Demographic Reporting and Phenotypic Exclusion in Functional Near Infrared Spectroscopy (fNIRS): Another Data Crisis

Jasmine Kwasa (1), Hannah Peterson (2), Lietsel Jones (3), Termara Parker (4), Kavon Karrobi (5), Nia Nickerson (6), Sossena Wood (1)

(1) Carnegie Mellon University (2) Massachusetts General Hospital (3) University of Central Florida, (4) Yale School of Medicine, (5) Boston University, (6) University of Michigan

Problems

Functional near-infrared spectroscopy (fNIRS) promises to be the leading non-invasive human neuroimaging method of the next few decades.

low cost | non-invasive | portable

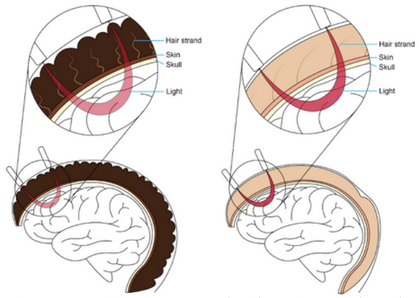
Concerns are rising over its inclusivity of all skin tones and hair types (Parker & Ricard 2022, Webb et al 2022).

Research in other modalities such as EEG exclude Black individuals from research due to hair type and skin tone (Bradford et al 2022, Choy et al 2020).

Questions:

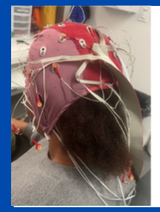
- Do biomedical optics researchers **developers of fNIRS** report performance variability in their systems between Fitzpatrick skin scales and hair textures?
- Do **neuroscience practitioners of fNIRS** systems report phenotypic and demographic details in their research articles? If so,
- Does a similar pattern of **exclusion of Black participants** seen in EEG literature also exist in the fNIRS literature?

Phenotypic Bias



Depiction of Afro-textured (left) vs Straight (right) hair with a fNIRS cap and a single optode signal

- **Hair type:** The density and thickness of Black hair may obstruct fNIRS optodes and fNIRS caps may not accommodate larger hair volumes (Khan 2012)
- **Skin or Hair color:** Dark colored hair of any texture introduces melanin, which acts as a NIRS signal attenuator.



Cultural and Methodological Bias

An unpleasant environment without culturally appropriate knowledge can lead to voluntary withdrawal of coarse, curly haired and dark skinned participants. fNIRS setup is notoriously:

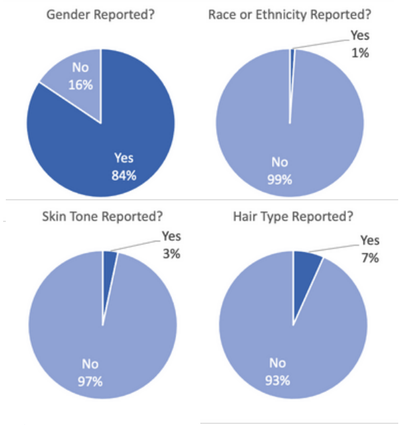
confusing | uncomfortable | time consuming | frustrating

Children and adults with intellectual disabilities – a large proportion of the fNIRS research participants due to its portability – are disproportionately affected.

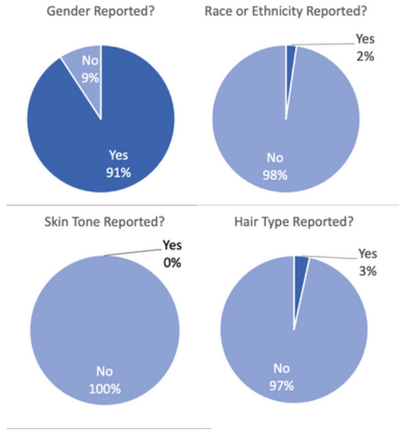
Phenotypic Exclusion in fNIRS Literature Review

Goal: Quantify reporting of race, hair type, and skin tone in fNIRS development and basic science. We compare these demographics to gender reporting, an exemplar.

