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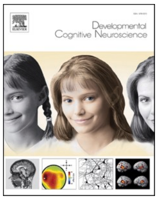

Increasing diversity in developmental cognitive neuroscience: A roadmap for increasing representation in pediatric neuroimaging research

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ABSTRACT

Understanding of human brain development has advanced rapidly as the field of developmental cognitive neuroscience (DCN) has matured into an established scientific discipline. Despite substantial progress, DCN lags behind other related disciplines in terms of diverse representation, standardized reporting requirements for socio-demographic characteristics of participants in pediatric neuroimaging studies, and use of intentional sampling strategies to more accurately represent the socio-demographic, ethnic, and racial composition of the populations from which participants are sampled. Additional efforts are needed to shift DCN towards a more inclusive field that facilitates the study of individual differences across a variety of cultural and contextual experiences. In this commentary, we outline and discuss barriers within our current scientific practice (e.g., research methods) and beliefs (i.e., what constitutes good science, good scientists, and good research questions) that contribute to under-representation and limited diversity within pediatric neuroimaging studies and propose strategies to overcome those barriers. We discuss strategies to address barriers at intrapersonal, interpersonal, community, systemic, and structural levels. Highlighting strength-based models of inclusion and recognition of the value of diversity in DCN research, along with acknowledgement of the support needed to diversify the field is critical for advancing understanding of neurodevelopment and reducing health inequities.

Since the term “cognitive neuroscience” was coined a mere 50 years ago (Gazzaniga et al., 2018), the invention of safe and non-invasive tools to measure the active functioning brain—such as electroencephalogram [EEG], functional magnetic resonance imaging [fMRI], magnetoencephalography [MEG] and functional near-infrared spectroscopy [fNIRS]—has led to a dramatic growth in our understanding of the human brain. Today, non-invasive neuroimaging methodologies have allowed unprecedented access to the developing brain at all stages of the life-course, culminating in the generation of the Developmental Cognitive Neuroscience (DCN) field. DCN is now a mature scientific discipline with a dedicated journal, a professional society with an annual meeting (i.e., the Flux Congress), and a substantial evidence base. The guiding principles, research questions, and methodological approaches of DCN emanate from and are entwined with the long histories of medicine, neuroscience, and psychology. Many scientists in DCN seek to improve the reach and theoretical shortcomings of the aforementioned scientific specialties. Unfortunately, established traditions have constrained the transformative potential of science in improving our understanding of individual differences in brain development, particularly among communities that have been economically and socially marginalized, including individuals with low socio-economic status (SES) and communities of color.

Initially, pioneering studies in DCN studied development by comparing brain structure and function between groups of participants

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of different ages (e.g., children vs. adults) (Bunge et al., 2002; Casey et al., 1997; Durston et al., 2002; Luna et al., 2001; Schlaggar et al., 2002; Thomason et al., 2009). As the field advanced and methodological techniques improved, larger samples permitted the study of development by examining individual differences in brain function as a function of age measured as a continuous variable, in samples spanning childhood and adolescence (Braams et al., 2015; Ordaz et al., 2013; Somerville et al., 2011). These larger samples also allowed researchers to examine questions about individual differences in brain development—not only as a function of age, but also in relation to other important individual and contextual factors such as early-life adversity, socioeconomic status (SES), the presence of mental or neurodevelopmental disorders (Beesdo et al., 2009; Church et al., 2009; Jenness et al., 2021; Noble et al., 2015; Tottenham et al., 2011). Unfortunately, the shift in the types of research questions being investigated was not accompanied by a similar shift towards recruiting samples that more accurately represent the diverse set of experiences in targeted populations (Green et al., 2022). DCN continues to rely largely on the use of convenience samples and lags behind other related disciplines in diverse representation and the use of intentional sampling strategies to more accurately represent the socio-demographic, ethnic, and racial composition of the populations from which participants are sampled. Additional efforts are needed to continue shifting DCN towards a more inclusive field that facilitates the study of individual differences across a variety of cultural and contextual experiences.

A meaningful limitation in many DCN studies pertains to the generalizability of findings to the target population of interest, and the lack of consideration as to how variation in socio-demographic backgrounds and contextual experiences may influence results within and across groups of people (Webb et al., 2022). Difficulties in the recruitment of diverse samples in the social sciences and public health are well documented, along with recommendations as to how to improve recruitment efforts in ways that are culturally sensitive, contextually appropriate, and ethical (Haack et al., 2014; Hernández et al., 2013; Rowley and Camacho, 2015; Yancey et al., 2006). Recruitment difficulties are magnified in DCN studies given additional barriers to participation, which we describe in more detail below. Despite guidelines from the American Psychological Association (APA, 2019), current standards in DCN do not require reporting of socio-demographic characteristics (e.g., race/ethnicity, SES) of participants in manuscripts. The scope of the problem is difficult to fully quantify. As one example, only 37.3 % of articles with human samples published in 2020 in the field's flagship journal, *Developmental Cognitive Neuroscience,* reported on the race, ethnicity, and/or SES of study participants. The lack of diversity, inclusion, and representation in DCN studies can perpetuate systems of oppression, compromise the validity of science, and introduce biases into our understanding of brain development. Recent work shows that the use of samples that do not reflect the underlying racial, ethnic, and socioeconomic composition of the target population can lead to different conclusions about fundamental neurodevelopmental processes, such as the association of age with cortical surface area and subcortical volume, found in representative samples (LeWinn et al., 2017). These types of biases can ultimately lead to biased assessments, interventions, and practices that lack generalizability and have the potential for harm to groups that are not represented in the data. Indeed, race/ethnicity and SES are socially constructed categories designed to identify and allocate advantage and power in society (Shim, 2021).

