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A Neurofeedback protocol using a sophisticated interactive video game to improve social responsiveness in children with ASD

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INTRODUCTION

Individuals with **autism spectrum disorder (ASD)** show deficits in social and communicative skills such as imitation, empathy, and shared attention, as well as restricted interests and repetitive patterns of behaviors. While no single explanation can account for the spectrum of autism, converging evidence implicates that a dysfunction in the **human mirror neuron system (MNS)** could be one underlying cause. ASD individuals exhibit normal EEG mu rhythm suppression, a presumed index of MNS activity, for self-generated movement, but fail to suppress during observation of movement. **Neurofeedback training (NFT)** to increase **mu rhythm power** (i.e. 8-12 Hz over sensorimotor cortex) was shown to reduce the behavioral symptoms in children with ASD as well as to increase mu suppression to movement observation [1].

In the present study we address
(1) the counter-intuitive observation that NFT that enhances **mu power** actually results in more **mu suppression** and
(2) the **interplay between neurophysiological and behavioral components** in children with ASD by the use of an interactive **video game** providing feedback that corresponds directly to the underlying significance of the trained signals (i.e. imitation behavior) as well as to the behavior that is reinforced such as successful **social interactions**.

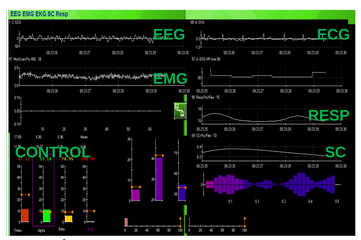
NEUROFEEDBACK PARADIGM

Participants and sessions

- 14 participants divided into 2 groups (7 still in training)
- Confirmed diagnosis of ASD
- 6-17 years old
- No prior NFT experience
- 16 one-hour NFT sessions 2-3 x a week plus Pre- and Posttest

Recordings

- Electroencephalography (EEG): C4
- Electromyography (EMG): left arm
- Electrocardiography (ECG): left wrist and right neck
- Skin conductance (SC): left index and ring finger
- Respiration: belt around the abdomen



Study design and game

The new **game** consists of game episodes (e.g. apple picking, balloon ride, dragon fight) as well as interaction sequences before each game episode. During the **game episodes** children can control the game by **enhancing mu** activity (8-12 Hz) and simultaneously decreasing power in the theta (3-8 Hz) and high beta range (18-30 Hz) over C4 [1].
Unique to this game are the **interaction sequences** in which the child's avatar must first approach the game character. Then, while facing the game character, children have to **increase (group 1) or decrease (group 2) mu power**. The rewarding feedback involves the child's avatar imitating the facial emotions of the game character.

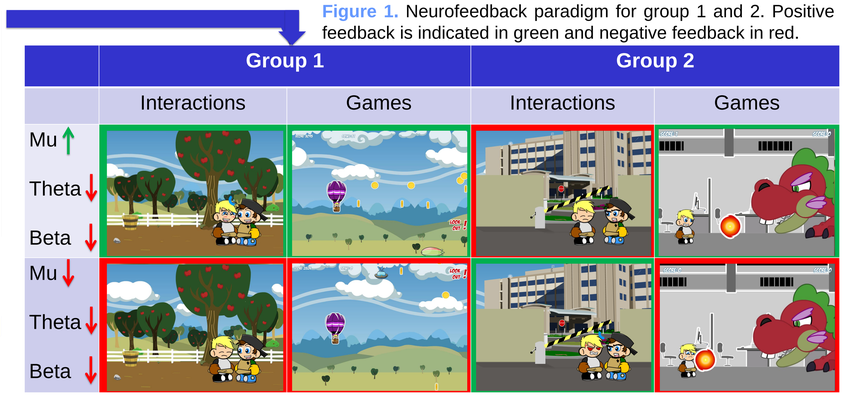


Figure 1. Neurofeedback paradigm for group 1 and 2. Positive feedback is indicated in green and negative feedback in red.

PRE- AND POSTTEST: PRELIMINARY EVALUATION OF THE NFT

Recordings

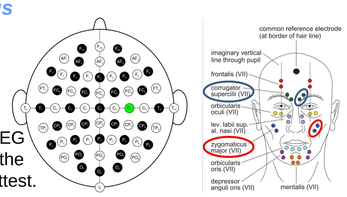


Figure 2. 32-channel EEG recording for the Pre- and Posttest.

Figure 3. Facial EMG electrodes on the cheek (smiling) and above the eyebrow (frowning).

Mu Power

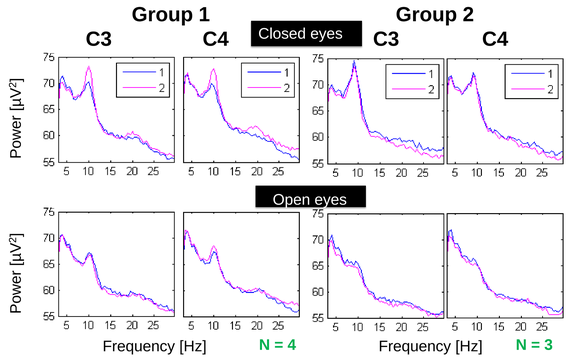


Figure 4. Power spectrum for the conditions eyes closed (top) and eyes open (bottom) for electrode positions C3 and C4. The Pretest is indicated by a blue line (1) and the Posttest in purple (2).

