Neural Correlates of a Smile: An fNIRS Investigation

Jeiyoun Park[6], J. Adam Noah[1], Xian Zhang[1], Swethasri Dravida[4], & Joy Hirsch[1,2,3,5]

Departments of Psychiatry[1], Neuroscience[2], and Comparative Medicine[3], MD/PhD Training Program[4], Yale School of Medicine, Yale University[6] New Haven, CT, 06511; Department of Medical Physics and Biomedical Engineering[5], University College London, WC1E 6BT, UK.

Introduction

- A naturally generated smile is a significant affective social cue that often conveys intention to communicate. However, the associated neural correlates are not well understood.
- We use functional near-infrared spectroscopy (fNIRS) and a facial classification system to acquire neural signals and facial expressions during natural responses to visual stimuli that varied between neutral and "smile inducing" content.
- We test the hypothesis that the underlying network engaged during the natural generation of a smile will include neural systems known to be involved in social cognition, and interpersonal interaction.

Methods: fNIRS

- 22 subjects (8 males, 14 females); Mean Age: 24±8.8 years; 21 right-handed
- fNIRS with extended head coverage to record hemodynamic signals (Shimadzu, LABNIRS, Fig. 1)[1]
- 105 channels (32 emitters and 32 detectors)
- 3 cm spatial resolution, 27 ms temporal sampling
- Facial classification program (GE Sherlock, Niskayuna, NY) to classify expression on faces and rate the intensity of a smile on a scale of 0 to 1.[2]

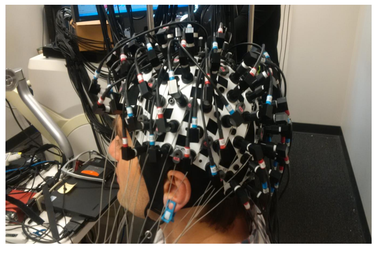


Figure 1. Configuration of emitters and detectors producing 105 acquisition channels. Channel locations are determined with a Polhemus Patriot 3D digitizer based on the standard 10-20 system.

- Channel locations are normalized to standard brain MNI coordinates using a Patriot 3D digitizing system (Polhemus, Colchester, VT).[1]
- Signals from fNIRS are based on reflected wavelengths of light that indicate relative changes in the concentration of oxygenated and deoxygenated hemoglobin.[3]
- Global components are removed using a previously developed PCA-spatial filter.[4]
- All analyses employed the deOxyHb signal, which is highly correlated with the BOLD signal in fMRI.[3]
- Individual functional activity was converted to a 4D data set and modelled through first-level general linear model (GLM) analysis using SPM8.[5]

Experimental Design

- Participants viewed neutral and smile-inducing images (Fig. 2) during 15 s epochs that included 3 images with 5 s duration; these picture epochs alternated with 15 s of baseline epochs for a total of four minutes; 4 total runs, 2 Smile and 2 Neutral

Figure 2 Neutral Exemplars Happy/Comical/Pleasant Exemplars

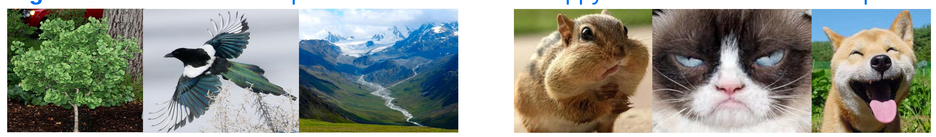
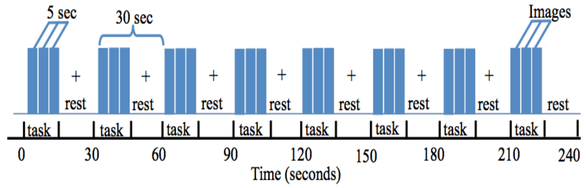


Figure 3. During the 15 s task period, subjects viewed and responded naturally to the images. Three images were shown for 5 s each during task blocks.



During rest periods, subjects were instructed to clear their mind and focus on a centrally located crosshair. This four-minute run was repeated four times, twice for neutral and twice for emotive stimuli.

Analysis and Results

- Event related signals were convoluted with both the smile intensities and the standard hemodynamic response function (HRF) of the block design.
- Smile Magnitude (GE Sherlock) was used as a regressor for neural data.

Smile Classification and Magnitude: GE Sherlock

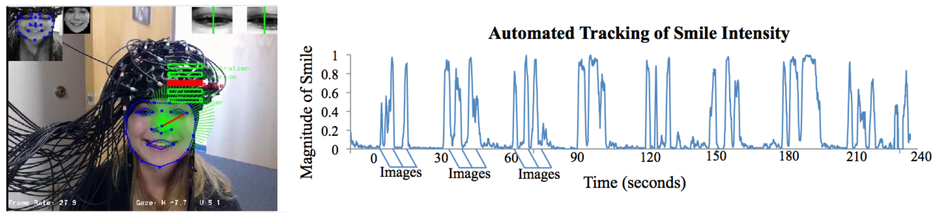


Figure 4. Facial Classification Program Outputs. Screen capture from the program's video recording. The full red bar (left) indicates that the smile is rated as the maximum magnitude. Trace of the magnitude of smiles during the four-minute smiling condition (right). Each task block shows three distinct peaks for three smiles generated in response to the image stimulus. See Fig 3.