Increasing diversity in DCN studies requires an understanding of factors at different levels of influence that contribute to the under-representation of diverse samples. To garner a comprehensive understanding of factors contributing to limited diversity in DCN, we draw on a socio-ecological approach, which highlights the interrelation of individual, community, systemic, and structural factors influencing human behavior (Bronfenbrenner, 1979; McLeroy et al., 1988). The socio-ecological approach provides a framework for understanding how social problems—including exclusion, racism, discrimination, marginalization, and stigmatization—are produced and sustained within and across various subsystems, that ultimately may contribute to the inequities and under-representation of specific groups in our science. The application of a socio-ecological perspective to increase diversity in DCN is needed to understand challenges in recruitment and retention, as well as facilitate the identification and implementation of strategies needed to diversify our field. In this commentary, we outline and discuss barriers within our current scientific practice (e.g., research methods) and beliefs (i.e., what constitutes good science, good scientists, and good research questions) that contribute to under-representation and limited diversity within DCN, and propose strategies to overcome those barriers. We discuss strategies to address barriers at different levels of analysis in the socio-ecological model, including those at the intrapersonal, interpersonal, community, systemic, and structural levels, as well as barriers related to the research process itself. We do so in consideration of both the subjects of our research and of the diversity of members of our academic community. We focus on a common set of barriers to participation in DCN research in contexts where this research is currently conducted. While these barriers may also be relevant in other contexts, barriers to participation in DCN research are likely to vary meaningfully across cultures, communities, and time.

We acknowledge that sources of individual differences and the complexity of intersecting identities are essential to consider, yet too broad to address adequately in a single manuscript. As an initial effort to shed light on the need for increased diversity in DCN, we focus our discussion on two aspects of social identity and context: (i) socioeconomic background, specifically individuals with lower SES; and (ii) historically marginalized racial and ethnic groups in the U.S., which includes Black individuals and African Americans, Asian Americans, Indigenous Peoples, Latinx/e/a/o, Pacific Islander, Middle Eastern, and North African populations. We hope that our focus on racial, ethnic, and socioeconomic representation as critical aspects to consider in DCN research can stimulate progress and enhance focus on increasing representation of a broader range of identities needed to diversify DCN, such as those pertaining to gender, sexuality, creed, religion, and ability.

1. Barriers at the intrapersonal, interpersonal, and community levels

In this section, we refer to intrapersonal and interpersonal levels as the perceptions, knowledge, attitudes and beliefs that individuals may hold, as well as the relationships and/or interactions with others that influence their behavior. By community, we refer to social groups whose members share something in common, such as values, culture or heritage, including experiences or history of oppression and marginalization. Collectively, the intrapersonal and interpersonal characteristics of community members influence the way that communities respond and engage with entities outside their networks, such as academic and research institutions. For communities with long-standing histories of marginalization and oppression, engagement with academic and research institutions can be challenging and often overwhelming due to mistrust (Hernández et al., 2013; Rivas-Drake et al., 2016).

Indeed, mistrust often hinders participation in research studies and is a primary barrier that needs to be overcome to increase representation in DCN samples. Exacerbated by historical events and current actions, mistrust in academic and research institutions restricts participation and representation of racial and ethnic historically marginalized communities in the behavioral and biological sciences including DCN (Hernández et al., 2013; Rivas-Drake et al., 2016). Trust within a research context relies on the belief that researchers and research institutions are responsible, competent, and will act in the best interest of participants and their communities, while also preventing harm to the individual and their community (Cubelli, 2020). Unfortunately, trust is difficult to establish and easy to lose, particularly among communities with a history of being marginalized and/or deceived (Best et al., 2021;

Hernández et al., 2013; Rivas-Drake et al., 2016; Scharff et al., 2010; Yancey et al., 2006).

Mistrust of governmental entities and related agencies—particularly of those disseminating health information, the provision of services, and those overseeing and regulating healthcare practices and/or research—is common within communities that have been historically marginalized (Jaiswal and Halkitis, 2019; Oakley et al., 2019; Williamson et al., 2020). Current ethical principles in human research (e.g., Nuremberg Code, the Belmont Report) were developed after non-consensual unethical research was conducted on communities that had been persecuted (Markman and Markman, 2007). Yet, even after the development of ethical guidelines, unethical treatment of marginalized communities by the medical community persisted (Carpio, 2004; Rutecki, 2011) and mistrust of the scientific process and medical institutions among racially and ethnically under-represented communities remains (Ball et al., 2013; Jacobs et al., 2006; Jaiswal et al., 2020; Pacheco et al., 2013; Thompson et al., 2021). For instance, Black Americans report concerns about genetic research misusing their biological data to initiate criminal investigations (Catz et al., 2005; Nooruddin et al., 2020). Mistrust among historically marginalized or under-represented communities has been exacerbated recently as a result of harmful rhetoric and actions against them. For example, anti-immigrant attacks undertaken against Latinx and Asian communities, as well as anti-Black discourse and racism have increased concerns, fears, and skepticism of medical institutions in those communities (Alang et al., 2020; Garcini, 2020; Garcini et al., 2021). Common concerns fueling mistrust include: fears of exploitation and experimentation without safeguards, using misleading information to manipulate decision making, lying or distorting reality to hide adverse effects or consequences, and disengagement from researchers once data collection is complete (Garcini et al., 2021; Smirnoff et al., 2018). Uses of the term “fake news” to denote lies perpetuated by politicians and the media have also led to confusion and questioning of the validity of sources of health information that were previously thought to be reliable (Tanzer et al., 2021). Within the context of the current COVID-19 pandemic, frequent attempts by government authorities to restrict information to the public and to discredit scientists about the seriousness of the coronavirus have also increased confusion and mistrust (Jaiswal et al., 2020). Thus, it is not surprising that serious concerns about research participation prevail among communities that have been historically marginalized and deceived.

