The Effects of Socioeconomic Status on Brain Structure and Function

Authors: Lü Ziyang, Peng Kaiping, Hu Chuanpeng

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Abstract

The relationship between socioeconomic status (SES) and brain structure and function is of significant importance for understanding the influence of socioeconomic factors on psychological and behavioral outcomes and for the prevention of brain/mental illnesses. Over the past decade, researchers have employed cognitive neuroscience approaches to investigate the relationship between SES and the brain, revealing associations between SES indicators and brain structure and function, though the consistency of conclusions across different studies remains unclear. This article reviews cognitive neuroscience research on the SES-brain relationship from two dimensions—brain structure and function—organized around two major themes: cognition and emotion, and subsequently compares the convergent and divergent findings across studies. The results indicate that (1) at the structural level, SES may be correlated with the hippocampus and prefrontal cortex, which subserve memory and executive function, as well as the limbic system involved in emotional processing; (2) at the functional level, individuals from different SES backgrounds may exhibit differential brain activity patterns in regions associated with executive function, learning, and memory, and brain activity elicited by emotional and reward processing may also vary across SES levels. Notably, due to challenges including the complexity of SES, the dynamic nature of brain development, the multi-level nature of SES influences on the brain, and methodological rigor, stable conclusions cannot be drawn from existing research. Therefore, this article further suggests that future studies must not only address these challenges but also consider cultural differences, thereby enabling a more accurate understanding of the SES-brain relationship and informing social policy.

Full Text

The Effects of Socioeconomic Status on Brain Structure and Function

Lyu Ziyang[1], Peng Kaiping[1], Hu Chuanpeng[2,3]

[1] Department of Psychology, Tsinghua University, Beijing 100084, China
[2] Neuroimaging Center (NIC), Focus Program Translational Neuroscience (FTN), Johannes Gutenberg University Medical Center, 55131 Mainz, Germany
[3] Deutsches Resilienz Zentrum (DRZ), Johannes Gutenberg University Medical Center, 55131 Mainz, Germany

Corresponding Authors:
Peng Kaiping, Email: pengkp@mail.tsinghua.edu.cn
Hu Chuanpeng, Email: hcp4715@hotmail.com

Abstract

The relationship between socioeconomic status (SES) and brain structure and function is crucial for understanding how socioeconomic factors influence psychological and behavioral outcomes and for preventing brain and mental illnesses. Over the past decade, researchers have employed cognitive neuroscience methods to explore the relationship between SES and the brain, finding associations between SES indicators and brain structure and function. However, the consistency of findings across different studies remains unclear. This paper reviews cognitive neuroscience research on the relationship between SES and the brain from two perspectives—brain structure and function—and two major themes: cognition and emotion. Based on this review, we compare similarities and differences across studies. The results indicate that (1) structurally, SES level may be associated with the hippocampus and prefrontal cortex, which are responsible for memory and executive function, as well as the limbic system involved in emotional processing; (2) functionally, individuals with different SES levels may exhibit different patterns of brain activity in regions related to executive function, learning, and memory, and brain activity induced by emotion and reward may also differ across SES levels. Notably, due to challenges such as the complexity of SES, the dynamic nature of brain development, the multi-layered influence of SES on the brain, and methodological rigor, stable conclusions cannot be drawn from current research. Accordingly, this paper further suggests that future research must not only address these challenges but also consider the influence of cultural differences to more accurately understand the relationship between SES and the brain and to provide guidance for social policy.

Keywords: socioeconomic status; brain structure; brain function; cognition; emotion

As social beings, individuals' psychology, behavior, and mental health are influenced not only by biological factors but also by social factors [1]. Socioeconomic status (SES), reflecting the social position of individuals or groups based on their access to material and non-material social resources [2], has significant impacts on both individuals and society [3-8]. The brain, as the biological basis of human psychology and behavior, serves as the foundation through which external environments—including socioeconomic factors—affect individuals' psychology and behavior. For instance, mental illnesses are largely disorders of brain function [9]. Therefore, understanding the relationship between SES and the brain is not only important for scientific inquiry but also has significant practical implications for individual and societal development. Over the past decade, researchers have conducted numerous exploratory studies using cognitive neuroscience methods to investigate the relationship between SES and brain structure and function. These research findings have already begun to guide national policy formulation [10].

