Study 2 separately. Second, we conducted an exploratory examination of the differing strength of the relationships between SES and MMN within different contexts: sound frequency features (ascending or descending that can influence MMN amplitude), task types (that can influence control load), and emotion (that can influence visual attention). Specifically, in Study 1, we incorporated a 2-way interaction term of sound condition and SES, and in Study 2, the 3-way interaction term of image condition, sound condition and SES. To explore if MMN relation to SES would be differ by task types (Study 1 vs. Study 2), we combined our two studies with each data point representing each participant's MMN averaging across conditions. We then analyzed the MMN relation to SES, incorporating an interaction term of Study and SES.

Analysis of reaction time to images. This analysis is specific to Study 2. We first removed trials with reaction time (RT) greater than 1500ms, leaving the majority (80%) of the participants had missing values of at most 10% for each image condition that contains 60 trials. Removing the 9 people with missing values over 10% for one or more conditions did not change conclusions about SES relations to RT; therefore, we reported the results including the whole Study 2 sample.

Before fitting the mixed linear model, we first averaged the RT across the 3 blocks within each condition for each participant, leading to a total of 6 RT values per person. Log transformation was applied to RT due to the right skewness of RT distribution. The model tested the main effects of SES, sound feature, and image sequence, and the two-way and three-way interactions among them, controlling for demographic covariates. Random effects were modeled for the sound feature and image sequence condition nested within each participant, separately. Additionally, to directly examine whether the possible SES-related MMN differences is related to behavioral task performance, we fitted another mixed linear model for log RT on MMN with the same random effects and covariates as mentioned above.

Results

Brain responses to changes in irrelevant sound are predicted by SES

There is a clear auditory evoked component at around 150 ms after the onset of the deviant sound. MMN amplitude is significantly associated with SES in Study 1 ($p = 0.0004$) and Study 2 ($p = 0.0006$), controlling for demographic covariates and experimental conditions. In both studies, none of the covariates show significant main effects, and only the sound condition showing ascending sound stream elicited greater amplitude (both $p < 0.01$). Statistics of the full models are shown in Table 2. Figure 2 depicts the MMN waveforms of each individual and MMN amplitude in relation to SES for Study 2 specifically.

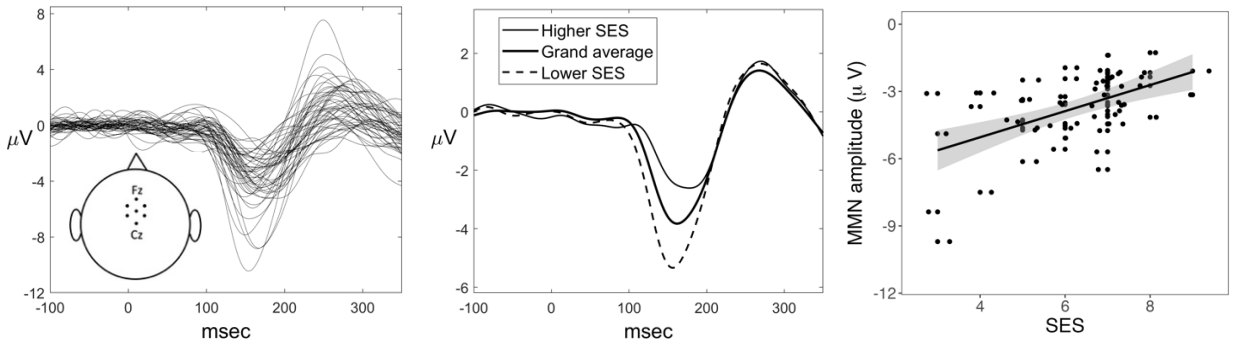
Table 2. Statistics of MMN amplitude and its relation to SES and other predictors. Standardized beta coefficients (standard error) are reported for ease of interpreting effect sizes.

	Study 1 (*N* = 16)	**Study 2** (*N* = 42)
MMN amplitude (μV)	-2.79 (0.29) 95% *CI* = -3.35 to -2.22	-4.08 (0.25) 95% *CI* = -4.61 to -3.63
SES	0.58 (0.16) *** 95% *CI* = 0.27 to 0.89	0.39 (0.11) *** 95% *CI* = 0.17 to 0.61
Sound condition (Low sound as reference)	High: -0.89 (0.28) **	High: -0.40 (0.08) ***
Image condition (Neutral image as reference)	NA	Negative: -0.01 (0.10) Dynamic: 0.07 (0.08)
Gender (Female as reference)	Male: -0.01 (0.46)	Male: -0.16 (0.28)
Age	0.06 (0.18)	-0.08 (0.13)
Race (Asian as reference)	White: 0.27 (0.32) African American: 1.22 (0.52) *	White: 0.06 (0.30) African American: NA

Notation: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

To examine if the effect of SES on MMN would differ by contexts, we conducted exploratory analyses by testing the interaction of the experimental conditions with SES on MMN. We found none of the interactions are significant (all $p > 0.112$). Additionally, controlling for perceived stress does not influence the SES effect ($p = 0.0007$). See supplementary Table S2 for MMN amplitude and SES relation separately for each experimental condition.

