Abstract submitted to the *Society for Functional Near Infrared Spectroscopy*, Montreal, Quebec Canada (Oct 2014)

Hemodynamic changes in cortical sensorimotor systems following hand and orofacial motor tasks and pulsed cutaneous stimulation.

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Background: The integrity of the cerebral cortex can be assessed by measuring its responsiveness to repetitive sensory and motor stimulation. This neurophysiologic feature is known as neural adaptation, and is thought to enhance learning and detection of environmental stimuli. The adaptation of hemodynamic responses to motor and sensory experiences in hand and face are of particular interest—as these are structures most commonly used in human communication—and proper delivery of oxy-hemoglobin to primary motor (M1) and somatosensory (S1) cortices is essential for functional cortical activation.

Objective: To examine the hemodynamic differences between hand and face cortical representations during motor and passive somatosensory conditions, as measured with functional near-infrared spectroscopy (fNIRS). The recorded data will be used to create a computational model of cortical adaptation for future neurodiagnostic and neurotherapeutic applications.

Methods: The ongoing study design includes 20 neurotypical adults, ages 19-30. A TechEn CW6 device was used for fNIRS data acquisition. A 4x3 optode montage with 2 short separation measurements (8 mm) was placed over left M1 and S1 to sample hemodynamic activity following repeated hand and orofacial motor activity and repeated pneumotactile stimulation. The two motor conditions consisted of a repetitive hand grip ("light squeeze"), and repetition of a voiceless bilabial syllable ("pa"), each at 2 Hz (30 sec ON/60 sec OFF, repeat 10x). For the passive sensory conditions, a Galileo™ Somatosensory stimulator was programmed to generate a biphasic pneumatic pulse train (-80 to 140 cmH_2O, 50-ms pulse width, 9 ms rise/fall time, pulse rate 2 Hz, 30 sec ON/60 sec OFF, repeat 10x) applied through TAC-Cells placed on the glabrous right hand and lower face near right oral angle. The order of conditions was counterbalanced among participants, each lasting 15 minutes. A custom processing stream built in Homer2 was used to remove motion artifact, regress physiological interference (via short separation optodes) out of data, and calculate group hemodynamic response functions (HRFs) across all channels. The 3 most representative channels over face and hand M1 and S1 were chosen for analysis. Oxy- and deoxyhemoglobin concentrations (HbO and HbR) were averaged over 10 trial blocks relative to 30-second stimulus ON periods with a 10-second pre-stimulus window, and a 30-second post-stimulus window.

Results: Preliminary results are from 3 females (mean= 22 yrs). As expected, motor activity of either the lip or hand was associated with a predominant HbO response localized to M1, whereas the passive somatosensory stimulation conditions resulted in predominant HbO responses in S1. Lip motor activity yielded significantly greater mean concentration levels of HbO in face M1 than hand motor activity in hand M1 ($t[1500]=196.62$, $p<.000$), as well as greater mean levels of HbO in face S1 than hand S1 ($t[1500]=83.51$, $p<.000$), during the 30 second stimulation periods. Oppositely, somatosensory stimulation of the hand yielded significantly greater mean HbO concentration levels in hand S1 than did the same stimulation of the face in face S1 ($t[1500]=5.43$, $p<.000$), during the 30 second stimulation periods. Adaptation patterns differed across both structures, most notably during passive somatosensory conditions. Also, a significant increase in HbO directly after stimulus offset was seen. This "cortical refill" was strikingly apparent after both motor and sensory tasks in the face, and less so for the hand.

Conclusions: Many significant differences were found in hand and face M1 and S1 across the different motor and sensory conditions, including distinctive HRFs, adaptation patterns, and cortical refill responses. These differential effects are likely due to differences in regional arterial/venous anatomy, cortical vascular beds, extent and orientation of somatotopy, task dynamics, and mechanoreceptor typing in hand and face.
Supported in part by the Barkley Trust (Barlow).