However, it is worth noting that the consistency of research findings on the relationship between SES level and brain structure and function, as well as how these conclusions can guide social practice [11], still require careful examination. Given that SES itself is a complex social phenomenon with considerable controversy surrounding its measurement [12], and that the cognitive neuroscience community has recently begun to reflect on and evaluate past research [13], a review and assessment of studies on the relationship between SES and brain structure and function is highly necessary. This paper reviews cognitive neuroscience research on the relationship between SES and the brain from two levels —brain structure and function—and two major themes: cognition and emotion, and on this basis compares similarities and differences across study findings.

1. Socioeconomic Status and Brain Structure

Voxel-based morphometry (VBM) provides data on brain structure, such as gray matter volume, cortical surface area, and cortical thickness. Many researchers have used this technique to measure individual differences in brain structure and correlate them with personality traits [14], behavioral performance [14,15], and mental illnesses [16] in search of biomarkers for human behavior. VBM has also been used to explore the relationship between SES and brain structure, with studies analyzing correlations between SES indicators and overall brain structure or specific brain regions involved in particular functions, finding that individuals with different SES may differ in brain structure [17,18]. These studies on the relationship between SES level and specific brain regions can be categorized into two major functional systems: cognition and emotion.

1.1 SES and Cognitive-Related Brain Structures

Among brain structures primarily involved in cognitive processing, researchers have most frequently reported associations between SES and the hippocampus

and prefrontal cortex (PFC). The hippocampus plays an important role in human memory and is susceptible to stress [19,20]. Individuals with low SES may need to process more stress, making the hippocampus a key region in the relationship between SES and the brain. Positive correlations between childhood family income (with some studies using multiple socioeconomic indicators) and hippocampal volume have been observed in both children [21-24] and adults [25-27]. These studies seem to indicate that lower SES levels are associated with smaller hippocampal gray matter volume. However, this conclusion is not without controversy: other researchers have failed to find such correlations [23,28-30]. For example, Yu et al. [23] found that when using subjective socioeconomic status, family income, parental education, and income-to-needs ratio as SES measures, SES was negatively correlated with hippocampal volume in a sample of 8- to 12-year-olds, but this correlation disappeared in participants aged 18 to 25. A recent meta-analysis on the relationship between childhood adversity (including poverty, abuse, and neglect) and hippocampal structure indicated a small negative correlation between childhood adversity and hippocampal volume [31], though it is noteworthy that childhood adversity does not completely correspond to low SES.

The prefrontal cortex is another brain region primarily responsible for cognitive processing, involved in many higher-order cognitive activities including conflict resolution [32], moral judgment [33,34], and self-information processing [35]. Some studies have reported correlations between SES and prefrontal cortex structure. For instance, Holz et al. used the orbital frontal cortex (OFC) in the anterior prefrontal cortex as a region of interest and found a correlation between family income and prefrontal volume [36]. Similarly, Krishnadas et al. used the inferior frontal gyrus (IFG) as a region of interest and found a positive correlation between SES (measured by personal income, education, and occupation) and thickness in the right prefrontal cortex [37]. Raizada et al. [38] used marital status, employment status, education, and occupational prestige to measure SES and found only a marginally significant positive correlation between left prefrontal cortex and SES level. Kong et al. [39] found that in a young adult sample, maternal education was correlated with gray matter volume in the middle prefrontal cortex. However, studies have also failed to find correlations between SES and the prefrontal cortex, including negative results in analyses of correlations between SES and orbital frontal cortex volume [40] and left inferior frontal gyrus [41]. Therefore, although some studies report correlations between SES and prefrontal cortex structure, this relationship has not received consistent support.