Another common barrier to research participation among communities that have been economically and socially marginalized is concern about the mishandling of personal information. Concerns about the misuse of personal information are particularly relevant for individuals for whom a breach in confidentiality or a release of personal information may lead to threats, instability, marginalization, and/or harmful legal action. For instance, certain groups of immigrants may be particularly vulnerable if their immigration legal status is compromised, and fearful that in such case they may face detention, deportation, loss of rights, and/or family separation (Garcini et al., 2020). In 2020, press investigations revealed that the federal government possessed personal information that could be used to target immigrants with temporary protected immigration legal status for detention and deportation (Lund, 2021). These kinds of unexpected and impactful revelations increase fear for oneself, family, and loved ones, which can increase skepticism and hesitation about participating in activities that may require the disclosure of health or personal information. Similarly, concerns about becoming a victim of financial scams lead many racial and ethnic groups that have been historically deceived to be hesitant about participating in research studies; a higher proportion of Black and Latinx people are victims of financial scams than White people (American Association of Retired Persons, 2021a, 2021b). The process of participating in studies also involves procedures (e.g., informed consent) that are regulated in ways that require legalistic language, formalities, and references to governmental agencies (e.g., funders, data sharing requirements, etc.), which can make families apprehensive. Similarly, compensating families for participation often requires release of financial or personal information that can increase hesitancy about research participation. As a result, it may be difficult for individuals facing discrimination to feel safe in undertaking research participation within the historical and current political context, especially as it continues to reinforce limited protections and safeguards for those at risk.

An additional set of barriers involves concerns about stigmatization and discrimination. A common belief among historically marginalized communities is that research findings will be used to stereotype their communities, perpetuating risk for oppression and discrimination (Smirnoff et al., 2018); this occurs frequently among those who identify as Black, Latinx, and Indigenous. For example, results from the Barrow Alcohol Study were used by the media to portray negative stereotypes of the Inupiat community, which contributed to a drop in the bond rate for the city where the study took place, undermining economic development in that region (Foulks, 1989; NOE et al., 2006). The consequences from the Barrow Alcohol Study led many Alaska Native communities to be doubtful about the benefits of research and increased concerns about the research process. Exposure to unequal treatment, disrespect, and limited cultural competence within the medical system further propagate concerns about stigmatization and quality of care among historically disenfranchised communities (Jacobs et al., 2006; Kennedy et al., 2007; Perez et al., 2009). Another set of examples are studies of SES-related differences in brain structure and function, which have been portrayed in the media as reflecting “brain damage” among children from families with lower SES (e.g., Bidwell, 2013). Even within the scientific community, differences in neural outcomes as a function of SES are frequently interpreted as reflecting dysfunction or disruption (as opposed to adaptations or compensatory mechanisms) among those from lower-SES backgrounds (Ellwood-Lowe et al., 2016), with less attention given to resilience. Careful consideration of how studies of individual differences in brain structure and function are presented and interpreted is critical to advance a more inclusive approach to DCN (Nketia et al., 2021).

2. Strategies for overcoming barriers at the intrapersonal, interpersonal and community levels

A number of reviews have outlined strategies for recruiting participants from under-represented backgrounds, and overcoming mistrust commonly experienced by these communities in relation to scientific research (Arredondo, 2021; Bakhireva et al., 2020; Haack et al., 2014; Hartmann et al., 2014; Rivas-Drake et al., 2016; Rowley and Camacho, 2015). In Table 1, we provide a summary of strategies researchers may use at each research stage (e.g., design, data collection, post-publication) to build trust within targeted communities. At a basic level, it is important that communities understand the value of DCN research and its potential benefit for their local communities. This requires that researchers disseminate information about the importance of brain development research and the scientific process, and that research institutions support long-term continued engagement with the community when studies end. This can be achieved through continued communication with participants and community stakeholders, as well as through community-level dissemination of study findings. In all cases, language must be used in ways that are developmentally, culturally, and contextually appropriate. In building partnerships with community organizations serving youth and families, churches, schools, and other grass-roots community agencies, it is essential to be mindful that these partnerships are only successful if mutually beneficial. Identifying how the research addresses community priorities and needs that are consistent with the partnering community organizations is also key to facilitating collaborative and long-lasting partnerships.

Efforts to sustain collaboration with community partners over time are essential to build trust and overcome interpersonal barriers. It is often the case that researchers gain access to communities that are

Table 1

Recommendations and examples on how to improve representation at different levels of the research process.