Automated Program Rating vs. Manual Video Rating of Smile Magnitude

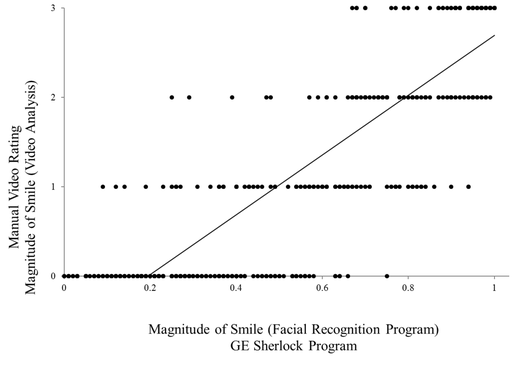


Figure 5. The smile intensities provided by the automated facial classification program were compared to the manual ratings of each smile from the recorded videos. For manual ratings, the smiles were rated as no smile (0), small (1), medium (2), and large (3) smiles. Correlation between automated and manual smile ratings validate the facial classification program (r = 0.87).

Covariation of Neural Responses with Smile Classification

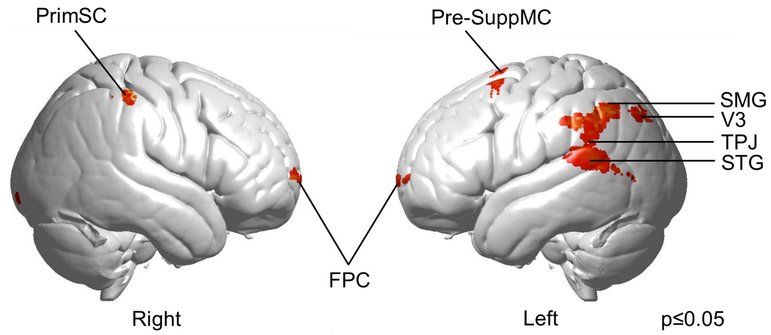


Figure 6. Brain regions responsive to smile generation. The clusters indicate increased neural activity with higher smile classification index in comparison to lower smile classification index. The results show significant (p≤0.05) activation in the left temporal/parietal regions including supramarginal gyrus (SMG), temporoparietal junction (TPJ), and superior temporal gyrus (STG), areas previously associated with language reception and comprehension (Wernicke's Area) as well as verbal interpersonal interaction[4]. Pre- and supplementary motor cortex (Pre-SuppMC) activity suggests planning and readiness for engagement.

Conclusion

- Production of a natural smile is associated with left hemisphere processes within social and communicative neural systems[6] in addition to the visual and sensory motor system.
- Together, findings are suggestive of a neural system to communicate the expression of a smile.

References

1. Noah, J. A., Ono, Y., Nomoto, Y., Shimada, S., Tachibana, A., Zhang, X., Bronner, S., & Hirsch, J. (2015). fMRI validation of fNIRS measurements during a naturalistic task. *Journal of Visualized Experiments: JoVE*, (100).
2. Tu, J., Laflen, B., Liu, X., Bello, M., Rittscher, J., & Tu, P., editors. LPSM: Fitting shape model by linear programming. 2011 IEEE International Conference and Workshops on Automatic Face & Gesture Recognition.
3. Huppert, T. J., Hoge, R. D., Diamond, S. G., Franceschini, M. A., & Boas, D. A. (2006). A temporal comparison of BOLD, ASL, and NIRS hemodynamic responses to motor stimuli in adult humans. *Neuroimage, 29*, 368-382.
4. Zhang, X., Noah, J. A., & Hirsch, J. (2016). Separation of the global and local components in functional near-infrared spectroscopy signals using principal component spatial filtering. *Neurophotonics, 3*(1), 015004-015004.
5. Hirsch, J., Zhang, X., Noah, J. A., & Ono, Y. (2017). Frontal temporal and parietal systems synchronize within and across brains during live eye-to-eye contact. *Neuroimage, 157*, 314–330. doi: 10.1016/j.neuroimage.2017.06.018
6. Hirsch, J., Zhang, X., Noah, J. A., & Dravida, S. The interactive brain model: An emerging theoretical framework for two-person social communication. Nanosymposium: Mapping Language Onto Structure. Society for Neuroscience, 2017. Abstract Control number 2017-S-5920-SfN.

Acknowledgements and Funding

This research was partially supported by NIH/NIMH R01 MH107513-01 "Mechanisms of Interpersonal Social Communication: Dual Brain fNIRS Investigations" (PI Joy Hirsch) and by the NIH Medical Scientist Training Program Grant T32 GM007205 (SD). The content is solely the responsibility of the authors and does not necessarily reflect the official views of the NIH. We thank Amy Shteyman for her pilot studies on this project.

Download.pdf