1.2 SES and Emotion-Related Brain Structures

Brain regions responsible for emotional processing are primarily the limbic system, including the amygdala and anterior cingulate cortex (ACC). Current research suggests that SES level may be associated with the structure of these brain regions. An analysis of brain results from 1,099 children indicated that cor-

tical regions such as the insula, temporal pole, anterior cingulate, and posterior cingulate were associated with parental income [42]. Results for the amygdala are more complex: two studies with adult and child participants respectively reported positive correlations between amygdala volume and composite indicators of income, education, and occupation, as well as income-to-needs ratio [25,43]. However, two other studies with adolescent participants found no correlation between amygdala volume and income or parental education [24,30]. These results cannot be directly compared because the SES measurement indicators used were not identical across studies. A meta-analysis on the relationship between childhood adversity and the amygdala found no correlation between childhood adversity and amygdala volume [31], which may provide partial support for the absence of a relationship.

In addition to region-specific studies, researchers have analyzed the relationship between overall brain volume and SES in adults, finding that cortical volume, surface area, and thickness may be positively correlated with income, education, and occupation [44]. In adolescents, correlations between family income and cortical volume and thickness also exist, but not with surface area [45]. White matter volume and integrity have been associated with family income and parental education in children and adolescents [46], income, education, and community SES in middle-aged adults [47], and occupation and personal education in older adults [48].

Overall, although many studies have explored the relationship between SES and brain structure, these results lack consistency and systematicity. Methodologically, the indicators used to measure brain structure are inconsistent, with various metrics such as cortical surface area, cortical thickness, or volume being used in correlation analyses with SES, while SES measurement indicators themselves are also diverse. These indicators represent different physiological meanings, making it difficult to explain differences across studies. Additionally, researchers have over-relied on region-of-interest analyses, but the definitions of these regions vary considerably: some studies use sulci and gyri, others use Brodmann areas, and some use "dorsal," "medial," or the entire frontal lobe as a region of interest. This lack of consistency may lead to false-positive results [14].

2. The Relationship Between Socioeconomic Status and Brain Function

In addition to searching for brain biomarkers of SES, researchers have attempted to understand how different SES levels relate to brain activity. Using non-invasive neuroimaging techniques such as event-related potentials (ERP) and functional magnetic resonance imaging (fMRI), researchers have found that SES may be associated with cognitive tasks such as executive function, memory, and learning skills, and may also influence emotional processing.

2.1 SES and Executive Function

Executive function refers to a set of top-down psychological processes required when individuals need to focus attention on something, primarily including inhibitory control, working memory, and cognitive flexibility [49,50]. Current research suggests that the neural basis of executive function may be primarily the executive control network, including the dorsolateral prefrontal cortex and posterior parietal cortex [51]. ERP studies on children from different family income, income-to-needs ratio, education, occupation, and subjective socioeconomic status backgrounds have found that although participants showed no significant differences in behavioral performance on executive function tasks, there were significant differences in frontal region brain activity [52,53]. Low-SES participants showed stronger prefrontal activity during inhibitory control tasks. fMRI studies have found similar results [54]. For example, Sheridan et al. [55] found that children from families with higher income, parental education, and parental subjective socioeconomic status showed lower activity intensity in the middle frontal gyrus, inferior frontal gyrus, and anterior cingulate cortex during executive control tasks, but higher activity intensity in the right frontal sulcus. These results may suggest that children from different SES backgrounds, while showing similar task performance, may differ in their underlying neural mechanisms.

Similar patterns have been found in studies of working memory. For instance, Sheridan et al. [55] found that family income, parental education, and parental subjective socioeconomic status significantly moderated the relationship between working memory load and brain activity intensity: when working memory load was high, children with higher SES showed greater activity intensity in prefrontal and parietal regions than children with lower SES; whereas under the lowest working memory demands, children with low SES showed higher activity intensity in these brain regions than those with high SES. That is, children with high SES showed greater increases in prefrontal and parietal activity as working memory load increased. Finn et al. [56], using family income as an SES indicator, also supported this conclusion. Therefore, it can be speculated that children with different SES may have different brain mechanisms when completing working memory tasks.

