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Shining a Light on Cultural Neuroscience: Recommendations on the Use of fNIRS to Study How Sociocultural Contexts Shape the Brain

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Abstract

Functional near-infrared spectroscopy (fNIRS) is a portable neuroimaging technique that may serve as a methodological tool for studying how sociocultural contexts can shape the human brain and impact cognition and behavior. The use of fNIRS in community-based research may (i) advance theoretical knowledge in psychology and neuroscience, particularly regarding underrepresented ethnic-racial communities; (ii) increase diversity in samples; and (iii) provide neurobiological evidence of sociocultural factors supporting human development.
OBJECTIVES: The review aims to introduce the use of fNIRS, including its practicalities and limitations, to new adopters inquiring how sociocultural inputs affect the brain. The review begins with an introduction to cultural neuroscience, and a review on the use of fNIRS follows. Next, benefits and guidelines to the design of fNIRS research in naturalistic environments (in the community, or in the field) using a cultural lens are discussed. Strengths-based and community-based approaches in cultural neuroscience are recommended throughout.

Keywords: fNIRS; cultural neuroscience; ethnic-racial minorities; strengths-based; community-based.

Shining a Light on Cultural Neuroscience: Recommendations on the Use of fNIRS to Study How Sociocultural Contexts Shape the Brain

Rapid changes in technology are altering the methodological approach to how researchers answer scientific questions. While common methods (surveys, qualitative observations, controlled lab-setting experiments) provide meaningful information about human behavior, combining these approaches with neuroimaging methods provides previously unearthed insight into how the environment shapes the individual, their cognition, and the brain. The present paper reviews how functional near-infrared spectroscopy (fNIRS), a portable neuroimaging method, has the potential to advance theoretical knowledge via community-based research, particularly for underrepresented samples. The present review uses the neutral term "underrepresented" to encompass ethnic- and racial-minority groups that are often overlooked in psychology research, specifically in the United States; these include Asian Americans, Black and African Americans, Indigenous Peoples, Latinx, and Middle Eastern and North African populations. Please note that within these communities, ethnic identities also intersect along identities related to gender, sexuality, social class, religion, and ability. To showcase the neuroimaging method and the types of research questions for which it is useful, a brief description of cultural neuroscience is provided. This description is followed by a review of fNIRS and strategies and procedures for carrying out an fNIRS-based study. fNIRS allows researchers to inquire how neural cortical regions are engaged and information is processed; the data can then be linked to behavior in "live" situations or as the behavior actively occurs. In addition, fNIRS is portable and participants can move freely about their environment during data collection, allowing the research to be executed within communities (i.e., in the participant's sociocultural context, outside of the lab setting). This freedom may further support the recruitment of diverse and underrepresented samples. Finally, the review encourages the expansion of cultural neuroscience research by using a strengths-based methodological approach.

Cultural Neuroscience: How Sociocultural Contexts Shape the Human Brain

Human behavior and its neurobiological responses are embedded in the individual's social and cultural context (Bronfenbrenner & Ceci, 1994; Chiao & Ambady, 2007). In some cases, the individual is self-aware of the intentions behind their behavior; in other cases, the responses are unbeknownst to the individual. Neurobiological responses, such as brain activity, can be categorized as those unbeknownst responses that may reveal significant information about the individual's abilities or environment (Poldrack, 2018). The emerging interdisciplinary field of cultural neuroscience merges cognitive neuroscience and sociocultural psychology to investigate how the individual's environment influences neuro-cognitive processes (Causadias, 2013; Chiao & Ambady, 2007; Lin & Telzer, 2018; Syed & Kathawalla, 2017). Sociocultural contexts are pervasive in an individual's life: these may be evident in the individual's linguistic environment, relationships among family and friends, parenting and community practices, as well as in their beliefs, ideas, and values (Chen, 2011; Rogoff, 2003; Rogoff et al., 2017). Though sociocultural contexts may seem distal, their impact on the individual can be bidirectional. Individuals actively engage in and practice their culture solitarily and with others through their ways of daily living (Rogoff et al., 2017). In other circumstances, however, the sociocultural context in which an individual is living affects their behavior and/or neurobiological systems. For instance, research by Hill et al. (2017) reveals how the ongoing experience of racial discrimination affects neurobiological systems across African Americans' lifetime, evidenced by an increase in resting heart rate, which in turn has a negative impact on overall health. Thus, while there are sociocultural environments in which an individual may choose to actively participate, there are also social structures outside the individual's control that can have a direct impact on their behavior and neurobiological responses.

