Optimization of Neuroimaging Apparatus for Diverse Hair Types

Background: Functional Near Infrared Spectroscopy (fNIRS) is a neuroimaging methodology that uses infrared light to detect changes in concentrations of oxygenated hemoglobin (HbO) beneath the skin. When applied to the scalp, fNIRS can indirectly measure brain activity. The technology works by projecting infrared light into the scalp via "source" optodes. This light passes through skin and bone but is differentially absorbed and/or scattered by HbO in the blood stream (Fig 1). Nearby "detector" optodes measure the amount of light reflected back out of the head, giving indication of the current concentration of HbO at the intervening area. When neuronal populations fire as a part of brain activation, they consume oxygen as a metabolic resource and thus induce localized changes in oxygenated blood flow. In this way, fNIRS can give a moment-by-moment indication of changes in brain activity.

The Problem: For fNIRS to measure brain activity, sufficient infrared light must be projected into the scalp. It is imperative that source and detector optodes make contact with the scalp for this light to reach beneath the skin rather than be lost to the outside environment. Hair can create a physical barrier to this contact and impede infrared signal. In subjects with fine, thin hair, there is little obstruction. However, thicker, darker hair blocks optode access to the scalp and/or absorbs too much infrared light to get good measurement of cerebral HbO (Fig 1). This difference in phenotype results in systematic underrepresentation of black, Latine, and Asian populations in the neuroscience literature.

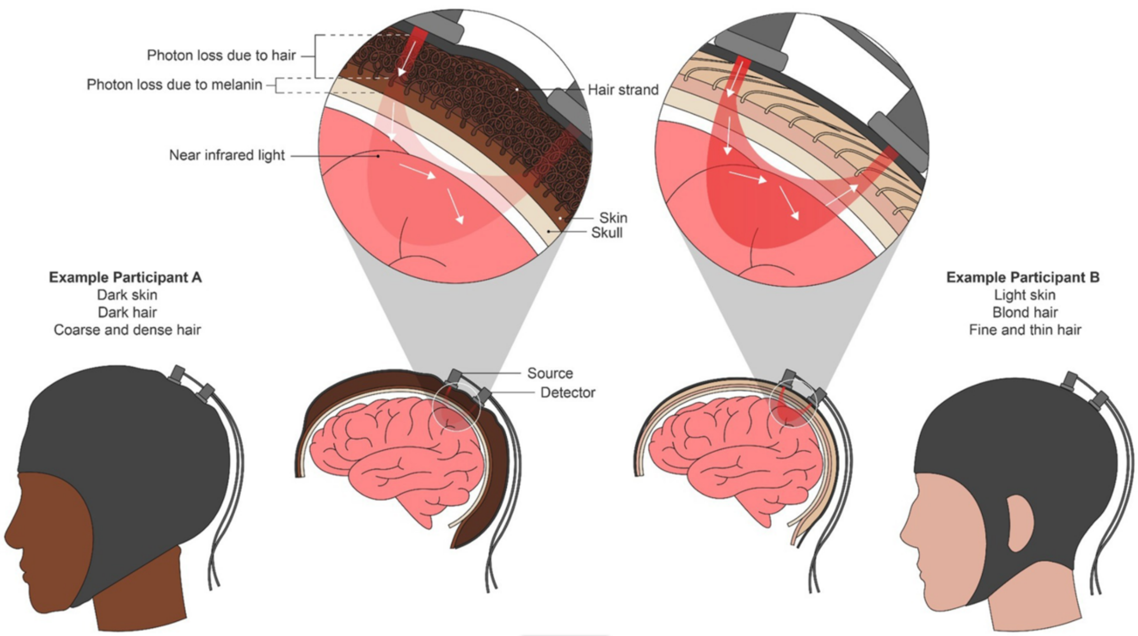

Figure 1 – Visualization of the fNIRS measurement mechanism. If infrared light is blocked by dark/thick hair, less is projected into the scalp and less is detected upon return, reducing signal strength and data quality. Figure from Kwasa et al. 2023, Frontiers in Neuroscience.

This Project: We hope to develop an attachment to the fNIRS optode that can help the optode head reach the scalp surface through thick hair, improving fNIRS signal quality in non-white subjects. At the moment, our fNIRS system (developed by NIRx Inc.) has 64 source and detector optodes that are approximately 0.5cm in contact surface diameter (Fig 2A), held to the head via a plastic mount in a stretchy headcap (Fig 2B). The flat surface of the optode does not easily thread through hair. Perhaps an attachment to the optode head can be created that passes through hair more easily, bridging the gap between the scalp surface and the optode (e.g., a fiberoptic brush or spiral). To be successful, this attachment must 1) improve signal strength in subjects with dark and thick hair; 2) be comfortable for the subject to wear for extended periods of time; and 3) be able to be attached/removed as needed by research assistants. Ideally, this attachment will fit within the current mounts in the fNIRS cap (though new mounts could be created to accommodate the optode + attachment if necessary).

A) 

B) 

Figure 2 – A) the optode head in a NIRx fNIRS device. The two nubs at the end project or detect infrared light and must make contact with the scalp to measure good-quality signal. B) These optodes are held in place plastic mounting bases that are themselves secured in a stretch headcap. These mounts can be removed and relocated to different locations in the cap depending on the needs of a neuroimaging study.