2.2 SES and Learning and Memory

In addition to executive function, numerous studies have explored the impact of SES on learning and memory. Research on SES and learning has primarily focused on how SES affects children' s academic skills such as mathematics and language. Finn et al. [56] found that math achievement could be predicted by working memory ability, and that family SES (measured by income-to-needs ratio) moderated this relationship: brain activity in working memory-related regions of the parietal cortex was positively correlated with math achievement in all children, but activity in the prefrontal cortex was only positively correlated with math achievement in children with higher SES. Demir et al. [57]

found that children with different parental education levels engaged different neural systems when processing subtraction tasks: in children with highly educated parents, math ability was more strongly related to regions such as the left middle temporal gyrus, which is associated with language; in children with less educated parents, math ability was more closely related to regions such as the right intraparietal sulcus, which is involved in spatial processing. Another study found that in students with high parental education and occupational status, improvements in math ability were more strongly associated with increased activity in language-related regions such as the left inferior frontal gyrus, whereas for students with lower status, spatial processing-related regions in the right parietal lobe were more strongly correlated with math improvement [58]. These studies suggest that SES may influence the brain regions children engage in mathematical learning, though the specific mechanisms require further investigation.

Beyond mathematical ability, SES also affects brain activity related to literacy and language skills [58,59]. For example, in phonological processing, children from different SES backgrounds show different patterns of neural specialization [38,60]. Noble et al. [60] conducted an fMRI study using a composite SES indicator of family income-to-needs ratio, parental education, and occupational status, scanning children across a wide SES range while they performed a task matching visually presented pronounceable non-words. They found no difference in phonological skills between low- and high-SES children, but phonological skills in lower-SES children better predicted activation in the left fusiform language area, while the correlation between this ability and that brain region was reduced in higher-SES children. This may be because higher-SES children have more knowledge and abilities related to literacy and rely more on these abilities to complete the task rather than using phonological processing to encode letter strings. Other studies have found that parental education moderates the relationship between phoneme identification ability and activation in the left anterior brain region [61]. However, some studies have found no relationship between SES and certain language-related abilities. For instance, Monzalvo et al. [62] found in an fMRI study of children that no differences were observed between children from different parental education and community SES backgrounds in the recognition of passive voice in printed text or spoken language.

The impact of SES on the neural mechanisms of memory has not yielded consistent conclusions. Older adults with higher education and occupational status showed more accurate judgments of recent memory (associated with the prefrontal cortex), and ERP studies confirmed higher frontal activity [63]. However, a study with adult participants found that childhood poverty (measured by childhood family income-to-needs ratio) did not affect their recognition performance on a picture memory task, though childhood poverty had a marginally significant effect on hippocampal activity during recognition [64]. This effect became more significant after controlling for adult SES covariation: those who did not experience poverty in childhood showed a positive correlation between recognition accuracy and hippocampal activation, while those who experienced

poverty in childhood showed a negative correlation. Another study of children found that hippocampal activation during a paired-associates memory task was related to maternal subjective social status but not to task performance, maternal education, or income-to-needs ratio [65]. Overall, the neural mechanisms through which SES affects memory are not yet clear and may be influenced by developmental stage.

2.3 SES and Emotion

Emotion represents another important aspect of SES effects on brain function, with low-SES individuals potentially being more sensitive to negative emotions. For example, when presented with threatening or fearful faces, adolescents with low subjective socioeconomic status [66,67] and adults from low income-to-needs ratio families [68] showed stronger amygdala responses [69] and stronger medial prefrontal cortex responses [67,68] compared to high-SES groups. In mothers with low income-to-needs ratio, the medial frontal cortex showed stronger responses to crying sounds [70], and the amygdala showed stronger responses to infants' negative expressions while responses to infants' positive expressions were suppressed [71].

In emotional information processing, functional connectivity between different brain regions is also modulated by SES. Individuals with lower subjective socioeconomic status and parental education showed less connectivity between cortical and subcortical regions [68,72]. Previous research has shown that the prefrontal cortex plays an important role in emotion regulation by reducing amygdala activity. However, this effect differs across SES groups: individuals with lower childhood family income showed lower prefrontal activation during cognitive reappraisal-based emotion regulation and less reduction in amygdala activation [73]. Resting-state fMRI studies of children from low family income backgrounds found lower functional connectivity between the amygdala and hippocampus and a series of cortical regions including the right superior frontal cortex [74], and individuals with low childhood family income showed less connectivity in the default mode network (DMN) [75]. Studies using family income and parental education as SES indicators found the same trend in 6-month-old infants [76]. These studies suggest that low-SES populations may differ from high-SES populations in emotion regulation, consistent with the phenomenon of more psychiatric disorders in low-SES populations [77].