Research stage	Recommendations	Rationale	Examples
Research Design	Involve community partners in decision making and study planning.	Building partnerships with community members that give them a voice in the research process, provide the opportunity to consult on priorities that need to be addressed, and share decision making and ownership of the research will help to build develop trust with the community.	Utilize community-based participatory research (CBPR; Harmann et al., 2014) methods to equitably involve community members in all aspects of the research process, from the design and implementation to interpretation of results. Engage in continual dialogue with community partners (e.g., through a community advisory board) and receive feedback that guides the research process over time, beginning at the inception of a study. Researchers learn, acknowledge, and respect the community's history and culture and facilitate dialogue about past abuse and mistreatment by the medical or research community.
	Consider the use of strength-based frameworks that highlight strengths and resilience, rather than deficit-oriented approaches.	Identify how aspects of the research or interpretation of results may stereotype, discriminate, marginalize, or oppress specific groups, and implement protections to minimize those risks.	In addition to asking about experiences of discrimination and adversity that are associated with adverse developmental outcomes, researchers should consider including assessments of culturally-relevant protective factors for historically marginalized groups. These could include measures of racial and ethnic socialization, cultural orientation, and familism (i.e., a sense of solidarity to one's family). Researchers could integrate assessments that attempt to capture not only the negative outcomes of adverse experiences, but also potential strengths that may develop among children who have experienced adversity (Ellis et al., 2020). Research questions related to stress and adverse experiences could be communicated to participants through this strengths-oriented approach rather than one focused on deficits that result from adversity.
	Tailor the research design and materials to the target population.	Use methods that are culturally sensitive and contextually appropriate. That is, research should be designed with participants' cultural and contextual backgrounds in mind.	Researchers use materials such as consent forms, questionnaires, and interviews that are contextually appropriate and aligned with the needs of the target population (e.g., language, literacy, and preferred response styles). Creation of consulting groups or forming alliances or collaborating with investigators who have expertise on the topic and common terminology, may help guide, advice and assist investigators in the development of study materials to ensure the use of inclusive and respectful language. When working with bilingual populations, researchers may consider administering the study assessments in both languages (Arredondo et al., 2019).
	Prioritize the recruitment of research staff from similar backgrounds as that of the target population.	Ensuring that some of the research staff is from a similar background as the target population will enhance knowledge of the needs and preferences of participants, facilitate positive interpersonal dynamics, and increase trust and understanding.	Offer paid research assistant positions, especially to individuals who are of similar backgrounds as the target population. For instance, if the study recruits Latinx Spanish-speaking bilingual participants, researchers should recruit research staff who speak Spanish and understand Latinx culture. Researchers play an active role in training and increasing the pool of scholars from historically marginalized racial and ethnic backgrounds by including them in important decision-making conversations (i.e., "make room at the table"). For instance, principal investigators should encourage open and honest conversations with scholars from these groups, listen to their ideas, and acknowledge their comments or concerns.
Data Collection	Reduce barriers to participation	Building trust and reducing logistical barriers is essential to increase willingness to participate in the research process and is helpful to increase retention and prevent attrition in studies that require multiple visits.	Researchers provide transportation to and from sessions; free babysitting for siblings, meals and snacks for participants and their families; appropriate compensation for both parents and children. Researchers provide incentives for the family as a sign of appreciation for their contribution, such as passes for a nearby museum or a meal after the study session. If possible, researchers consider carrying out parts of the study at home or at a trusted community venue (e.g., EEG and fNIRS are neuroimaging methods that can be administered remotely and taken to collect data at a participant's home).

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Table 1 (*continued*)

Research stage	Recommendations	Rationale	Examples
	Invest time explaining and demonstrating the research process to prospective participants.	In taking time to show participants the procedures prior to consenting, participants will develop trust and feel empowered in their decision to consent and discontinue participation, if they so wish. This step is especially important for those who might not be familiar with the research process. It is important to take time to ensure participants fully understand that their participation is voluntary and answer questions regarding confidentiality and privacy.	Researchers record a video that introduces staff and research procedures and shows prospective participants the technology to be used in the study. Researchers provide family members with opportunities to assist and watch the study sessions, which increases trust and engagement. Researchers are encouraged to treat the research session as a "family activity," by allowing family members to be present, while asking family members for their assistance in minimizing distractions while the study takes place.
	Increase competence of researchers and research staff in communication and engagement that is contextually and culturally appropriate.	Increasing cultural competence and training research staff on best practices for creating safe spaces and respectful communication is important to build trust and facilitate engagement between the researcher and participants.	Researchers consult with community partners on best practices for communication with prospective participants, for instance regarding the purpose of the study, study benefits, and how the results will be used. Researchers convey information in ways that are appealing to cultural values and respectful of cultural practices that are important to the target population and local community.
	Consult and collaborate with community experts.	Community experts can advise and guide practices and venues for recruitment and retention (e.g., churches, barbershops, libraries, etc.), interpersonal dynamics that facilitate the interviewing process, selection and distribution of incentives, etc.	Researchers attend and encourage lab involvement during recruitment and data collection at community events, such as festivals or cultural events. Researchers offer volunteering time and relevant resources at community events.
Post Data Collection	Strive to give back to participating communities in meaningful ways. Dissemination of research findings to the community and continued engagement.	Communicating and sharing the research findings to the community and maintaining efforts to remain connected and establish long-term alliances builds trust and facilitates future research collaborations.	Researchers create and disseminate educational resources for schools and afterschool programs (e.g., podcasts, short videos) that are related to brain development. Researchers offer interactive presentations on research findings and topics that families and the community might be interested in, such as "steps for improving academic performance" or "this is what your child's brain looks like." Researchers provide a list of referrals to low cost and accessible community services that are relevant to the target population (e.g., mental health, physical health, educational, or legal services). Researchers undertake initiatives for local families to learn and engage with science (e.g., development of community newsletters, volunteer participation in community or non-profit community boards, development of websites, podcast episodes, or hands-on activities for school systems, etc).

under-represented in research, but disengage from them upon completion of data collection (also known as "helicopter research;" Adame, 2021). As such, participants are left wondering about the results of studies and how the findings could have benefitted their communities. We encourage scientists to shift their focus from how the community can benefit research, to how science and the knowledge derived from it can *support* the community. By shifting this mindset, participants and their communities may begin to see researchers as "givers" rather than "takers." The shift will require the development of stable and lasting community partnerships at all stages of the research process, starting from the inception of a research study and continuing after study completion with a focus towards translating results to be impactful to the community. See Table 1 for specific recommendations and examples. Ultimately, the goal is to build collaborative alliances so that science is used to amplify the voices of communities that have been historically marginalized, in an effort to reduce existing gaps in knowledge, access, and resources.

3. Barriers related to the research process

Barriers related to the research process refer to the setting, logistics, and contextual situations that make it difficult for individuals to engage in research participation. Given the complex nature of neuroimaging data acquisition, a significant barrier that can preclude participation in DCN research involves location and convenience of research sites. Neuroimaging facilities (e.g., MRI and MEG scanners, EEG booths) are typically located on university or medical campuses, providing an intimidating and often inconvenient location that requires participants to travel and navigate unfamiliar environments. Medically underserved areas often lack access to neuroimaging equipment, creating a higher burden on participants from rural or remote communities, or for people with less access to transportation to travel to the research location. In addition, most neuroimaging technology acquires data from one participant at a time, removing group supports or carpool options. Similarly, data collection often occurs during work hours, high-traffic times (i.e., after school/rush hour), or at times that interfere with family quality time (i.e., weekends), all of which make it difficult for working families to participate.