Cognitive systems and their associated brain networks (e.g., sensory, language, higher cognitive functions) also mature at different rates across development (Hensch, 2005; Werker & Hensch, 2015). In turn, cultural neuroscience also incorporates developmental frameworks to examine whether specific periods in human development are especially sensitive to sociocultural contexts and more likely to impact or shape the brain, including its cognitive and affective domains (Chen, 2011; Chiao, 2018; Werker & Hensch, 2015). For instance, bilingual infants show increased brain activity in language- and attention-related regions when listening to both of their native languages, as compared to monolinguals, suggesting that bilingual environments impact the brain as early as the first year of life (Ferjan Ramírez et al., 2016; Garcia-Sierra et al., 2016; Nacar Garcia et al., 2018). Another example is found in work by Telzer and colleagues (2010, 2013) where adolescents of Mexican ethnic background, who place importance in helping their family, activate regions of the brain that are associated with "reward" when they make monetary decisions that contribute to their family. Mexican-origin adolescents also show decreased brain activity in these 'reward' regions when participating in risk taking behaviors. These studies show that sociocultural values and parenting practices shape children's cognition and brain development from a very young age, and these effects may be evident at various ages corresponding with sensitive periods of brain development.

One important aspect of research methodology that cultural neuroscience is beginning to address is the increasing need for a strengths-based approach in the field. Much has already been said about the negative effects on neurobiological systems of the experience of adverse events such as racial discrimination, poverty, and social stratification (e.g., see Causadias et al., 2017;

Fuller-Rowell et al., 2012; Hoggard & Hill, 2018; Mendoza et al., 2017; Muscatell et al., 2016; Noble, Norman, & Farah, 2005; Zeiders et al., 2012). While understanding the negative effects of adverse experiences is important in addressing social disparities, much remains to be learned about how neurobiological systems are shaped by individuals' resilience or protective factors in the face of such adversity (Causadias, 2013). For instance, research on how social stratification impacts brain development often measures a small set of variables (e.g., income, parents' education level) to assert the negative consequences of poverty (e.g., see Farah, 2017; Noble et al., 2005; Raizada et al., 2008). However, social stratification is systemic, and social mobility is highly complex (Lenski, 2013). Focusing on the negative effects limits our complete understanding of these populations, and perpetuates the notion that negative effects represent the full extent of knowledge that can be gained from studying adverse experiences or underprivileged populations. Rather than relying on a "deficit" approach, a strengths-based approach allows for the discovery and exploration of protective factors (Bozic, 2013; Gleason, 2007; Powell et al., 1997; Rogoff et al., 2017). Protective factors are defined as an individual's characteristic that mitigates the development of a negative outcome when the individual is faced with a high level of risk and adversity in their environment (Masten et al., 2009). For instance, in the case of ethnic and racial minority youth, cultural considerations such as racial and ethnic identity and ethnic-racial socialization can serve as protective factors (Neblett et al., 2012). A strengths-based approach highlights those strategies, talents, or skills held by an individual or community that counter negative outcomes, yet these remain largely unexplored in neuroscience (Case & Robinson, 2003; see Neblett et al., 2012; Rivas-Drake et al., 2014a, 2014b).

Take for instance the case of bilingualism in the United States, a country with a history of linguistic and cultural assimilation that is especially pronounced in minority and immigrant communities. Nearly one in every four American children (~12 million) between the ages of 5 and 17 speaks a language other than English at home (U.S. Census, 2019). Research shows that bilinguals' heritage language(s) supports children's learning about their heritage culture and their emotional connection with their heritage community (Arredondo et al., 2016; Oh & Fuligni, 2010). Positive feelings about one's heritage culture and development of an ethnic identity are associated with academic success (Rivas-Drake et al., 2014b). Children as young as 5 years old provide extensive information about their family's ethnic background, and they express both positive and negative emotions regarding their cultural experiences such as pride in their family's background and difficulty with mastering both languages (Arredondo et al., 2016).