Furthermore, individuals from different SES backgrounds process reward information differently. For adults with lower parental education, personal education, and income, reward stimuli elicited lower activity intensity in frontal, anterior cingulate (ACC), and striatal regions, while negative stimuli elicited greater cortical and subcortical responses [72,78], possibly indicating insensitivity to reward but high sensitivity to loss. This may be related to decision-making in low-SES individuals in behavioral economics research: previous studies have found that poverty affects temporal discounting and risk preference, with low-SES individuals preferring immediate gains and lower risk [79]. This may represent the

physiological mechanism underlying this effect and the asymmetry between loss and expected gain.

In summary, recent findings on the relationship between SES and brain function are intriguing, with one major discovery being that individuals from different SES backgrounds may show no behavioral differences but differ in neural activity. However, precisely because of the lack of behavioral differences, differences in brain activity patterns become difficult to interpret, as we currently cannot infer individuals' psychological and cognitive activities from brain activity results. Therefore, what these differences in brain activity patterns represent remains speculative. Additionally, similar to brain structure research, the relationship between SES and brain function also shows inconsistent results.

3. Challenges in Researching the Relationship Between SES and Brain Structure and Function

A review of published literature reveals that while current research on the relationship between SES and the brain has yielded many findings, issues such as lack of systematicity and consistency hinder the integration of these results and deeper understanding of the issue. For example, SES measurement typically includes only a small number of indicators, and whether these indicators can reflect individuals' true SES levels remains questionable. Very few studies have examined the many intermediate variables between SES and brain structure or function, preventing us from understanding the mechanisms underlying the SES-brain relationship. Participants' SES and age ranges are typically small, preventing us from understanding the characteristics of the relationship between SES, age, and brain structure and function across broader ranges. Additionally, as mentioned above, differences in details of brain structure and function data analysis methods affect the comparability and integration of research findings. To better understand the relationship between SES and the brain, we must consider the complexity of SES, the dynamic nature of brain development, the hierarchical nature of SES effects on the brain, and consistency in research methods.

3.1 The Complexity of SES

As seen in the review above, the SES indicators used in research exploring SES-brain structure and function relationships are highly diverse and inconsistent. This phenomenon is not surprising, as SES itself is a very complex social phenomenon. Specifically, its complexity includes two aspects: first, the diversity of factors for accurately measuring SES; and second, the comprehensiveness of the SES range.

First, SES measurement corresponds to a diverse set of social and economic factors. Previous research on the health effects of SES has found that different socioeconomic factors affect health at different life stages (childhood vs. adulthood), at different levels (individual, family, community), through different

causal pathways, and these socioeconomic variables typically show only moderate correlations of 0.2-0.7 [12]. Similarly, research on SES and children' s math achievement has found that family income and parental education affect children' s math achievement through different pathways [80]. Therefore, to accurately measure the effects of SES, it is necessary to consider the specificity of the SES indicators measured and their mechanisms of influence on psychology and behavior. If possible, it is best to comprehensively measure and consider the effects of multiple socioeconomic factors. Additionally, special attention must be paid to the subjective construction and experience of SES. Subjective and objective SES likely show some degree of inconsistency [81-83], and subjective SES is a more proximal and direct influencing factor on psychology and behavior. Future in-depth exploration from the perspective of how objective SES affects brain function and structure through different dimensions of subjective experience and self-perception, such as narrative identity, social identity, and future identity [84], may help understand the specific mechanisms of SES effects.