Time commitment is another salient barrier to participation in DCN studies contributing to marginalization. Typically, data collection sessions are lengthy, require parents to be present which may conflict with caregiving for other siblings or family members, and create scheduling challenges particularly for people with busy and/or variable work schedules. In addition to the time required for the neuroimaging portion of the study, parents and children typically need to complete numerous and lengthy questionnaires and interviews. In aggregate, these barriers may then lead to selection biases and result in samples more heavily comprising children whose parents have close connections to universities or medical settings or have the time and financial resources to participate in lengthy study protocols. These samples are more likely to include highly educated families who are already knowledgeable about the research process. Furthermore, a need for high compliance from children and families can make DCN research particularly challenging. Neuroimaging technologies are highly sensitive to motion (Liu, 2016; Power et al., 2012), which can lead to meaningful loss of data in pediatric studies. The neuroimaging environment can be challenging for young children and youth with sensory difficulties, anxiety, or difficulty sustaining attention, which further increases the potential for data loss. In sum, the study's resource demands and challenges introduced by the neuroimaging equipment are barriers that compound with the limited information that communities receive about the importance of research, the research process, and opportunities on how to get involved.

Another barrier for participation in DCN research is the linguistic demand in English proficiency, which may be high for non-native English speakers or for families with limited literacy. This linguistic barrier can significantly interfere with participation of non-English speaking families and of those from lower-SES backgrounds. Materials or measures used in studies may also contain language that is complex, marginalizing, or stigmatizing for the participating families. For instance, the Confusion, Hubbub, and Order (CHAOS) Scale is a commonly used measure in developmental studies of early-life adversity, where parents self-report about the degree of household "chaos" as defined by high levels of noise, crowding, and home traffic patterns (Lauharatanahirun et al., 2018; Matheny et al., 1995). Aside from the pejorative name of the scale itself, the measure includes items with language that may be stigmatizing and off-putting to families (e.g., "it's a real zoo in our house," "there is often a fuss going on at our home"). For economic and cultural reasons, families from historically marginalized communities (e.g., Latinx and lower-SES families) may be more likely to reside in multi-generational homes with many people living in one house or apartment, which could inevitably lead to greater noise and crowding (Evans, 2004; Evans and Saegert, 2000). Making assumptions without attending to the effect of contextual influences on behaviors, such as preferences or the need for different home arrangements, may reinforce stigmatization among communities with different cultural values or life experiences (e.g., families facing social disadvantage and economic hardship). Limited cultural sensitivity and little attention to social norms that guide interpersonal interactions in the target population may also lead to misunderstandings of verbal and non-verbal behaviors that may lead to micro- or macro-aggressions and could deter participants from engaging in the research process. Unfortunately, researchers often have limited knowledge or awareness of preferred interpersonal styles, cultural values, and language preferences that are important to consider in facilitating interactions and motivating engagement with participants from different social, linguistic, and cultural backgrounds (Jacobs et al., 2006; Kennedy et al., 2007).

4. Strategies for overcoming barriers related to the research process

Concerted efforts are needed to facilitate access and improve logistics that would increase participation in DCN studies for historically marginalized communities. Advancements in portable neuroimaging technologies (e.g., EEG, fNIRS, low field MRI) make it possible for researchers to travel to the community and collect data from participants in their home or local community, rather than only at university campuses or hospitals (Arredondo, 2021). Establishing data collection sites that are located at convenient locations near the targeted community is a major advantage. For studies in which it is difficult to conduct the research in a community site or at a participant's home, it is important that researchers provide transportation at no-cost to the participant or reimburse families immediately for any transportation or parking costs. It is also important that researchers offer and arrange childcare for accompanying siblings, as it ensures that parents can devote proper attention to the study's procedures without having to arrange for childcare or incurring additional expenses.

Regarding time commitment, researchers should offer flexible schedules for participation (e.g., weekends, after work hours), and offer accommodations for families to complete certain research tasks at home, such as completing surveys online in advance of study visits, that could make it more convenient for families to participate. These alternatives can reduce time constraints for families with demanding work schedules or caretaking responsibilities. Moreover, compensating parents adequately for their participation and time, in addition to child and adolescent participants, signals appreciation of the time and effort that parents devote to participation in neuroimaging studies, and may make it more feasible for families with lower income to participate and continue participation through the years, while being mindful that financial incentives are not seen as being ethically coercive.

Making the research process familiar to targeted families ahead of time is also important for building trust and increasing compliance when there are rigorous study procedures that may be intimidating for people unfamiliar with neuroimaging research. We recommend the use of tools or strategies that help make the research environment more friendly and inviting for participants, such as sharing short videos introducing the research team and the neuroimaging technology, incorporating the use of a mock scanner to discuss the research collection process with families prior to participation, and using preparation kits that families can take home in advance of a neuroimaging scan (i.e., recordings of MRI sounds); these strategies have all been shown to be helpful in familiarizing families with neuroimaging research (Barnea-Goraly et al., 2014; Copeland et al., 2021; Greene et al., 2016; Hendrix and Thomason, 2022; Raschle et al., 2009). During imaging collection, researchers should consider the use of culturally and age-appropriate movies, engaging tasks, and other pleasant distractions to increase comfort and reduce motion. Following imaging participation, researchers can present families with brain pictures or other mementos of the participation process, along with study explanations and educational information. Remaining still for long periods of time is a challenge for all developmental populations, however, technical advancements and post-processing tools that remove transient motion artifacts will allow retention of more participants (Fair et al., 2020; Siegel et al., 2014).

