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REVIEW

The importance of diversity in cognitive neuroscience

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The vast majority of what is known about the neural underpinnings of human cognition comes from studies limited to racially, ethnically, and socioeconomically homogeneous samples. Furthermore, although most studies include both males and females in their samples, sex differences in patterns of brain activity and performance are rarely evaluated. We discuss recent research suggesting that one's socioeconomic status, race/ethnicity, and sex contribute to individual differences in neural structure, function, and related cognitive performance across a variety of cognitive domains. These studies make it clear that findings from decades of cognitive neuroscience research are likely not generalizable to a population that is much more diverse than the samples tested. We argue that these demographics cannot be ignored if we want to understand the neural substrates of human cognition for the diverse, general population. Cognitive neuroscience has been, and continues to be, used to inform education policy and clinical practice. We argue that greater diversity in cognitive neuroscience research is needed to improve reproducibility and to serve the treatment needs of a diverse population. We discuss the challenges to achieving this goal, including consideration of confounding and correlated variables, recruitment, necessary costs, and best practices for dealing with them.

Keywords: diversity; race; socioeconomic status; cognitive neuroscience

Introduction

Diversity can be defined in many ways, but, in the sciences, we are typically referring to the inclusion of individuals who are nationally underrepresented at many career stages in the sciences. This usually includes people from certain racial and ethnic groups, such as African Americans and Latinos; individuals with low socioeconomic status (SES), including income and educational attainment; people with disabilities; and in many scientific areas, women. Thanks in part to the strategic efforts and provision of resources from K-12 educators, universities, and funding agencies, such as the National Institutes of Health (NIH) and the National Science Foundation over the last couple of decades, diversity is broadening among cognitive neuroscientists.

Arguably, one of the natural consequences of having a more diverse cognitive neuroscience workforce is increasing interest in understanding the impact of demographic variables, such as race/ethnicity and SES on research outcomes. Despite evidence from population-based studies suggesting that these variables are related to cognitive performance,[1–3] cognitive neuroscience studies have not consistently reported demographic information about their samples nor investigated the impact of demographic variables on their outcomes of interest. We surveyed articles published in two leading cognitive neuroscience journals between August 2018 and August 2019 to document how often sex, race/ethnicity, and SES were described in the study samples, tested as a factor in the analyses, or both. Across 208 original research articles with human samples, all but two articles reported the sex distribution in their sample; however, only 8% examined sex as a predictor in primary or secondary analyses. Race/ethnicity and measures of SES (e.g., income and education) were much less often

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reported (14% and 18% of studies, respectively). Only three studies (<1%) examined their outcomes by race, ethnicity, or SES. Among the studies reporting race or ethnicity, three described samples that were 100% White, while the representation of other racial and ethnic groups ranged from 2% to 50% for Asian participants (for studies conducted outside of Asia), 0–19% for Hispanic/Latino participants, and 0–42% for Black/African American participants. This sampling of recent studies clearly shows the need for more diverse samples and more transparency about participant demographics in cognitive neuroscience research.

A variety of reasons likely contribute to this problem. Recruitment considerations are one factor. Many studies use a convenience sample that comprises primarily college students and alumni. Since some groups, such as ethnic minorities and individuals of lower SES, are less represented on campuses,[4] this results in research samples that do not represent the general population. In addition, historical mistrust and lack of access may hinder recruitment of underrepresented groups in research.[5]

The increasing push for larger sample sizes in cognitive neuroscience research compounds these recruitment issues.[6,7] Even larger samples are needed to have sufficient power to examine demographic factors using either between-group designs or as covariates in cognitive neuroscience studies. The historical homogeneity of research samples in science combined with current practical recruitment concerns leads to a vicious cycle: The lack of available data regarding the relationship between demographic variables and brain structure and function means there are few established models to test. Therefore, new studies are limited in their ability to make informed predictions, and consequently are less likely to examine demographic variables. For investigators who do aim to measure and examine demographic factors, there are challenges in defining variables, for example, how to operationalize SES, as discussed below.