Second, it is necessary to clearly locate research subjects' position within the entire social SES spectrum. Many previous SES studies have focused on poverty as the research object, but due to limitations in sample representativeness [85], the lowest-SES samples included in these studies vary greatly, with few or no individuals who are absolutely poor in some samples, making it impossible to distinguish the special role of poverty from the general role of SES. If it is the special role of poverty, then the SES-neural association only holds when SES is below a certain threshold. If it is the general role of SES, then SES across the entire range is associated with brain indicators. Existing research has found that in children, the effect of SES on cortical surface area [22] and brain volume [86] is a gradient effect across the full SES range, with greater effects at the lower end. This full-range threshold effect may reflect the combined influence of diminishing marginal effects of different influencing factors at different SES levels, or simply non-linearity in SES measurement. The existence of this long-tail effect indicates that poverty and SES are not interchangeable concepts, and results from studies based on extreme groups or large SES ranges should be interpreted separately.

3.2 The Dynamic Nature of Brain Development

From early postnatal life through maturation and aging, the human brain follows dynamic patterns of change [87,88]. Current research has found that during this process, the relationship between SES and the brain may also be dynamic, meaning SES may have different effects at different stages. For example, studies of infants and young children show that SES differences in the brain are not significant at birth [89] but emerge early in life at 4-6 weeks [90], persist thereafter [76,91], and some differences gradually increase [92]. However, some differences are temporary and may indicate that SES effects on certain functional developments during this period influence developmental trajectories and speed. Studies of children and adolescents also support that SES differences

in the brain gradually increase with age and that SES affects brain development patterns. For example, Piccolo et al. [93] examined cortical development trajectories in 1,148 participants aged 3-20 years, finding that in lower-SES participants, cortical thickness declined faster during early and middle childhood, while the rate of decline slowed during adolescence until stabilizing. In higher-SES participants, cortical thickness showed a linear decline that lasted longer. SES showed the same influence pattern on the development of the left fusiform gyrus and left superior temporal gyrus (STG). Combined with animal research on early adversity and precocious brain development [94], these studies suggest that SES may affect brain function and structure development patterns during childhood and adolescence. Future research frameworks need to further consider the dynamic process of the SES-brain relationship and explore its developmental mechanisms.

3.3 The Hierarchical Nature of SES Effects on the Brain

As a distal cause of brain differences, SES often affects individuals' brains and behavior directly or indirectly by influencing more micro-level, personal proximal causes such as chronic stress, parenting behavior, and environmental stimulus complexity (see Figure 1 [Figure 1: see original paper]). Animal studies have identified many effects of similar proximal causes on brain function, including stress, parenting behavior, and environmental complexity and diversity. Among these, stress and parenting behavior are the most studied proximal causes. Stress during development or adulthood causes numerous cellular and molecular changes in the brains of rodents and non-human primates, most commonly in the hippocampus and frontal lobes [95]. Parenting behavior is influenced by environmental factors such as stress [96,97] and plays a causal role in buffering offspring from the effects of stress [98] (in humans, parenting behavior is influenced by factors such as parental education, making measurement of this variable more complex). These proximal causes are all affected by SES factors [99,100]. In human research, the influence of SES on brain structure and function through proximal factors such as stress has been partially validated [101]. These studies suggest that future research needs to integrate distal and proximal causes rather than searching for relationships between individual factors and the brain in isolation.

Figure 1. The simplified model of SES influencing the brain through proximal factors. SES factors affect brain structure/function through one or more proximal factors. The green area in the figure is the prefrontal cortex, the yellow area A is the anterior cingulate cortex, the blue area is the ventral striatum, the red area is the amygdala, and the orange area is the hippocampus. These five brain regions are frequently reported to be vulnerable to SES effects.

3.4 Consistency in Research Methods

Neuroscience research, especially fMRI, involves numerous preprocessing and analysis operations, each with choices about parameters and methods. Differ-

ent choices can lead to substantial differences in results [102]. The definition of regions of interest, different analysis indicators [42], and the degrees of freedom introduced by the complexity of neuroimaging [103] lead to a lack of comparability between study results. Additionally, diversity in study design, sample size, age, SES range, and other aspects can introduce considerable noise, and statistical inference issues (such as low power [104] and researcher degrees of freedom [105,106]) also affect result credibility [13,107,108]. To address this issue, researchers can use meta-analysis to quantitatively summarize past homogeneous studies [109]. More importantly, future research needs to adopt more standardized, open, and transparent methods. For example, before conducting research, methodological and analysis plans including planned sample size, analysis tools, region-of-interest definition methods, analysis indicators, and predicted results should be preregistered on open platforms (e.g., Open Science Framework); all details of exploratory analyses should be fully and completely reported to avoid selective reporting; and research data should be made publicly available [110] to facilitate subsequent analysis and comparison.