At the design phase, participant and family materials and measures should be approachable and written to convey information that is widely accessible to the communities under study. Translating study measures and recruitment materials into other languages common in the local area, or relevant to the target population, will expand the range of families who are eligible to participate. Translation services are widely available and investing in high-quality certified translation to ensure language accommodation should be done at the design phase of research studies. Studies recruiting families who are not primarily English speakers should hire staff or interpreters who are fluent in those languages and researchers should plan for these expenses in their research budgets. Similar to recommendations in Table 1, it is important to ensure that effective and respectful communication is achieved between the study team and participants. In addition to using the language that is easy for participants to understand or the language that participants find more comfortable to engage in, it is also imperative to convey information in ways that are appealing to cultural values, framed according to strengths rather than deficits, and that are important to the target population and local community. Avoiding offensive language and non-verbal cues is of primary importance, and whenever possible, researchers should ask participants for anonymous feedback on their experience regarding the testing session. We encourage researchers to review the recently published guidelines by the Association of American Medical Colleges and the American Psychological Association for the use of inclusive language and respectful narrative for diverse populations (American Medical Association, & Association of American Medical Colleges, 2021; American Psychological Association, 2021).

5. Barriers at the systemic and structural levels

Systemic and structural barriers refer to attitudes, rules, regulations, policies and structures within research institutions and healthcare systems that may assist or hinder research participation or research of certain topics. At the systemic level, explicit attitudes and implicit biases may arise at the level of the investigator, institutions, and/or the field, and may result from unconscious assessment of the value of certain research topics, frameworks, or approaches (Brady et al., 2018). For instance, beliefs about fundamental or universal psychological processes can lead to deeply ingrained assumptions about aspects of brain development that apply equally to all groups regardless of cultural and contextual life experiences. Nonetheless, a growing body of research reveals that by not accounting for the influence of cultural factors and contextual experiences (e.g., racial and/or ethnic identity, gender, and SES), psychological research has overgeneralized patterns of cognition, emotion, and behavior of study participants who are overwhelmingly from White racial backgrounds, from western or developed countries, and of middle or high SES (Henrich et al., 2010). Prioritizing the experiences of certain groups limits generalizability of human development research (Gergen et al., 1996; Henrich et al., 2010; Watters, 2010). The limited ability to understand individual experiences and behaviors in relation to cultural contexts and from a strengths-based approach is leading to renewed efforts to recruit and retain diverse samples in psychology research and to expand the interpretative power of psychological science by integrating culture and the study of resilience into research designs more explicitly (Brady et al., 2018; Simons et al., 2017). Only recently has similar work appeared in DCN (Dotson and Duarte, 2020; Lin and Telzer, 2018; Nketia et al., 2021), demonstrating limits to the assumption of universal neurodevelopmental processes, invariant across groups (LeWinn et al., 2017).

A critical step for the field is to begin to identify and grapple with the types of biases that have led to systematic under-representation of historically marginalized groups in DCN research. For instance, perceived sameness with a particular group or preference for a singular approach may drive perception of relatability or enhance desirability or affiliation with a topic (Zajonc, 2001). In other words, what is familiar can be more comfortable and can skew objective determinations about what type of research is important and of value. Further, topics that are the focus of research can be perceived as having more or less significance if they apply towards a larger segment of the population (Wilholt, 2009). This assumption increases the risk of overlooking topics or areas of research that may be of greater impact to communities that have been historically marginalized, such as the study of resilience and studies with a strengths-based focus. Identifying and carefully attending to the effects that the aforementioned biases may have on research agendas is essential to develop a science that fully captures the diversity of human functioning.

The limited representation of researchers from ethnically and racially historically marginalized groups is another systemic and structural barrier to recruiting and retaining diverse samples in DCN studies. The demographics of scientists and physician-scientists in the biosciences, including DCN, do not represent that of the U.S. population. Scientists of color (especially Black, Latinx, Indigenous, and Pacific Islander) remain marginalized, along with women, and sexual and gender minorities (Carter et al., 2019). Indeed, in 2016, Black and Latinx individuals made up about 27 % of the overall U.S. workforce, but together only accounted for 16 % of those employed in a science, technology, engineering, and medicine (STEM) fields (Funk and Parker, 2018). In an analysis by the Pew Research Center, Black scientists accounted for 9 % of the STEM workforce in 2019, the same proportion as in 2016, while over the same period, the proportion of Latinx scientists in STEM jobs rose minimally from 7 % to 8 % (Funk and Parker, 2018). The magnitude of under-representation drastically increases with increased faculty ranks, and disproportionately so at advanced professorial and administrative leadership levels (Casad et al., 2021; U.S. Department of Education, 2020). Unfortunately, efforts and funding committed to increasing points of access and recruitment of scientists from economically and socially marginalized backgrounds continue to be insufficient and unsuccessful (Allen-Ramdial and Campbell, 2014; Miriti, 2020; Whittaker and Montgomery, 2014).

Limited representation of ethnic and racial identities in DCN scientists constrains scientific innovation and scientific rigor. Scientists from historically marginalized backgrounds are uniquely positioned to share experiences with their communities, may understand and voice the needs of their communities, play a key role in building trust, encourage the formulation of research questions that align with community priorities, strengths and goals, and have insight into existing barriers to research participation and factors that may facilitate engagement (Swartz, 2019). The ability for academia and the scientific community to embrace inclusion and representation of racial and ethnic diversity requires an acknowledgement of systemic and structural barriers that prevent transformation; such as, inequities in access to training opportunities for undergraduate students (e.g., unpaid summer research opportunities), as well as inadequate recruitment and retention efforts for historically marginalized scientists (Liu et al., 2019; Swartz, 2019). Similarly, environments and rhetoric that precipitate practices of exclusion, discrimination, and contextual biases perpetuate hostility and bias that impose unnecessary and unfair burdens among historically marginalized students and scientists (Brown et al., 2016; Eaton et al., 2020; McGee, 2016; Park et al., 2020; Swartz, 2019). For instance, undergraduate students who are marginalized in the sciences are more likely to leave the STEM field when instructors privilege theories, methods and experiences of the majority cultural norms and values (Carlone and Johnson, 2007; Camacho et al., 2021). Camacho and Echelbarger (2022) recommend instructors of undergraduate research methods to intervene on the pathway by incorporating practices that are equity-minded and inclusive, such as using examples that reflect diverse groups, including readings of scholars who are of historically marginalized backgrounds, and facilitating discussions about diversity, equity and inclusion (see Camacho and Echelbarger, 2022 for more details). Finally, inequities in funding for historically marginalized scientists are pronounced, which restricts the development of diverse research agendas. Indeed, Taffe and Gilpin (2021) demonstrated that principal investigators from historically marginalized ethnic and racial backgrounds were consistently less likely to receive funding from the National Institutes of Health (NIH) when compared to their White counterparts. Challenges in securing funding and institutional support are associated with limited institutional understanding of the complexities involved in community-engaged research, such as extended timelines to conduct formative research, build and maintain relationships with community partners, and development of research protocols that are culturally sensitive and contextually appropriate (Swartz, 2019). The unique challenges that scientists from historically marginalized groups often face interfere with the promotion of scholars advancing this work, but also lead to delays and/or difficulties in the implementation of community-based research (Turner and González, 2015; Zambrana et al., 2015).