The NIH has required clinical researchers to report the anticipated and actual enrollment demographics for the sex, race, and ethnicity of our research participants for many years. More recently, NIH-funded researchers must consider these demographic variables in our analyses to determine whether different groups differ in their responses to clinical trial interventions. Recent changes to the NIH definition of clinical trials have resulted in many cognitive neuroscience studies now being reclassified as such. It seems highly likely that findings from the last 30 years of cognitive neuroscience research, in which sample diversity is limited and a rarely considered independent variable, will begin to be subject to reinterpretation.

In our review, we will discuss recent research, published within the last 5 years, suggesting that one's race/ethnicity, SES, and sex contribute to individual differences in neural structure, function, and related cognitive performance across a variety of domains, including episodic memory, attention, and emotion. Studies meeting these criteria, using one or more neuroscience methods (i.e., structural and/or functional neuroimaging, electroencephalography (EEG), and magnetoencephalography) and one or more cognitive domains, included ∼60 publications, of which we highlighted a subset, some including healthy children, adults, and/or people with neurodegenerative disease (i.e., dementia). This is by no means an exhaustive list of studies but those we highlighted allowed us to best describe the major issues of interest within the short review format. Our selection of the articles reviewed here was agnostic with respect to country of origin. However, the majority of the research reviewed here has been conducted in North America, particularly in the United States, because this is where most of the published work in this area has been conducted. There is no reason to think that the patterns emerging from diversity in cognitive neuroscience research are limited to North American samples, of course. Indeed, several studies showing sex/gender differences in neural correlates of cognition were conducted in Asia. As discussed below, in some countries with relatively less pronounced economic inequality, like Norway, income may play a less significant role in individual differences in neural underpinnings of cognition. Regardless, more research is needed globally that explores the country-/region-relevant demographic factors that may contribute to these individual differences. As we discuss below, some existing repositories of neural data collected across different countries, like the EU Human Brain Project, offer an opportunity for researchers to explore these research questions.

These studies make it clear that the results obtained from decades of cognitive neuroscience

research are, in many cases, not generalizable to a population that is much more diverse than the samples tested in this research. We will argue that these factors should not be ignored if we want to understand the neural substrates of human cognition and behavior not just for our highly selective samples, but for the diverse, general population. We argue that cognitive neuroscientists, going forward, must directly assess demographic variables if we are to achieve our goal of understanding the neural underpinnings of human cognition for all people. We will acknowledge the issues surrounding this approach, including consideration of confounding and correlated variables, recruitment, and necessary costs, and present best practice strategies for dealing with them.

Race and ethnicity

To date, there is a dearth of neuroimaging studies that include diverse samples, and even fewer that compare race and ethnic group differences in their outcomes. The few existing studies have often found important group differences, but findings are not always consistent and need to be replicated.

Aging

Emerging studies are documenting the impact of race and ethnicity on cognitive and brain aging. For example, one study[8] compared structural magnetic resonance imaging predictors of cognitive functioning in older African Americans, Hispanics, and Whites, controlling for numerous differences in levels of cognitive, imaging, demographic, and cardiovascular health variables across racial/ethnic groups. In this study, compared with non-Hispanic Whites, white matter hyperintensity volume was a stronger predictor of language and speed/executive functioning in African Americans and hippocampal volume was a weaker predictor of memory among Hispanics. Group differences were also noted in hippocampal atrophy and cortical thinning. A longitudinal study that followed older adults for an average of 5.3 years also found race and ethnicity differences in the relationship between brain measures and cognitive decline.[9] Specifically, global gray matter change was the strongest predictor of cognitive decline in Whites and African Americans, but baseline white matter hyperintensity volume was the strongest predictor of cognitive decline in Hispanics. These two studies suggest that the neurobiological underpinnings of cognitive decline may vary by race/ethnicity. It was also suggested[9] that race and ethnicity may represent proxies for factors that influence cognitive functioning, including modifiable risk factors, such as cardiovascular disease.