Furthermore, we examined if MMN relation to SES differs across studies. Because the effects of SES are not affected by experimental conditions in either Study 1 or Study 2, we averaged MMN across conditions for each participant. The interaction is not significant ($p = 0.6119$), and the SES main effect held ($\beta = 0.53$, *S.E.* = 0.11, 95% *CI* = 0.31 to 0.75, $p < 0.0001$), meaning the MMN SES relation does not vary by study type.



(A) (B) (C)

Figure 2. (A) Waveforms of MMN in the frontocentral region for each participant. The MMN waveforms are the grand average of the 7 electrodes around Cz and Fz channels and are averaged across experimental conditions for each participant. (B) Waveforms of MMN for higher- vs. lower-SES groups. To visualize the SES groups, we selected individuals above 1 standard deviation from the mean of SES measure as high SES group (SES > 7.5, 5 people) and individuals below 1 standard deviation from the mean of SES measure as low SES group (SES < 4.5, 8 people). (C) Scatter plot of MMN amplitude for each individual in relation to SES.

We also repeated the analyses with MMN from a single electrode located at Fz, the results of which do not differ from the grand averaged MMN across electrodes around frontocentral region (Table S3 & Figure S1). Taken together, lower SES is associated with greater brain detection to sound changes and this effect is invariant across sound features, emotional contexts, and study types.

Behavioral performances in attended tasks are invariant across SES

SES is not associated with RT in any experimental conditions (all $p > 0.529$; statistics see Table S4). Although all participants performed well in the image detection task across different image conditions (mean RT = 423.74 ms), the RTs ranged from 222.07 to 943.81 ms, and about half of the RTs (median = 413.11 ms) are greater than the mean, indicating that the task is not too easy to causing ceiling effect. Nevertheless, participants reacted slower to negative images than neutral ones in both ascending ($p = 0.029$) and descending sound conditions ($p = 0.008$)

(Figure S2), confirming that our study successfully manipulated emotional context (Pereira et al., 2010). Additionally, the model for MMN on log RT shows neither a main effect of log RT nor an interaction between condition and log RT (all $p > 0.171$). In conclusion, lower-SES participants focused on the task as their higher-SES peers did.

Discussion

In daily life, we process multiple sensory information simultaneously with different priorities. For example, we may focus on reading a textbook and simultaneously suppress repetitive noise from construction; but we may still monitor background sound sources to catch all important calls. We examined the link between SES and adult brain responses to sound changes that are irrelevant to task goals in a healthy population using perceived social standing during childhood as an indicator for SES. We find that those brain activities of automatic change detection reflected in MMN are consistently stronger in those with lower SES backgrounds. This occurs independently of attentional load in the attended tasks or auditory stimuli that could influence the sustained allocation of attention salience and the overall MMN amplitude.

SES relation to automatic change detection in the acoustic environment

To our knowledge, no studies have formally investigated how SES is associated with adult brain detection of task-irrelevant auditory changes. Given the interest in SES effects on cognition and the role of neural processes in such SES effects, our study expands upon this literature.

The current study extends prior findings on SES concerning the neural processing of irrelevant information using a selective attention paradigm (D'Angiulli et al., 2008; D'Angiulli, Weinberg, et al., 2012; Li et al., 2022; Stevens et al., 2009, 2015). First, we examined this question with multi-modalities, i.e., visual and auditory information. Second, while prior studies compared brain activities in processing attended and unattended auditory sources, we examined brain activities specifically to changes in unattended auditory sources. The degree of processing for unattended sound change is stronger in low SES, which started at a very early time.

Third, unlike prior studies using objective SES measures (e.g., maternal educational attainment or family income), we employed a validated measure of subjective SES, which may provide a more comprehensive index to capture SES in relation to health and brain functions (Adler et al., 2000; Anwyl-Irvine et al., 2021; Hoebel et al., 2017; Singh-Manoux et al., 2005). For example, subjective SES is related to perceived stress shown in our sample, which could support its gradient in measuring SES (c.f., Steen et al., 2020). We also controlled for other potential confounding variables, such as age, gender, race, and perceived stress (Study 2 only), which permitted more strict evaluations of the link between SES and brain functions. By recruiting from a top university in the United States, we were able to minimize the variance in participants' current objective SES (e.g., their educational attainment), thus, suggesting correlates of subjective childhood SES. As a result, we observed striking differences in auditory processing of change detection of irrelevant information based on differences in perceived social standing in their childhood.

Furthermore, we found that the SES effect on MMN is invariant across contexts through exploratory examination. Affective stimuli can impact attention and compete with other sources of top-down control on perception (Vuilleumier, 2005), and processing emotional contexts with varying valence and arousal levels (i.e., the dynamic condition in the current study) has been shown to tax more executive functioning (Hao, Yao, Smith, et al., 2019). Nevertheless, behavioral responses to images were invariant across SES, meaning they might not differ in the attended task regarding visual attention. Across different emotional contexts that participants attended, low SES was consistently associated with greater brain responses to unattended auditory changes. Moreover, the SES effect also held across different sound conditions or study types. However, interpreting no interaction as invariance in larger MMN response in lower SES requires caution because detecting significant interaction effects needs a much larger sample size (Gelman et al., 2020).

