Neural mechanisms in processing of emotion in real and virtual faces using functional-near infrared spectroscopy (fNIRS)

by

Dylan Rapanan

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Faculty of Science Ontario Tech University Oshawa, Ontario, Canada

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**Abstract**

This study investigates the neural mechanisms underlying face and emotion perception

in both real and virtual stimuli using functional near-infrared spectroscopy (fNIRS), a

question of growing importance given the increasing prevalence of avatars/virtual charac-

ters in our lives. We employed multiple analyses, including General Linear Model (GLM)

analysis, functional connectivity, and supervised machine learning classifiers. The GLM

analysis was used to identify brain regions activated by different face types and emotions,

revealing differences in activation mainly in occipital regions. Functional connectivity

analysis provided insights into the correlation between brain regions in the time-frequency

domain, finding significantly correlated brain regions. Our findings reveal the similar-

ities and differences in how the brain distinguishes between real and virtual emotional

expressions. This research has implications for the development of virtual environments

and the design of more effective virtual characters.

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**Acknowledgements**

\*\* Put your Acknowledgements here. \*\*\*

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**Bibliography**

[1] M. S. Hossain, A. Khandakar, M. Alhatou, A. A. A. Bakar, S. Kiranyaz, S. H. M. Ali,

M. M. Hossain, M. B. I. Reaz, M. E. H. Chowdhury, and R. Habib. Motion Artifacts

Correction from Single-Channel EEG and fNIRS Signals Using Novel Wavelet Packet

Decomposition in Combination with Canonical Correlation Analysis. *Sensors*, 22,

Apr. 2022.

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