A few studies have also focused on race and ethnicity differences in biomarkers of Alzheimer's disease. For example, older African Americans have a twofold increase in amyloid beta deposition, but lower concentrations of tau in cerebrospinal fluid compared with Whites, though the latter was found to only be true in participants who were *APOE* ε4 allele positive.[10] Controlling for cerebrospinal fluid markers of amyloid beta, researchers[11] found that cognitive dysfunction in African Americans was more associated with white matter hyperintensity burden and less associated with tau markers compared with Whites.

Together, these findings suggest that our understanding of cognitive and brain aging might be incomplete and might not generalize across racial/ethnic groups, which has important implications for the diagnosis and treatment of age-related cognitive disorders. Indeed, a recent review found that across 31 cognitive training studies in older adults, only 39% reported racial/ethnic demographics of their participants and that minorities were greatly underrepresented in the studies that reported these demographics.[12]

Racial biases

Cognitive neuroscience methods have also been applied to the study of racial biases. A series of studies examined event-related potential (ERP) correlates of own-race memory biases comparing the response of White participants to White and Asian faces. One study[13] found that young participants show an own-race bias for younger but not older faces. Additionally, a more pronounced early parietal ERP old/new effect (300–500 ms) was found for young Caucasian "in-group" faces, and a more pronounced old/new effect in a later time window (500–800 ms) was found for own-race faces. A more recent study[14] documented a larger N170 response to other-race faces, thought to reflect more effortful perceptual processing. In older adults, both low- and high-memory performers demonstrated an own-race bias and a parallel increase in N170 for other-race faces, which was thought to reflect less efficient early perceptual processing.

An enhanced N170 to other-race faces was also found in an ERP study that included a more diverse sample of 13 non-Hispanic White, 12 Hispanic White, seven Asian, and three "other" participants.[15] Participants showed better location memory for Black faces than for White faces, accompanied by greater P300 amplitude during encoding, which was interpreted as greater motivated processing when attending to Black faces. A follow-up study using the same task in separate sample of non-Hispanic White and Asian participants found that both White and Asian participants had better working memory for Asian relative to White faces.

These studies suggest that other-race faces are more salient than same-race faces, which can, in turn, result in better memory. However, these findings are predominantly based on examining the response of White participants to other-race faces. The same is true of affective neuroscience studies examining the neurobiological correlates of in-group biases in empathy. Recent ERP and functional magnetic resonance imaging (fMRI) studies in this area have shown a reduced empathic response to pain in other-race individuals in primarily White participants. As a result, even the cognitive neuroscience literature on race biases is biased since the response of ethnic and racial minorities to other-race faces has been largely unexplored. Notable exceptions include a recent fMRI study in which, compared with White participants, Asian and Black participants with and without major depression showed enhanced amygdala activity in response to viewing White faces that displayed a range of sad expressions.[16] In addition, a series of studies in Chinese participants have confirmed differences in empathic responses and neural activity to pain in other-race individuals,[17–22] and a recent fMRI study found differences in functional brain activity in response to in-group and out-group physical and social pain in White and Black South Africans who lived through apartheid.[23] More studies with ethnically and racially diverse samples are needed to better understand the neurobiology of cognitive, affective, and social processes across groups.

Socioeconomic status

What is SES?

Of the demographic variables discussed in this review, SES has arguably been explored the most in cognitive neuroscience research, particularly as it relates to neurocognitive function in childhood. SES is a concept that is often discussed but not always clearly or consistently defined across studies. At a broad level, SES can be conceptualized as one's access and attainment of resources. Most commonly in the literature, SES is captured through measures of income, educational level, and educational quality (see Ref. 24 for a review). One's neighborhood, which can indicate the percentage of households below the poverty line, and occupational status are sometimes also included as components of SES. A complication for researchers when reviewing the literature, as we encountered here, is that studies involving children as subjects necessarily measure SES differently from those involving adults. Specifically, family income and parental education and occupation are common SES metrics in studies of children, whereas those same variables might be used, supplemented, or replaced by one's personal income, educational level, and occupation in studies of adults. Components of SES are often correlated with one another but if they were perfectly correlated, researchers could rely on one component as their SES index (e.g., family income). However, there are many cases in which individuals can be high in one component but low on another. Imagine a 5th year graduate student living off a meager stipend or a medical doctor doing residency in an impoverished, rural community. Indeed, an early population-based study from Sweden assessing multiple SES factors in adults (i.e., personal educational level, income, and occupation) found only small to moderate correlations between them.[25]