Enhanced neural response to deviance as a possible adaption to LSES environment

Automatically detecting changes in task-irrelevant information is necessary and even beneficial, given that unpredicted salient events could take place anytime in the background. From the adaptation perspective (D'Angiulli, Lipina, et al., 2012; Ellis et al., 2017), this type of change detection should be especially important for LSES people because they often live in more chaotic, unpredictable environments (D'Angiulli et al., 2008; D'Angiulli, Lipina, et al., 2012; D'Angiulli, Weinberg, et al., 2012; Ellis et al., 2017), and may feel inferior to others during social interactions (Wilkinson & Pickett, 2006), both of which make them sensitive to subtle changes that may signal physical or social threats. Herein we have shown that adults with lower childhood social standing had greater neural responses to automatic change detection in task-irrelevant sound. This may arise from adaptation to early life experiences.

The generation of MMN has been argued to reflect a failure of the brain to suppress prediction error (i.e., the discrepancy between the actual sound input and the brain's prediction of it), and the adjustment of the brain's prediction model (Garrido et al., 2009). When the brain makes precise predictions of the input based on the previously learned regularity, it gives less weight to the bottom-up influence of sensory input, leading to a reduced post-synaptic responsiveness to the input (Garrido et al., 2009) and a suppressed prediction error response (i.e., MMN). Conversely, brain's prediction precision is reduced when deviances occur, and it assigns more weight to the unexpected events and consequently enhances the salience of the deviances.

Therefore, the amplitude of MMN is argued to be linked to the precision of the brain's predictive model of sensory input, as well as the salience of the input that this precision can modulate (Fitzgerald & Todd, 2020; Quiroga-Martinez et al., 2020, 2021). Although previous studies have shown that the precision of the predictive model can be modulated by attention, a more plausible explanation for our current finding is that extra neural weights were assigned to the unexpected sound change in LSES participants due to the greater salience of these deviant sounds perceived by their brains without conscious awareness. From the adaptation perspective, for LSES people, deviances may be more likely to signal threats and dangers in their environment and, in turn, are taken more seriously than for HSES people. The deviant sounds

may require more cognitive resources in LSES than HSES individuals and be processed with higher priority at the early auditory processing stage. Consequently, a salience-related enhancement in MMN amplitude may occur without our LSES participants paying more attention to task-irrelevant sounds.

Taken together, our finding does not necessarily indicate lower-SES participants were less capable of inhibiting distractions (also evidenced by similar flanker task performance across SES in our sample). Instead, they might just be used to not doing so. However, more responsiveness to the environment, noticing and responding to subtle changes, might seem advantageous, but it can be costly as a "reactive" coping style (Aron et al., 2012).

Limitations and future directions

The current study has a few limitations. First, it remains to be seen whether our findings can be generalized to populations other than college students and what the full ramifications of these neural differences might be. Nevertheless, this study makes an essential first step by establishing that SES and neural responses underlying change detection of irrelevant information processing are linked. In addition, given that our sample had similar behavioral responses to attended stimuli, our findings highlight the small differences in cognitive ability yet larger neural effects manifested by perceived social standing.

Second, although childhood SES is associated with adults' brain structure and functions, even controlling for adult SES (Loued-Khenissi et al., 2022; McDermott et al., 2019), we didn't examine participants' current SES. Given that research has shown continued development in young adults' brains, especially in the prefrontal cortex (Kolk & Rakic, 2022; Sowell et al., 1999), future studies may examine how childhood and adult SES may jointly influence neural functions in young adults.

Lastly, using mediation analysis, previous studies have shown the partial mediating role of brain differences in the SES-cognitive ability association (e.g., Finn et al., 2017; Hair et al., 2015; Noble et al., 2015). We do not know the behavioral consequences of sensitive detection of changes associated with SES. Our study does not imply that behavioral differences are absent. Our sample is from a highly selective university, and our cognition task is simple. Future studies may consider employing more challenging and comprehensive cognitive measures to see if there are other possible behavior differences related to automatic change detection across SES.

In conclusion, prior selective attention studies have found SES differences in processing irrelevant auditory information. In the current study, we further uncovered that change detection in ambient sound also varied by SES. Although the mechanisms of this association and how the SES-related differences in MMN may affect other behavioral outcomes are still under investigation, the current study serves as an important initial step in exploring the mechanisms and a possible causal pathway between SES, brain, and cognition.

Author Contributions

Y.H. developed the study concept, designed the experiment, and collected the data. Y.H. and L.H. analyzed the data and wrote the paper.

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Declaration of Conflicting Interests: None.

Data availability

The dataset and code for the current study are available from the corresponding author on reasonable request.

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