Language abilities are a strong predictor of academic success (Bleses et al., 2016). Much of the research on child bilingualism, however, addresses the unique linguistic challenges that young bilinguals in the United States often face with English, such as "delayed" development of language abilities as compared to their monolingual peers (Hoff, 2018; Hoff & Ribot, 2017). Emerging evidence in cognitive neuroscience suggests that bilingual experiences may strengthen the child brain's language pathways and cognitive control networks, even for children from underprivileged backgrounds (Arredondo et al., 2017; Arredondo, Satterfield et al., 2019; Arredondo, Seifert et al., 2019; Brito & Noble, 2018; Hsu et al., 2019). Bilingual children and adults show stronger and more restricted brain activation in left hemisphere regions associated with language, suggesting a higher degree of brain specialization, likely as a result of their enriched lifelong bilingual experiences (Kovelman et al., 2008). Thus, bilingualism appears to "train," or actively engage, neural networks that possibly keep the brain more agile or "healthier," given evidence showing delayed onset of dementia in bilinguals with Alzheimer's disease (Craik et al., 2010; Perani et al., 2017). In addition, research with bilingual children who are also biliterate shows that reading abilities in the minority heritage language (e.g., Spanish) supports better reading abilities in the majority English language (Kremin et al., 2019). Nevertheless, bilingual programs in the public school system continue to be underfunded or defunded across the United States. The remaining programs often focus on increasing children's English language skills, rather than supporting dual-language learning (Petig et al., 2018).

Using brain evidence, research on bilingualism is beginning to bust the myth that this sociocultural experience delays language development. This evidence can then inform policy makers, program evaluators, and educators as they seek to design better community-based programs and choose where to allocate financial support (e.g., Smith et al., 2014). Use of a strengths-based approach shifts the power back to the individual and their community (Hartmann et al., 2014; Hernández et al., 2013; Rivas-Drake et al., 2016). Furthermore, use of neuroscience to "flip the script" from a deficit- to a strengths-based approach has the potential to provide evidence on the cultural practices (e.g., bilingualism, parenting practices) that may best support individuals in reaching their highest potential in society. How might we gain this insight from communities? The most efficient approach is to take neuroscience to the communities.

Functional Near-Infrared Spectroscopy (fNIRS): Taking the Science to the Community

Portable neurophysiological techniques (e.g., eye tracking, heart rate monitoring, electroencephalography) are transforming methods in the social sciences by allowing us to take a leap beyond the lab setting to collect data in natural environments. One of these portable methods is functional near-infrared spectroscopy (fNIRS), which measures changes in activity in the brain's cortical responses across time by reflecting light (Delpy & Cope, 1997). In comparison to other similar techniques, fNIRS straddles a combination of functional magnetic resonance imaging (fMRI) and electroencephalography (EEG). A strength of EEG is its higher temporal resolution in measuring electrical activity by the millisecond; however, this technique is also highly sensitive to motion which limits its use in natural environments. fNIRS is non-invasive, silent, safe, cost-efficient (more affordable than fMRI or other neuroimaging techniques), generally tolerant of movement, small in size, and easy to transport. fNIRS is also suitable and ideal for testing in all populations, including those who are often ineligible to participate in fMRI or magnetoencephalography studies such as newborns, toddlers, pregnant women, and individuals with metal in their bodies (including those with braces, pacemakers, cochlear implants), or those who find it hard to stay still for long periods of time such as toddlers. fNIRS is also suitable for use in unconstrained environments (Balardin et al., 2017) such as face-to-face conversation or interactions (see Figure 1) (Jiang et al., 2012; Quiñones-Camacho et al., 2020; Suda et al., 2011; Takei et al., 2013, 2014); dancing or playing a video game (Noah et al., 2015); driving (Yoshino et al., 2013); playing the violin (Vanzella et al., 2019); exercising (Kenville et al., 2017); and climbing (Carius et al., 2020). Importantly, its portability makes fNIRS suitable to be transported internationally, as well as to homes, community centers or schools, to carry out cross-cultural research within everyday-life scenarios and naturalistic environments rather than strictly within the lab setting (Balardin et al., 2017; McKendrick et al., 2016; Pinti et al., 2015, 2018).

An fNIRS system is composed of emitters that produce near-infrared light and detectors that collect hemoglobin changes in the brain’s cortex (Delpy & Cope, 1997). Both emitters and detectors are attached to a cloth cap, or band, and placed on a participant’s head (see Figure 1). The light is absorbed and reflected as it passes through the skull and cerebrospinal fluid, before and after reaching 2–3 millimeters of the cortex. Since fNIRS uses light (690–900 nm wavelengths), brain activity from deeper brain structures (e.g., basal ganglia, hippocampus) cannot be measured (Delpy & Cope, 1997). The connection between the source and detector is called a "channel," which is placed on the head atop a region of interest (Figure 1). When the brain's region of interest is engaged and active during a task (or induced by stimuli), the typical response is for oxygenated hemoglobin to increase and deoxygenated hemoglobin to decrease or show little change (Scholkmann et al., 2014).