Cultural and societal factors may change what variables should be considered in definitions of SES, multicultural studies, and comparisons of research from different countries. For example, income may be less relevant as an SES component in highly impoverished countries and consequently, an index that includes alternative variables, such as access to water and sanitation, may prove useful in this regard.[26] It should be noted that other stressors that also affect neurocognitive development, such as childhood maltreatment, may be important to consider as potential covariates of SES. While not a component of SES, maltreatment (i.e., abuse and neglect) is sometimes correlated with childhood SES.[27] However, recent evidence has shown that they independently influence limbic volumes

measured in young adults,[28] and brain volume, cerebral blood flow, and cognitive functioning in children and young adults.[29]

Thus, it is important that researchers consider multiple SES components within a study to separate their respective contributions to research outcomes. This is by no means an easy feat, involving a combination of census data and self-reports that might make some research participants uncomfortable to answer. Still, the vast body of epidemiological and cognitive psychology literature showing that SES is related to numerous cognitive, behavioral, and health outcomes, including IQ, depression, and heart disease, suggests the importance of SES in human research.[30,31] Given that the brain subserves these constructs and may be affected by them, investigating how SES interacts with brain structure and function and related cognitive performance across the life span may inform our understanding of this complex construct.

SES and neurocognitive functioning in children

What have we learned about the relationships between SES and human cognition using neuroscience approaches? Most of the work in this area has focused on children and on tasks with relevance to educational performance, including math and language abilities (see Refs. 24 and 32 for reviews). For example, fMRI evidence shows that prefrontal cortical activity measured during performance of a working memory task supports math ability in high, but not low SES children.[33] This might suggest that the neural substrates underlying working memory ability, which in turn, supports scholastic achievement, may be SES dependent. SES is also related to cognitive outcomes through brain structure. For example, SES is related to hippocampal volume, which also predicts individual differences in memory performance, in adolescents but not in adults, potentially suggesting that at least some adverse effects of low SES may be transient.[34] A recent meta-analysis of task-based fMRI and voxel–based morphometry studies that included a combination of children and young adult subjects showed that low SES most consistently manifests as reduced recruitment of frontoparietal regions implicated in executive control, and increased recruitment of the caudate nucleus, which is associated with reward learning.[35] Analogous impacts of SES were shown in gray matter volumes of frontal and limbic areas. These results support well-established SES influences on performance in tasks highly dependent on executive control,[36] as well as those measuring sensitivity to reward.[37] Collectively, what these emerging results suggest is that SES may exert its influence on brain structure and function from an early age, which in turn has consequences on cognitive abilities in children who manifest both in scholastic performance and in susceptibility to risky decision making, which have long-term consequences for one's wellbeing.

SES and neurocognitive functioning in adults

Arguably, little work has explored the influence of childhood SES, apart from education, on the cognitive neuroscience of advancing age. Generally, these studies show that older adults with high cognitive reserve, including education level, can maintain cognition despite pronounced neuropathology and atrophy (see Ref. 38 for a review). Much remains unknown about how SES throughout one's life affects neurocognitive aging. For example, if one's SES improves, can that overcome early negative influences on brain and behavior? On the flip side, if one experiences a reversal of fortune, can this attenuate early life benefits of high SES, perhaps through stress-induced mediators? Childhood SES has been shown in one recent study to primarily influence neurocognitive function in childhood compared with young adulthood.[34] But, does low childhood SES exacerbate age-related declines in neural systems implicated in cognitive aging? At least one Norwegian study suggests that this may not be the case, finding that parental education affects cortical surface area related to general cognitive ability to the same degree across the entire life span.[39] As discussed by these researchers, however, SES factors, such as income, may have greater influences on neurocognitive development in countries, such as the United States, where economic inequality is more pronounced. Another study investigated how one's current SES, controlling for childhood SES, moderates functional network connectivity across the adult life span.[40] Unexpectedly, results showed that lower SES in middle-aged adults only was associated with reduced network segregation, which has been previously associated with reduced cognitive performance across domains.[41] The lack of similar relationship in young or older