Given that both SES and brain structure are highly complex systems, current research on their relationship is largely exploratory, with few consistent conclusions. Even when correlations have been identified, the underlying mechanisms remain unclear, and causal relationships remain to be verified. To clarify the relationship between SES and brain structure and function, the challenges outlined above must be addressed. Specifically, future research can proceed with further exploration from the following four aspects.

First, researchers should comprehensively collect participants' SES information and other data valuable for exploring potential mechanisms. Current studies still lack unified standards for SES measurement and reporting, with many collecting only one or two aspects of SES such as income or education, preventing researchers from fully understanding SES effects. Future research may need to collect as many SES indicators as possible, such as income-to-expenditure ratio, education level, occupation, neighborhood relationships, and subjective social status. Additionally, SES-brain relationship research needs to consider cultural differences; researchers can collect SES indicators specific to particular sociocultural contexts, such as political capital [111]. By enriching data, researchers can analyze the mean, variance, and effects of each SES indicator on neural systems of interest, providing evidence for how different factors of SES affect different aspects of neural systems.

Second, researchers should collect and report participants' SES information across different life stages as much as possible. For example, for older participants, information can be collected on childhood, middle age, and current SES [112]. Because the mechanisms of SES-brain influence are complex, different SES factors at different ages may have different effects. Where possible, using long-term longitudinal studies, such as the Color Nest Project [113], to study the dynamic changes in SES and the brain would greatly advance understanding of the role of developmental stages in the SES-brain relationship and

potential influencing mechanisms.

Third, most participants used in psychological research cannot represent the general population [85]. Future research should expand the SES range of participants, especially sampling more from the lowest and lower SES populations, to increase understanding of the SES-brain relationship across the full SES range and resolve the controversy between threshold and gradient effects. This is particularly important for contemporary Chinese society. For example, more targeted research on poverty and left-behind children, with longitudinal follow-up, may help address mental health issues [4,5,8] and crime problems associated with poverty. Currently, multi-center collaboration models are an effective way to conduct large-scale data collection. Shared neuroimaging big data platforms such as the International Consortium for Reliability and Reproducibility [114], Beijing Aging Brain Rejuvenation Initiative [115], Chinese Imaging Genetics Study, REST-meta-MDD Project for major depressive disorder [116], Chinese Brain Template and Atlas Project, and the ENIGMA project provide a good direction for addressing sample representativeness issues.

Finally, previous studies on the brain-SES relationship have many detailed methodological differences, leading to a lack of stability and comparability among published studies. The most effective way to address these problems is to adopt open and transparent research practice standards [117]. Comprehensive reporting of study-related information is important for promoting result stability and comparability.

Over the past three decades, Chinese society has developed rapidly, with tremendous changes in individuals' SES. These changes may bring about significant psychological and life changes for individuals and have profound impacts on social mentality. Studying the relationship between SES and the human brain from a neuroscience perspective, especially within the framework of psychological resilience [118], will together with research from other disciplines such as sociology and behavioral economics provide a more complete understanding of SES effects on individuals. East-West cultural differences are important moderators of SES effects on psychology and behavior [119], and different traditional Chinese cultural thoughts may also affect social cognition such as fairness and justice concepts, thereby influencing the SES-brain relationship. Future research needs to pay attention to the impact of cultural differences on conclusions and carefully consider the practical implications of research findings for Chinese society. Future research needs to "eliminate the false and retain the true," emphasizing reproducibility and scientific rigor to provide a solid scientific foundation for theoretical development and policy formulation, and to provide precise, scientific, and effective guidance for poverty intervention programs, thereby promoting social equity.

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