6. Strategies to overcome systemic and structural barriers

The lack of representation of diverse groups in DCN samples is difficult to quantify given that most neuroimaging journals do not require that papers report on basic socio-demographic variables of the sample being analyzed. A necessary step to stimulate progress towards building a more representative scientific foundation in DCN is to adopt recent recommendations from psychology in which all studies identify the target population, justify the inclusion of particular groups, and discuss the constraints on generality as a requirement for publication (Simons et al., 2017). If journals begin to require that sample composition is reported, justified, and integrated into the interpretation of results (including limits to their generalizability), such an endeavor would send a powerful message that may lead to rapid changes in how investigators recruit and report on representation in their samples and, in the longer term, may shape assessment, study design, and sampling practices. Similarly, reporting guidelines for race and ethnicity (e.g., as required by NIH) can have meaningful influences on recruitment and representation by specifying the groups that must be included in research studies.

Promoting diverse representation in DCN samples enhances interpretive power and promotes our ability to understand and respect individual differences, for example, in relation to cultural contexts and life experiences that may have important influences on neurodevelopmental processes (Brady et al., 2018). Addressing systemic biases that have prevented diversity in DCN requires that these biases be made explicit and that the field articulates and embraces the ways in which science is improved when diverse perspectives and experiences are incorporated into DCN and the associated theoretical frameworks. Science is enhanced by knowing the extent to which an observation is universal versus expressed under certain conditions and in different contexts. This is reflected clearly in recent work demonstrating that patterns of age-related variation in the structure of both cortical and subcortical regions are meaningfully different when estimated in a convenience sample versus a sample weighted to reflect the underlying population in terms of race, ethnicity, and SES (LeWinn et al., 2017). Another recent example using data from the Adolescent Brain and Cognitive Development (ABCD) sample demonstrates that Black and Latinx youths living in contexts characterized by high levels of structural stigma toward their racial and ethnic identity, respectively, have smaller hippocampal volume than youths of the same racial and ethnic background who are living in contexts with lower levels of structural stigma (Hatzenbuehler et al., 2022). Together, these findings suggest that important differences in brain development are missed when we utilize samples lacking in diverse representation or when failing to consider how developmental processes vary across individuals or cultural contexts. If we possess limited knowledge about the environmental, cultural, and structural conditions that influence neurodevelopmental processes, we fail to understand factors influencing brain development, misidentify variation as problematic, or miss opportunities to develop effective interventions. If, as a field, we focus on developing discourse on the ways in which neurodevelopmental patterns are conditionally variable, it will help us reduce pervasive biases and move conversations forward towards diversifying DCN research.

A critical approach to increase representation in DCN research is to promote diversity, equity and inclusion as a cornerstone of the mission of academic and scientific institutions, as well as scientific and professional societies. Many universities and medical research centers in the U. S. have pledged to increase diversity in recruiting and retaining scientists from historically marginalized backgrounds, but progress has been slow. Although an in-depth review of how institutions can accomplish this is beyond the scope of this paper, Swartz and colleagues (2019) provide many helpful and practical recommendations for achieving greater levels of equity and representation in academic and scientific institutions (Swartz et al., 2019). Table 2 summarizes a range of potential solutions to increase diversity in DCN at the systemic and structural levels. Implementing the recommended solutions requires institutions to cultivate culture change and implement strategies to facilitate transparent and equitable hiring and promotion practices, reduce application barriers, increase pay equity, implement flexible work arrangements and policies, and build direct and indirect sources of cultural support and mentoring for scientists of historically marginalized backgrounds. Institutions should foster ongoing dialogue about diversity, equity, and inclusion (Funk and Parker, 2018), and acknowledge the need for evolving practices to continue to place these values at the forefront of institutional culture and practice. Scientific and professional societies can commit to upholding values that are inclusive and encourage diversity in the scientific enterprise. For instance, meetings of the society can highlight the research of scholars whose work incorporates theoretical frameworks that contextually situate findings on the experiences of samples from historically marginalized backgrounds. By featuring this work in professional meetings, the scientific community can begin to value this work and shift their practices and perspectives towards a more inclusive and equitable scientific environment.

A final key strategy for increasing representation in DCN is reprioritization of funding. Financial support is necessary to achieve most of the changes recommended to overcome existing barriers in recruiting and retaining diverse samples. Examples of financial support that have shown helpful in increasing representation include phased grant awards, incentives for recruitment and retention of diverse samples, and funding to support applied science projects and investigators conducting community-engaged research. For instance, phased grant awards provide support during a preparatory phase where specific community partnerships can be established or legal/ethical analyses can be performed to assure support for participants throughout the project, such

Table 2

Domains, rationale and recommendations how to increase diverse representation in the DCN scientific workforce.