adults is unclear but highlights the need for further investigation of SES influences on different kinds of neurocognitive metrics (e.g., structural and functional) across the life span. Collectively, these studies underscore the influence of SES, measured in childhood and adulthood, on neurocognitive functioning in children and adults. An important question for further study is how SES measured in early life independently or synergistically with SES measured in later life impacts cognitive decline and risk of neurodegenerative disease.

Sex/gender

Compared with other demographic variables, sex differences have received more attention in the affective and cognitive neuroscience literature.

Emotion processing

A number of studies have shown sex differences in functional activity during emotion processing tasks. For example, men have been shown to have higher amygdala activation compared with women during high provocation conditions on an fMRI task designed to provoke aggressive behavior, and this amygdala activation correlated with trait anger in men but not in women.[42] This pattern was evident despite similar behavioral performance in men and women. In the same study, the association between the tendency to respond aggressively and activity in the orbitofrontal cortex, rectal gyrus, and anterior cingulate cortex was positive in men but negative in women. This pattern was thought to reflect a sex difference in the use of automatic emotion regulation in response to provocation. Other affective neuroscience studies have found increased prefrontal activity in men following exposure to emotional pictures,[43,44] but lower activation in men in prefrontal areas, the amygdala, and the ventral striatum during downregulation of negative emotions.[45] Thus, it appears that men and women differ in their response to emotional stimuli and in the brain correlates of affective processing. Affective neuroscience studies that examine sex differences have important clinical implications, as they are able to enhance our understanding of sex differences in affective disorders like major depression, and in turn lead to improved diagnosis and treatment.

Cognitive processing. Men and women also differ in brain activity during cognitive tasks. For example, a meta-analysis of neuroimaging studies of working memory revealed greater limbic and prefrontal activation in women and a more distributed network that included parietal regions in men.[46] Other cognitive neuroscience studies suggest that women show increased and more bilateral activation patterns for verbal tasks.[47] A recent study found sex differences in fMRI activation between verbal and spatial dual-task performance after developing the task and selecting participants in a manner that equated men and women on behavioral performance.[48] Specifically, activation in the prefrontal cortex, orbitofrontal cortex, and the paracingulate gyrus was increased in women compared with men during dual task performance if the primary task required processing of verbal stimuli. Activation in areas of the occipital cortex implicated in visual processing was increased in men compared with women during a spatial dual-task compared with a spatial single task.

As highlighted in a review of recommendations for sex/gender neuroimaging research,[49] any observed differences must be considered in the context of interactions between the brain, genes, social experience, and culture. Still, these studies highlight the importance of examining sex differences in cognitive neuroscience studies, rather than simply controlling for sex as a nuisance variable. The NIH's requirement for grant proposals to address sex as a biological variable will help to address this issue, but we encourage non-NIH studies to consider sex differences as well.

Implications of the lack of diversity in cognitive neuroscience research

The research reviewed here suggests that demographic factors, including sex, race, and SES, affect—either directly or through associated mediators—neural structure, function, and, related cognitive performance across the life span. However, most studies have either not considered these variables at all or assessed them only as nuisance covariates in statistical analyses. This has major implications for scientific reproducibility, generalizability, and the development of disease treatments.

Reproducibility of results has become an issue of growing interest over the last several years.[50] Large-scale attempts by research teams across the globe to replicate numerous research studies have met with arguably limited success. Some scientists have

referred to the limited reproducibility of research findings as a "crisis" in the field.[51] Although there are likely many contributing factors to this reproducibility issue, study-to-study variation in the sample demographics is potentially one contributor. As a response to emerging awareness of the reproducibility crisis, the NIH now requires all grant applicants to document the scientific rigor of proposed and funded work. One component of this documentation of rigor is the requirement to consider sex in proposed experimental designs and analyses. This is most definitely a step in the right direction but as we have presented here, it is likely that race, ethnicity, and SES also warrant consideration. To the extent that cognitive neuroscience researchers include these variables in our investigations, we should be able to improve reproducibility within our field.