Facial EMG

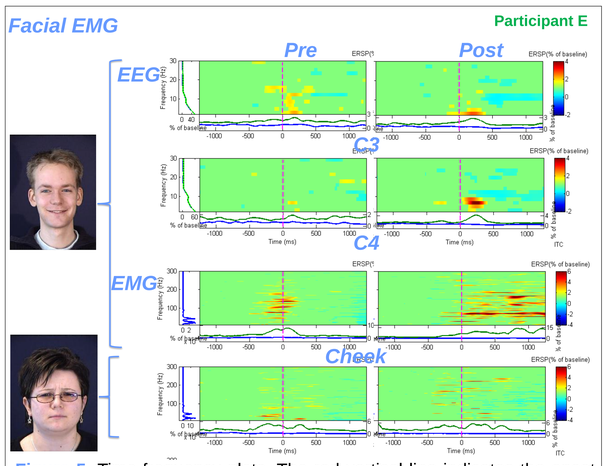


Figure 5. Time-frequency plots. The red vertical line indicates the onset of the videos of emotional faces. An increase in power relative to the baseline is indicated in red, a decrease in blue.

Mu Suppression Index (MSI)

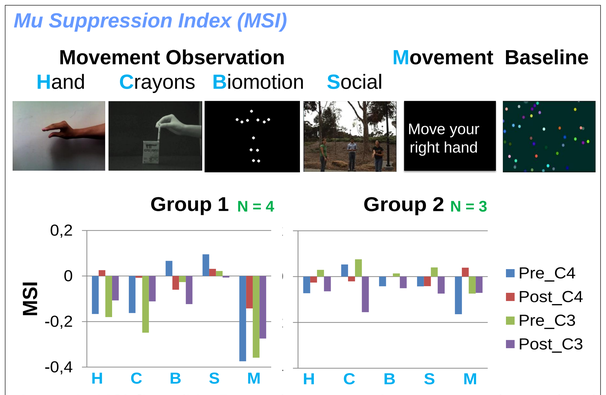


Figure 6. MSI [Log (Mu Power (movement & movement observation / baseline))] for movement observations (Hand, Crayons, Biomotion, Social Interaction) and actual movement (M) for the Pre-and Posttest at the electrode positions C4 and C3. Negative Values indicate mu suppression.

"Reading the Mind in the Eyes"- Test

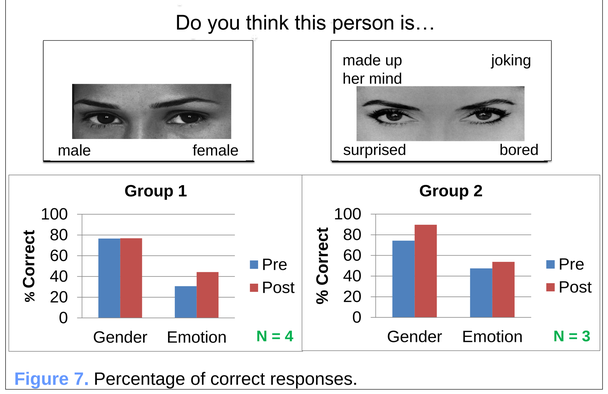


Figure 7. Percentage of correct responses.

Parents evaluation

- Autism Treatment Evaluation Checklist (ATEC)
  The more effective the treatment, the lower the scores
- Social Responsiveness Scale (SRS)
  The less social impairment, the lower the scores
- Vineland Adaptive Behavior Scales
  The higher the score, the more adaptive behavior

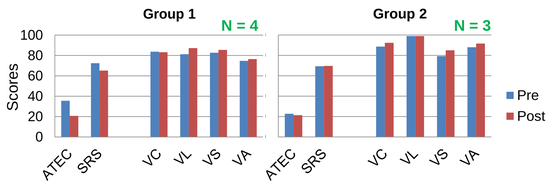


Figure 8. Parents' ratings in the Pre- and Posttest for the ATEC, SRS as well as the Communication (VC), Daily Living (VL), Socialization (VS) and Adaptive Behavior (VA) Scale of the Vineland.

FUTURE DIRECTIONS

Cortical deficiencies might not be the only causes for ASD symptoms. Peripheral physiological activity such as the heart rate is closely linked to neurophysiological signals as well as associated to social engagement. Our future goal is to investigate the relationship between neurophysiological and peripheral physiological components and train heart rate variability in addition to brain rhythms.

CONCLUSIONS

(1) Both groups improved in the "Reading the Mind in the Eyes" - Test and in adaptive behavior indicated by the parents. Group 1 additionally improved in social responsiveness and the treatment was rated more effective.
(2) The two different NFTs achieved specific effects:

- Group 1 trained only mu increase and showed more mu power as well as more mu suppression during two out of four movement observations at C3 and C4 in the Post- compared to the Pretest.
- Group 2 trained mu increase during game episodes and mu decrease during interaction sequences. Group 2 showed the same level of mu power and more mu suppression during all movement observations at least at C3 in the Post- compared to the Pretest.

(3) The sample size is still too small to draw final conclusions about which NFT protocol is more beneficial to children with ASD.

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[1] Pineda J. et al., 2008. Research in Autism Spectrum Disorders 2 (3), 557–581.

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