Unlike fMRI, fNIRS is limited in its spatial resolution, since researchers cannot accurately localize where in the brain's cortex the light is absorbed or reflected from. To address this limitation, researchers often use EEG caps for choosing the location to place channels on the participant's head. More specifically, researchers approximate the brain locations from regions of interest using the 10-20 electrode placement system, since prior research has associated these specific points on the head with underlying brain regions (e.g., point F7 is likely near the left inferior frontal gyrus) (Jurcak et al., 2007; Okamoto et al., 2004). Prior to placing the fNIRS cap or band on the participant, researchers measure distances across the participant's head (such as the circumference) so that the cap is placed accurately on the participant's head and near the associated 10-20 electrode points. The systematic placement of the headband or head cap across participants (who may vary in head sizes) is critical, in order to reduce the variability in brain response that may affect Type I or Type II errors (Tachtisidis & Scholkmann, 2016). Once the cap or band is placed, the channels' signals are examined. A limitation of fNIRS is that because hair also absorbs light, signal quality may be affected in reaching the cortex, especially for those participants with dark or thick hair. In the case that signal quality is affected, the experimenter may opt to temporarily remove any emitter or detector with a poor signal, part any hair affecting the signal in that location (e.g., using crochet sticks or chopsticks), place back the emitter or detector, re-examine signal quality, and proceed with data collection as the signal improves. A few fNIRS systems (e.g., BIOPAC Systems) use brush-like emitters which improve signal quality by penetrating through the hair and attaching to the scalp (Khan et al., 2012); nevertheless, these new developments are still in their infancy. In the case that the research includes participant samples that wish not to have the experimenter touch their head or their hairstyles (e.g., women who wear headscarves for religious reasons), researchers may wish to adopt culturally-sensitive procedures for their fNIRS study, including: (i) use a silicone headband rather than a headcap to hold the sensors (see Perlman et al., 2014 for example); (ii) measure brain activity from frontal regions (forehead); (iii) instruct and show the participant how to place the sensors on themselves to minimize contact; (iv) consult with community experts on what is and is not appropriate to say and/or do; (v) include scholars and research assistants from similar backgrounds as the participants (gender, race/ethnicity) who might also know the culturally appropriate manners. For the remaining participants who have poor signal quality, data from these channels will need to be removed when preprocessing the signal prior to data analysis.

When choosing brain regions of interest, as well as when designing neuroimaging tasks or when forming a brain-specific hypothesis, researchers review neuroimaging evidence on the regions that are active during a similar or exact behavior. For instance, some use the BrainMap searchable database, which has a growing number of neuroimaging papers mapping experiment results onto brain regions (Fox & Lancaster, 2002). Toolboxes that help maximize the design and placement of fNIRS channels are available, such as AtlasViewer (Aasted et al., 2015); fOLD (Morais et al., 2018); and Array Designer (Brigadoi et al., 2018). Regarding the measurement of the hemodynamic response, oxyhemoglobin is slow to rise, peaking at 8–16 seconds, and slow to go back to baseline following a stimulus event (Shan et al., 2014). Therefore, specific procedures are often integrated into the design of the experiment and analysis of the data. An experimental task often includes multiple (at least two) conditions that induce different reactions or behaviors from the participant (e.g., easy vs. challenging levels of difficulty, happy vs. neutral faces) to engage brain activity differently across conditions (e.g., increased vs. no change) (Petersen & Dubis, 2012). Experiments in the lab setting are often methodologically designed as blocks or event-related (Petersen & Dubis, 2012). A block design will present the stimuli for a longer period (e.g., 20 seconds) than event-related designs. The block is followed by a period of rest (often of the same length) so that the hemodynamic response is at baseline before the next experimental condition is presented. An event-related design presents stimuli in a more natural manner, by presenting stimuli at shorter lengths than a block (e.g., 2–8 seconds), along with short inter-stimulus interval periods of rest that vary in length (Dale, 1999). For instance, in a naturalistic environment with bilingual participants, the researcher may present a condition in which participants switch between their languages, while in another block the participant may focus on producing one language. Differences in brain activity across conditions are then visualized on a 3D brain image and discussed as active for specific behaviors.