The U.S. population is increasing in racial and ethnic diversity. U.S. Census estimates from 2017 indicate that 13.4% of the population is Black or African American, and 18.1% is Hispanic or Latino.[52] From 2016 to 2060, the population of African Americans is expected to increase by 40.6% and the Hispanic/Latino population by 93.2%. As the population ages, with an estimated one in four adults over the age of 65 by 2060, there is also an increase in diversity within older adults. Specifically, the percentage of older Americans who are ethnic minorities will increase from 20.7% in 2012 to 39.1% in 2050.[52] With this increasing diversity comes a critical need for more representative samples in cognitive neuroscience studies in order to ensure generalizability.

Perhaps most critically, it is important to assess the relationships between these demographic variables and the neural underpinnings of cognition since cognitive neuroscience is being used to inform treatment of neurological disease and disorders. For example, there has been increasing interest in the neuroscience of sleep as related to many aspects of cognition across the life span (see Refs. 53 and 57 for reviews). Several EEG signatures associated with sleep seem to predict individual differences in episodic memory ability, and these same signatures are affected by age, potentially mediating age-related memory decline (see Ref. 55 for a review). It is conceivable that this research may help inform future interventions that target particular aspects of sleep's neural architecture. However, despite the well-known finding from population studies that subjective sleep quality is typically worse in Black than in White adults (see Ref. 56 for a review), the cognitive neuroscience of sleep studies has not assessed the influence of race or ethnicity. Interestingly, emerging evidence suggests that African Americans show a reduced percentage of slow wave sleep (SWS) compared with European Americans (see Ref. 57 for a review), which may be exacerbated in those with greater African genetic ancestry.[58] SWS, an EEG component of deep stage sleep, has been linked to episodic memory consolidation and related performance and shown to be reduced by age, concomitant with memory decline (see Refs. 54 and 55 for reviews), but the impact of race or related factors, such as race-related stress, on these relationships is unknown. At this point, we cannot be certain that our understanding of sleep's role in memory consolidation, for example, extends beyond what we know from White participants. This is problematic as researchers are starting to conduct studies to improve memory through targeted interventions. For example, researchers have recently shown that transcranial alternating current stimulation applied during sleep to enhance the slow wave oscillations that have been linked to episodic memory consolidation improves recognition performance.[59] The demographics of the participants were not reported in this study, but it is safe to assume that with such a small sample ($n = 16$), there is insufficient diversity to assess the efficacy across race and ethnicity.

Cognitive neuroscience methods are increasingly being used to inform treatments for a variety of neurological and psychological disorders, including dementias, depression, schizophrenia, and anxiety disorders. These methods have contributed greatly to our understanding of the neurobiological mechanisms underlying cognitive and psychiatric symptoms, which can serve as targets for both behavioral and biomedical treatments. For example, cognitive neuroscience studies have elucidated a frontolimbic network underlying depressive disorders that includes the dorsolateral prefrontal cortex, anterior cingulate, hippocampus, and striatal regions.[60] Cognitive neuroscience methods have also clarified the neurobiological impact of interventions, such as psychotherapy, cognitive training, and physical exercise.[61,62] Thus, treatment for depression can be improved by utilizing interventions that best

target the frontolimbic network linked to mood symptoms. Moreover, brain stimulation therapies are being used to target dysfunctional brain networks in depression and other disorders.[63,64] This is an important issue considering the fairly poor response to antidepressant medications and the contraindications to pharamacotherapy in some patient groups, which necessitates the identification of alternative treatments.