Domain	Rationale	Recommendation
Recruitment of scientists from historically marginalized backgrounds	The demographics of scientists in DCN do not represent national population trends; inequities exist in accessing training opportunities and degree attainment; people in communities that are under-represented want to see scientists and leaders like themselves, which helps to build trust and facilitates the building of collaborative alliances.	Create a pathway by providing training and funding to increase points of access and recruitment of scientists from historically marginalized backgrounds; provide robust guidance and counseling at early career stages; cluster hiring of scientists conducting similar line of work to facilitate support and collaboration; implementation of equitable hiring practices regarding compensation and evaluation.
Retention of scientists from historically marginalized backgrounds	Environments that precipitate practices of exclusion and discrimination and perpetuate hostility and oppression impose unnecessary and unfair burdens to historically marginalized scientists; scientists from historically marginalized ethnic and racial backgrounds often lack adequate support and have limited access to mentorship.	Cultivate workplace cultural acknowledgement of systemic and interpersonal barriers; provide access to mentors from under-represented backgrounds (when possible); train and incentivize both mentor and mentee to invest in creating and maintaining this relationship; ensure equity and parity in compensation; support collaborative networks and funding efforts to foster community-engaged research; support programs that improve understanding of the complexities involved in community-engaged research and facilitate avenues to make the work possible (e.g., extended timelines, phased grant awards).
Promotion of scientists from historically marginalized backgrounds	Marginalization drastically increases with elevated faculty and administrative ranks; scientists from historically marginalized backgrounds are consistently less likely to receive federal funding when compared to their white counterparts; community-engaged research involves significant time commitment that is not consider in promotion.	Improve transparency in promotion processes and in available resources for growth and training; formalize mentors as career advocates; encourage and nominate scholars from under-represented groups to pursue leadership positions; exercise caution about over-commitment of scientists from historically marginalized backgrounds to service roles; consider establishing and sustaining community partnerships as a deliverable to inform promotion.

occurred in the National Institutes of Health Healthy Brain and Child Development (HBCD) initiative (Volkow, Gordon, and Freund, 2021). For the HBCD study, competitively reviewed grants were provided to carry out preparatory work to establish community partnerships and protections that would scaffold later phases of the study. Creative funding solutions that reward diverse research efforts are key to enabling researchers to choose more challenging but important research directions.

7. A path forward

Despite limited attention to issues of representation and diversity in DCN research, progress is evident and continues to be necessary. Several recent multi-site large-scale studies including the ABCD Study (Barch et al., 2018), the Human Connectome in Development Study (HCP-D; Somerville et al., 2018); and the HBCD Study (Volkow et al., 2021) have been designed to ensure community representative sampling and inclusion of participants that have been economically and socially marginalized. The ABCD study includes measures specifically designed to examine the impact of cultural background on cognitive development, along with the assessment of other important aspects of identity and contextual experiences (Zucker et al., 2018). These studies reflect positive developments that improve the quality and potential impact of DCN research. It is imperative that the field continues to grapple with barriers to recruitment and retention of diverse samples, and also continue to promote systemic and structural changes in our institutional environments to build a diverse scientific workforce.

Inclusion and representation goals must be approached with cultural humility and appropriate caution about the potential for misuse of neuroimaging results that report de-contextualized differences across groups (e.g., as a function of racial/ethnic background or SES). Prior commentaries about the reporting of SES and adversity-related differences in brain structure and function highlight the detrimental consequences that can arise when reporting and interpreting group differences without attention to culture and context (Ellwood-Lowe et al., 2016; Nketia et al., 2021). Particular caution is needed to avoid de-contextualized reporting of racial or ethnic differences in measures of brain structure and function (Helms, Jernigan, and Mascher, 2005), given the high potential for misuse of the type that has occurred in relation to research examining group differences in IQ, where group differences in test performance have been used to argue that certain racial groups are inherently inferior in intellectual ability than others (Herrnstein and Murray, 2010). It is not difficult to imagine similar types of inappropriate inferences being made on the basis of racial or ethnic differences in brain structure or function. Focusing on neurodevelopmental differences associated with variations in lived experiences, such as those pertaining to life adversity and disadvantage commonly experienced by youths from historically marginalized backgrounds or lower-SES families (e.g., racism, discrimination, stigmatization, victimization) can mitigate this type of misuse. Consistent with a focus on emphasizing variations in lived experiences, researchers can facilitate the proper contextualization of findings by acknowledging and stating historical narratives of oppression and inequity related to their sample (American Medical Association, & Association of American Medical Colleges, 2021; American Psychological Association, 2021). Likewise, carefully attending to the use of frameworks focused on strength-based approaches, the effect of language differences, and the inclusion of concepts that are equity-focused is essential.

In this paper, we emphasize the need to overcome barriers at multiple levels of influence as essential to diversifying DCN research and highlight specific recommendations that can facilitate the process. To diversify, innovate, and succeed in this effort, institutions, academic leaders, and researchers must understand that there is no simple solution to this complex problem. However, with appropriate levels of accountability, leadership and continued engagement, ongoing and consistent improvements may be attainable. Recognition of the value of diversity in DCN research and acknowledgement of the additional support needed to diversify the field is critical for advancing understanding of neurodevelopment, reducing health inequities, and promoting social justice.

CRediT authorship contribution statement

Garcini: Conceptualization, Writing – original draft, Writing – review & editing, Visualization, Resources. **Arredondo:** Conceptualization, Writing – original draft, Writing – review & editing, Visualization, Project Administration, Resources. **Berry:** Conceptualization, Writing – original draft, Writing – review & editing, Resources. **Church:** Conceptualization, Writing – original draft, Writing – review & editing, Resources. **Fryberg:** Conceptualization, Writing – original draft, Resources. **Thomason:** Conceptualization, Writing – original draft, Writing – review & editing, Visualization, Resources. **McLaughlin:** Conceptualization, Writing – original draft, Writing – review & editing, Visualization, Project administration, Resources.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

No data was used for the research described in the article.

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