More recently, new experimental designs have emerged that are better suited for naturalistic environments. Resting-state and functional connectivity provide insight into regions of the brain that might be communicating over time while the participant sits silently for an extended period (5–20 minutes) or while engaged in a task (Lu et al., 2010; Camacho et al., 2020). Connectivity analyses are ideal for investigating whether individuals engage different brain networks. For instance, the left fronto-parietal network is more active at rest for bilinguals than monolinguals, possibly signaling that bilinguals' language networks are ready to process or produce either of their languages at a moment's notice (Gullifer et al., 2018; Kovelman et al., 2008; Sulpizio et al., 2020). Another emerging experimental design in fNIRS is "hyperscanning," which is used to measure brain activity from multiple (2+) individuals simultaneously while they interact in social situations (Czeszumski et al., 2020; Quiñones-Camacho et al., 2020). Recent hyperscanning studies have investigated concepts of cooperation while two people played a block-stacking game called Jenga (Liu et al., 2016); interactions among friends, lovers, strangers (Pan et al., 2017); and parent–child dyads (Reindl et al. 2018; Quiñones-Camacho et al., 2020).

There are several excellent review articles on the fNIRS technique (Almajidy et al., 2020; Ferrari & Quaresima, 2012; Gervain et al., 2011; Pinti et al., 2018; Quaresima & Ferrari, 2019), including detailed information on how to set up the system, studies outside of a lab setting and while in the field (Baker et al., 2017; Jasińska & Guei, 2018; Katus et al., 2019; Nishiyori, 2016;); the technique's limitations and challenges (Tachtsidis & Scholkmann, 2016); how to carry out signal preprocessing (Di Lorenzo et al., 2019; Novi et al., 2020; Pfeifer et al., 2017); and analytical procedures (Pinti et al., 2019; Tak & Ye, 2014). Data preprocessing and analytical tools are open-source, offer documentation, online tutorials, as well as in-person or online workshops: AnalyzIR (Santosa et al., 2018); HomER2 and HomER3 (Huppert et al., 2009); NIRS-SPM (Tak & Ye, 2014); nirstorm (Tadel et al., 2011); and FieldTrip (Oostenveld et al. 2011). Wearable fNIRS systems that are wireless and as light as one ounce have emerged, which have a high level of comfort (e.g., Gowerlabs Lumo, Artinis Brite and Octamon, NirX Nirsport 2, and fNIR Devices). Nevertheless, smaller fNIRS systems including wireless or more portable varieties may be limited to a smaller number of channels (i.e., fewer sources and detectors) or limited to collecting data in the brain's prefrontal lobe, unlike larger systems which can provide full coverage of the head.

"*Flip the Script*": Recommendations for New Adopters of fNIRS

As researchers merge strengths-based methods into cultural neuroscience, they should be mindful on how they involve underrepresented communities in the science. In the following section, I first provide recommendations and examples for how new adopters of fNIRS and the next generation of neuroscientists can formulate research questions that merge fields of knowledge and avoid asking the classic question of whether a psychological concept replicates with a different sample. Second, I discuss strategies on how to take neuroscience outside of the lab and into the community, summarize approaches on how to recruit and retain underrepresented and ethnic-racial minority samples, and discuss briefly on how this work benefits the community.

(1) Your questions and methods should merge knowledge across fields. Linking cognitive and brain processes to real-world situations and everyday behaviors remains a challenge for neuroscience. Given the unique and exploratory nature of integrating sociocultural and cognitive neuroscience methods, the researcher should be cautious in formulating the methodological design. First, a thorough review of the literature across multiple fields of knowledge will need to be carried out. If little evidence exists on the subject matter, then research exploring a similar line of work could provide support for a missing link (see example below on bilingualism and bidialectal code-switching). While developing a hypothesis, the researcher should consider which brain regions might be engaged during a demanding/conflicting task condition versus a less demanding/conflicting condition. While designing the study, the researcher should consider the tasks and/or situations that the participant will engage in, as well as how and where should data be collected (e.g., at home, at school). If considering naturalistic environments, the experimenter will need to decide whether the experiment should be carried out via a computer or tablet at home, while interacting with confederates, or in a natural "live" setting such as a family dinner. Researchers should also use mixed-methods and collect qualitative interviews or quantitative self-reports (e.g., demographics) to support their claims, describe their sample, and discuss any strategies that participants may have used during the study.