These very important lines of research are limited in their impact when research samples lack diversity. Race/ethnicity, SES, sex, and other demographic variables influence the risk for, and expression of, many psychiatric and other medical conditions;[65–68] thus, it is not clear if the relationship between symptoms and neurobiology is the same across groups. Greater diversity in cognitive neuroscience studies is needed to serve the treatment needs of a diverse population. Considering the number of publicly funded studies in cognitive neuroscience, we contend that increasing diversity is imperative to promote fairness—the research should reflect the demographics of the people who support it.

Future directions, challenges, and opportunities

We have argued that cognitive neuroscientists have a responsibility to not only diversify the field, but also to diversify samples and examine demographic variables in our research. As we have presented in our review, there are a number of challenges to achieving these goals. Below, we provide some ideas for approaches we believe researchers should take to assess diversity and how we can go about overcoming challenges to doing so in future cognitive neuroscience research.

Studies investigating how variables like race, SES, and sex affect patterns of neural activity underlying cognitive performance are slowly emerging. Most of these studies have examined these variables in isolation but, as we have discussed here, there is likely to be at least moderate correlations between them. Thus, in order to avoid conflating the impact of different demographic factors, it is important to design studies in which the unique contributions of these demographic variables to neurocognitive results can be determined. We suggest that future studies accomplish this by increasing and broadening their participant recruitment in order to assess SES, race/ethnicity, sex, and so on, as variables of interest. We acknowledge that this is easier stated than done, as a much larger number of subjects would be needed than what is typical for a cognitive neuroscience study, which is costly, and recruiting participants from historically underrepresented groups is not possible in every city and may require a different approach than relying on convenience samples.

Here, we see the potential for multisite collaborative studies. Such approaches are common in clinical and aging research, such as the Alzheimer's Disease Neuroimaging Initiative projects, but to a much lesser extent in cognitive neuroscience. More recent arms of the Human Connectome Project include structural and functional imaging data, including task fMRI, brief cognitive measures of episodic memory and executive function, and some demographic variables (gender, race, and ethnicity) from hundreds of children and adults across the life span collected from a few sites in the United States. Some of these data have been recently made available to the public and could be used to address questions related to diversity in a large sample. A nonmutually exclusive approach, which is already emerging, albeit slowly, is for researchers to contribute to and capitalize upon publicly available data-sharing platforms.[69] Both approaches have the added benefits of helping to reduce the silos that exist between cognitive neuroscience laboratories, encourage transparency, allow for assessments of reproducibility, and promote "sharing of the wealth." For cognitive neuroscientists to make use of these approaches for investigations of diversity, however, the demographic variables discussed here must first be represented in data.

Collaborative studies and data-sharing platforms also address issues related to the high cost of conducting cognitive neuroscience studies, which can be even greater if sample sizes are increased to have sufficient power to perform demographic group comparisons. Another way to address this challenge is for cognitive neuroscientists to look for and respond to requests for grant applications that focus on diversity or health disparities. These opportunities are offered by federal agencies as well as private foundations. The NIH also has a National Institute on Minority Health and Health Disparities that funds research as well as training awards.

An additional challenge stems from the use of neuropsychological tests as screening measures, as

outcome measures, or both in cognitive neuroscience studies. Many of these tests have limited validity in diverse samples, an issue that is well known among neuropsychologists,[70] but not always by cognitive neuroscientists with a background in other fields. As we seek to increase the representation in cognitive neuroscience studies of different ethnic and racial groups and across a range of SES, a critical issue will be to consider the psychometric properties of the cognitive measures we plan to use in our studies. These issues can be addressed in multiple ways, including selecting measures with the best evidence of cross-cultural validity, or using cutoffs for screening measures that have been shown to be appropriate for each demographic group. An important goal is the development and validation of culturally sensitive cognitive and neuropsychological measures.

Finally, we argue that even if diversity factors are not directly considered as variables of interest, per se, it is important to ensure that study participants are as representative of the general population as possible. This is critical for the generalizability of our understanding of the neural underpinnings of human cognition. Furthermore, as cognitive neuroscience research continues to inform our understanding and treatment of a variety of neurological disorders, it is critical for health outcomes that our results be generalizable to as many individuals as may be affected by them.

Competing interests

The authors declare no competing interests.

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