3 Top Biomedical Optics Journals (N=87)



2 Top Neuroscience Journals (N=110)



Methods

PubMed Search, June 2022

- Search terms: "fNIRS" and "Journal Name"
- 3 top biomedical optics journals (N = 87) hardware and algorithm development in fNIRS
  - 2007 – 2022
- 2 top neuroscience journals (N = 110) fNIRS as a tool for basic or clinical neuroscience
  - 2017 – 2022

Data collected

- Number of participants
- Quantitative or qualitative reports of data exclusion
- Participant demographics. Any mention of:
  - sex or gender
  - race, ethnicity, or nationality
  - melanin, pigmentation, or Fitzpatrick scale
  - hair type

Discussion

35% of all articles mention exclusion of any type.
Only a handful mention hair, skin, or race / ethnicity.
Contrastingly, gender is reported in the vast majority of articles

Quotes indicating phenotypic bias:

- "poor data quality… from the subject's relatively thick, black hair"
- "unable to collect effective signals… due to the participant's thick, strong hair,"
- "had a lot of hair to obstruct light"
- "due to dense and/or dark-colored hair."

Solutions

Best Practices

1. **Recruit a diverse research team**.
   a. Researchers from marginalized groups serve as representation of the community of interest.
   b. Build trust with non-white communities.
   c. Hire with diversity in mind.
   d. Prioritize cultural competency to the level of technical skill.
2. **Train on inclusive methodology.**
   a. Train to work with a range of hair types
   b. Avoid longer setup times, microaggressions, participant discomfort, and participant dropout.
   c. Consult guidelines for hair preparation from Etienne et al. 2020 and A Guide to Hair Preparation for EEG Studies (Jones, et al., 2021).
3. **Report demographics and phenotypes.**
   a. Quantifying the association of hair type, density, and melanin content of the scalp with fNIRS measurements.
   b. Define these limitations through a systematic review.

Technological Solutions

- Carnegie Mellon: Meta-funded research team led by Sossena Wood developing fNIRS for dark skin & curly hair.
- University of Michigan uses crotchet hooks with LED lights to gently move hair during the setup before inserting optodes.
- Khan et al 2012: Designed brush optodes to improve photon transmission, specifically for participants with dark hair colors and high hair density.

Funders, IRBs, and Journals

- IRBs:
  - Offer institutionally mandated best practices to researchers
  - Question race-based exclusion criteria
- Journals: Require demographic reporting and data demographic disaggregation
- Foundations:
  - Invite research explicitly about exclusion
  - Fund innovative and equitable technologies

Conclusions

Our results point to two distinct issues:

- The **under-reporting** of exclusion
  - Responsibility of researchers, funding bodies, and regulatory bodies
- Potential, but unconfirmed, disproportionate **exclusion** of marginalized phenotypes: dark skin and coarse, curly, and dark hair
  - Responsibility of engineers and innovators

Acknowledgments

J Kwasa was supported by NINDS / NIMH under award K00NS115331. T Parker was supported by NSF GRFP #1752134.

Bibliography

- Bradford, Daniel E., et al. "Whose Signals Are We Amplifying? Towards a More Equitable Clinical Psychophysiology." (2022).
- Choy, Tricia, Elizabeth Baker, and Katherine Stavropoulos. "Systemic racism in EEG Research: considerations and potential solutions." Affective Science 3.1 (2022): 14-20.
- Etienne, Arnelle, et al. "Novel electrodes for reliable EEG recordings on coarse and curly hair." 2020 42nd Annual International Conference of the IEEE Engineering in Medicine & Biology Society (EMBC). IEEE, 2020.
- Jones, Lietsel. *A Guide to Hair Preparation for EEG Studies*, 2021. https://hellobrainlab.com/research/eeg-hair-project/
- Katus, Laura, et al. "Implementing neuroimaging and eye tracking methods to assess neurocognitive development of young infants in low-and middle-income countries." Gates Open Research 3 (2019).
- Khan, Bilal, et al. "Improving optical contact for functional near-infrared brain spectroscopy and imaging with brush optodes." Biomedical optics express 3.5 (2012): 878-898.
- Parker, Termara C., and Jocelyn A. Ricard. "Structural racism in neuroimaging: perspectives and solutions." The Lancet Psychiatry 9.5 (2022): e22.
- Webb, E. Kate, J. Arthur Etter, and Jasmine A. Kwasa. "Addressing racial and phenotypic bias in human neuroscience methods." Nature Neuroscience 25.4 (2022): 410-414.