Example. It is well established that African Americans engage in code-switching behaviors (i.e., alternating between their Black identity and the White "mainstream" culture, including shifting between linguistic styles; Baldwin, 1997; Cross & Strauss, 1998; Wyatt & Seymour, 1988). Researchers may want to investigate what cues a participant to code-switch, what are the neuro-cognitive processes supporting code-switching, or whether some individuals are more adept code-switchers and why. Using a strengths-based approach, researchers may ask whether environments that demand code-switching "train" the brain and whether these experiences provide some benefits, such as better perspective-taking skills or better cognitive and brain health. Cognitive control mechanisms (such as attention, inhibition, and memory) support planning behavior and focusing on the goal in mind; these mechanisms are also associated with multiple aspects of everyday life, such as mental health, and academic and professional success (Diamond, 2013). One possibility is that, similar to bilingualism, cognitive control mechanisms support bidialectal code-switching in African Americans. Indeed, some suggest that there is overlap in the linguistic experiences of bilingual children and bidialectalism that many African American children experience (Terry et al. 2018). This area of research is largely unexplored, yet some are beginning to ask whether African American children who engage in bidialectal code-switching behavior are enhancing their cognitive control mechanisms (Carrera et al. 2019; Webb et al. 2019). If so, similar to bilingualism, there could be specific factors when bidialectal code-switching supports brain health across the lifespan (Craik et al., 2010; Perani et al., 2017). To investigate this line of inquiry, researchers may wish to investigate the long-term effects of code-switching behaviors, and consider testing code-switching across different settings (e.g., home, school, work environments).

(2) Strategies for moving neuroscience to the community. Several challenges arise when recruiting and retaining participants from communities that are underrepresented in science, especially when using neurophysiological methods. One common challenge is overcoming participants' level of mistrust rooted from scholars who gained access to these communities and did not provide support nor otherwise positively contributed to the community following study completion (for more details, see Rowley & Camacho, 2015). For instance, being a Spanish-speaker does not automatically make a researcher a member of a Latinx/o/a or Hispanic community. In my experience, as a first step, I take advantage of volunteering activities to understand the needs of the community and understand how to apply my skills. In the past, I have acted as a language evaluator at Spanish heritage language learning schools and tutored in afterschool programs, for example. I also give interactive talks in community centers on topics of interest to the community, such as how to apply to college, how to support children's bilingualism, and how bilingualism supports reading abilities. Through these activities, I met and befriended community leaders (teachers, principals, and families), and I was invited to social events at schools, churches, and family events (baptism, birthdays, school graduations). These events fostered trust by the community and also served as recruitment events for my research. Similar strategies are shared across several articles discussing how to increase the representation of ethnically and racially diverse communities in psychology research (Haack et al., 2014; Hartmann et al., 2014; Rivas-Drake et al., 2016; Rowley & Camacho, 2015).

An important concern when using portable technologies is that participants are often wary of the testing procedures and unsure of their rights as participants, and/or what a testing session entails. In my research, we break down step-by-step the entire testing session, demonstrating the technology, and explaining the safety of the procedure. During the testing session, bilingual research assistants are available to help and to encourage family members to observe the session. Testing materials (surveys, questionnaires) are available in multiple languages and modified so that the translations are culturally relevant. We show participants the intensity of the near-infrared lights and place the fNIRS cap on ourselves or on a plush toy.

There are few examples of cross-cultural or field research using fNIRS (see Table 1). Most of this work compares White European samples to samples from countries in Africa or Asia, and focuses on the negative effects of poverty and malnutrition on infants and children's brain development (Jasińska & Guei, 2018; Jensen et al., 2019; Katus et al., 2019; Papademetriou et al., 2014). Nevertheless, these studies provide key strategies for carrying out research in naturalistic environments, including: (i) training staff on how to protect and actively maintain the fNIRS system from dust, heat, humidity, power surges, and outages; (ii) ensuring that spare parts, including caps are available on-site; and (iii) ensuring that testing rooms are comfortable to participants, such as having a portable air-conditioner unit or fan that also cools the fNIRS system and prevents it from overheating (Fuhrimann et al., 2019; Jasinska & Guei, 2018; Katus et al., 2019). Some research labs have their experimental setup inside a "research van" that they drive into communities, making research accessible for anyone to take part (Lewis, 2019). Many research labs may also offer payment, weekend availability, childcare during testing sessions, and/or go into participants' homes, schools, libraries, or community centers.

As researchers gain the community's trust, it is also key to address how the research and its findings benefit the community. Using fNIRS in the community will attract trainees who are members of these communities and are also under-represented in the sciences, thus fNIRS research can play an active role in training and increasing the pool of under-represented scholars in the sciences. Researchers can also communicate the findings to the community (either in special events, print or email newsletter reports with updates, podcasts, online livestream feeds), become allies and begin to brainstorm alongside the community how to apply this knowledge in everyday life. The findings may inform policy makers, program evaluators, and educators when designing community-based programs and when choosing where to allocate financial support in the community (e.g., Smith et al., 2014). In sum, taking the science to the community can actively benefit the community by bringing positive changes and resources.

Future Research Directions

As cultural neuroscience advances its direction to uplift communities using community-based and strengths-based approaches, fNIRS can support the investigation of topics that unearth insights on the neuro-cognitive processes that are not fully apparent from behavioral responses. As mentioned above, fNIRS is appropriate for assessing neuro-cognitive processes that rely on the cortex, can be transported to settings outside of the lab (e.g., to participants' homes), allows for participants to move freely (e.g., walking, talking), and is suitable for use in everyday-life scenarios such as face-to-face interactions (e.g., conversation among individuals). The technology is ideal for studies examining how the brain processes information which can then be linked to a behavior, such as: academic abilities in the classroom (e.g., comparing students who learned and did not learn during class time by measuring brain activity during the lesson and comparing to later performance); how concepts are actively learned in an environment and whether they are learned better in one cultural setting versus another; whether brains between individuals can synchronize and which individuals are more or less likely to show synchrony (e.g., Piazza et al., 2020); how dyads (parent–child, friends, or strangers) interact or use strategies, such as emotional self-regulation (Quiñones-Camacho et al., 2020), when discussing difficult topics (e.g., politics).

As mentioned earlier, it is key that future work relies on mixed methods to inform and describe differences in brain activity. Researchers should also use conceptual models to design research and explain differences in brain activity. One great example of a strengths-based model is Neblett et al. (2012)'s integrative approach for mechanisms of protection in ethnic and racial minority youth. In this model, the authors propose a framework for how ethnic and racial identity, ethnic-racial socialization, and cultural orientation may act as promotive factors (i.e., a characteristic that increases the likelihood of developing a positive outcome when faced with all kinds of risk and adversity; Masten et al., 2009) and protective factors (i.e., a characteristic that mitigates the development of a negative outcome when faced with a high level of risk and adversity; Masten et al., 2009). Using fNIRS, researchers may test how parents and children discuss ethnic-racial socialization (i.e., teach children how to cope with discrimination; Hughes et al., 2006), including their communication styles, or emotional processing strategies when discrimination is experienced. In testing these questions, mixed methods would allow for associating brain activity during ethnic-racial socialization to survey data regarding cultural orientation and ethnic-racial identity.

Limitations

The lion's share of the limitations in this work primarily resides within the researchers. It should now be apparent how time- and labor-intensive cultural neuroscience in the community becomes for new fNIRS adopters. In addition to merging scientific fields, there is also a need to invest time and resources in the community, an investment that can be ultimately advantageous for researchers and the public. Although the present paper is not exhaustive in describing all aspects of the method as it excludes analytical techniques, it briefly summarizes the available resources for developing portable neuroimaging studies. Regardless, researchers might find the amount of information overwhelming, and to lessen these concerns, new fNIRS adopters should seek help, guidance, and advice from collaborators with extensive experience in the technique. Academic review panels for graduate students and early career scholars should understand and recognize that progress for this work is slow, due to the careful manipulation that is required at different levels of the research and in favor of good science (i.e., task design, data collection, participant recruitment, and community involvement). Finally, researchers should acknowledge the limitations of correlational analyses and small samples, as neuroimaging data are also prone to inflated effect sizes (Fiedler, 2011).

Conclusion

The article discussed the use of fNIRS as a portable neurophysiological technique and its benefits for expanding cultural neuroscience into the community. By contextualizing the effects of sociocultural experiences on the human brain, researchers can gain better access to the unearthed processes behind behavior and cognition. Although the review is limited in its scope, the primary goal was to equip new fNIRS adopters with the key tools and resources to begin their research agenda. Portable neuroimaging technologies may reward new users with skills that are transferable to other fields. First, in merging knowledge from sociocultural and cognitive neuroscience fields, researchers can understand the different levels of bio-social systems affecting human behavior and shaping the brain. Second, neurophysiological methods collect large amounts of data that may require the user to learn computing environments and programming languages to ensure proper data management (e.g., R, MATLAB, Python, MPlus). Given the extent of the data, researchers may consider learning how to apply advanced statistical models, such general linear modeling and path analyses. Third, by engaging in community research, trainees can gain firsthand knowledge of the community needs that have a direct impact on the individual and mechanisms that serve as protective factors. New fNIRS adopters may undertake a herculean effort in taking neuroscience to naturalistic settings and communities. Therefore, it becomes essential that researchers equip themselves with the skills to continue to thrive, but more importantly, to conduct good science. Finally, the paper encourages the use of strengths-based approaches rather than relying on a "deficit" approach to support the discovery and exploration of protective factors supporting resilience in the face of adversity. In doing so, cultural neuroscience will continue to highlight and uplift the talents, strategies, and skills employed by underrepresented ethnically-racially diverse communities.

Figure 1. Illustrations of portable technologies. Left panel depicts how fNIRS works, in which a source emits the near-infrared light and a detector measures cortical activity. Middle panel depicts a study in a lab-setting environmnet, in which a participant sits in front of a computer to complete a task. Right panel depicts a study in a naturalistic environment, in which an adult-child dyad are interacting while wearing a wireless fNIRS system.

Table 1.
fNIRS studies incorporating a diverse ethnic, racial, or cultural sample

Author	**Year**	**Title**	**Journal**	**Race/Culture**	**Location**	**Age**
Arredondo, Hu, Satterfield et al.	2016	Bilingualism alters children's frontal lobe functioning for attentional control	Developmental Science	48% Latinx, 52% White	United States	Children
Arredondo, Hu, Seifert et al.	2018	Bilingual exposure enhances left IFG specialization for language in children	Bilingualism: Language and Cognition	54% Latinx, 46% White	United States	Children
Arredondo, Hu, Satterfield et al.	2019	Bilingual effects on lexical selection: A neurodevelopmental perspective	Brain & Language	50% Latinx, 50% White	United States	Children
Burns, Barnes, McCulloh et al.	2019	Making social neuroscience less WEIRD: Using fNIRS to measure neural signatures of persuasive influence in a Middle East participant sample	Journal of Personality and Social Psychology: Attitudes and Social Cognition	100% Arab Jordanian	Jordan	Adults
Jasińska, Wolf, Jukes, & Dubeck,	2019	Literacy acquisition in multilingual educational contexts: Evidence from Coastal Kenya.	Developmental Science	100% African/Coastal Kenya	Coastal Kenya	Children
Jensen, Tofail, Haque et al.	2019	Child development in the context of biological and psychosocial hazards among poor families in Bangladesh	PLOS ONE	100% Bangladeshi	Bangladesh	Children
Koenig, Wu, Gao, & Li	2020	Abnormal cortical activation in visual attention processing in sub-clinical psychopathic traits and traumatic brain injury: Evidence from an fNIRS study	Journal of Psychopathology and Behavioral Assessment	34.8% White/Caucasian, 9% Black/African-American, 34.9% Asian, 6.9% Hispanic/Latino, 13.9% Mixed/Other	United States	Adults
Lloyd-Fox, Papademetriou, Darboe et al.	2014	Functional near infrared spectroscopy (fNIRS) to assess cognitive function in infants in rural Africa	Scientific Reports	100% Gambian	The Gambia	Infants
Lloyd-Fox, Begus, Halliday et al.	2016	Cortical specialisation to social stimuli from the first days to the second year of life: A rural Gambian cohort	Developmental Cognitive Neuroscience	100% African/Gambian	The Gambia	Infants, toddlers
Lloyd-Fox, Blasi, McCann et al.	2019	Habituation and novelty detection fNIRS brain responses in 5- and 8- month- old infants: The Gambia and UK	Developmental Science	66% African/Gambian, 34% English	The Gambia, United Kingdom	Infants
Perlman, Huppert, & Luna	2015	Functional near-infrared spectroscopy evidence for development of prefrontal engagement in working memory in early through middle childhood	Cerebral Cortex	44% Caucasian, 50% African American, 4% Asian, 2% Native American	United States	Children
Ruocco, Rodrigo, Lam et al.	2014	A problem-solving task specialized for functional neuroimaging: Validation of the Scarborough adaptation of the Tower of London (S-TOL) using near-infrared spectroscopy	Frontiers in Human Neuroscience	34.2% Chinese, 21.1% Caucasian, 13.2% South Asian, 5.3% Black, 5.3% Filipino, 5.3% Latin American, 2.6% Japanese, 2.6% Korean, 2.6% Southeast Asian, 2.6% West Asian	Canada	Adults

Notes. fNIRS studies, either cross-cultural comparisons of a non-Western developing country to a developed country, or studies with a diverse sample in which at least 50% self-identified as non-White European ethnicity.

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