# Exploring EEG Responses during Observation of Actions Performed by Human Actor and Humanoid Robot

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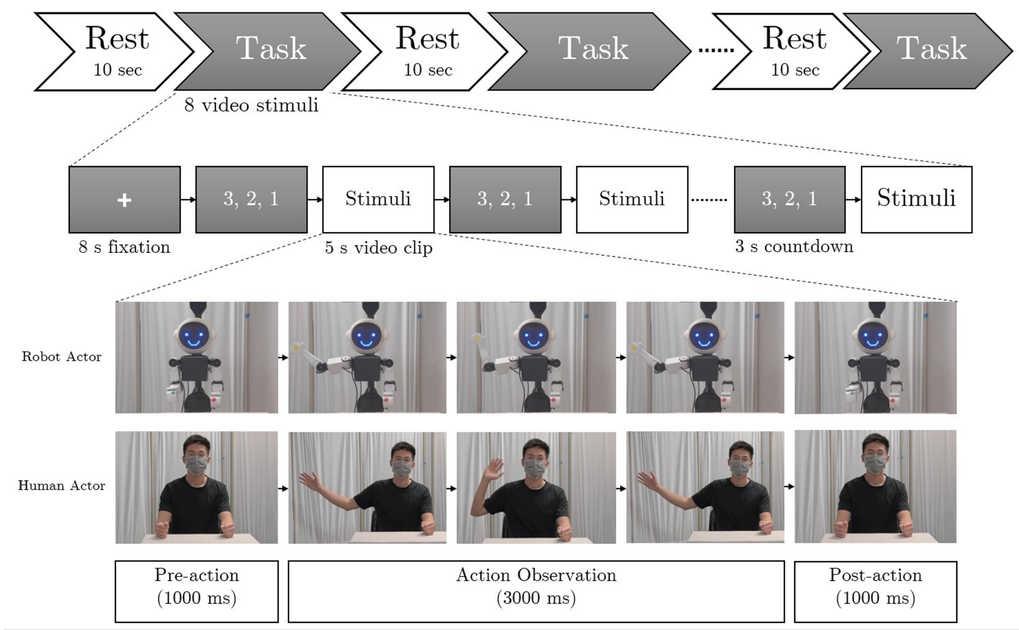
Action observation (AO) therapy is a promising rehabilitative treatment for motor function in individuals recovering from neurological conditions such as stroke. This pilot study aimed to investigate the potential use of humanoid robots to support AO therapy in rehabilitation settings by monitoring and analyzing neural responses to the observation of robot- and human-induced actions.

## Introduction

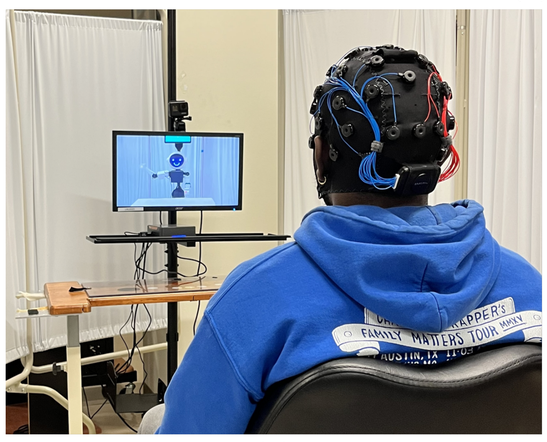
- AO therapy helps recover motor function in people with neurological conditions like stroke by using the brain's mirror neuron system (MNS) [1]. When someone watches an action, their brain mirrors the activity as if they were performing it, aiding recovery by engaging the same neural pathways.
- Humanoid robots in AO therapy can offer a new way to deliver rehabilitation. By watching robots perform actions, patients can participate in therapy in a controlled, consistent manner, potentially improving results and adherence.
- This study examines the neural response to watching actions performed by human versus robot using electroencephalography (EEG). We analyzed brain activity related to motor functions to see how well robots can support AO therapy.

## Materials and Methods

- Three healthy participants watched videos of a human and a humanoid robot performing actions with their left and right arms.
- EEG data from C3 and C4 channels were analyzed to examine activity in sensorimotor mu (8-13 Hz) and beta (13-30 Hz) bands.
- Event-related spectral perturbation (ERSP) was calculated to measure changes in brain activity. Event-related desynchronization (ERD) was used to identify decreases in EEG power, indicating neural activation.




(A)



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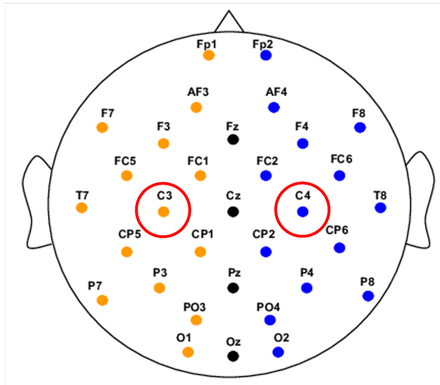


(C)

**Figure 1:** **(A)** Block design of the video stimuli administration **(B)** One of the subjects participating in the experiment, observing a video clip of "robot" condition. **(C)** The 32-channel EEG system follows the international 10-20 method.

## Main Findings

- The study observed changes in brain activity, known as event-related spectral perturbation (ERSP), in response to watching both human and robot actions (Fig. 2).
- Event-related desynchronization (ERD) in the mu and beta frequency bands was detected, indicating activation of the motor areas of the brain [2],[3].
- Different patterns of brain activity were found between observing human and robot actions, suggesting varied neural responses.
- Positive correlations were noted between the brain's responses to human and robot actions (Fig. 3), implying consistency in neural processes involved in observing both.
- The results support the potential use of humanoid robots in AO therapy for rehabilitation.

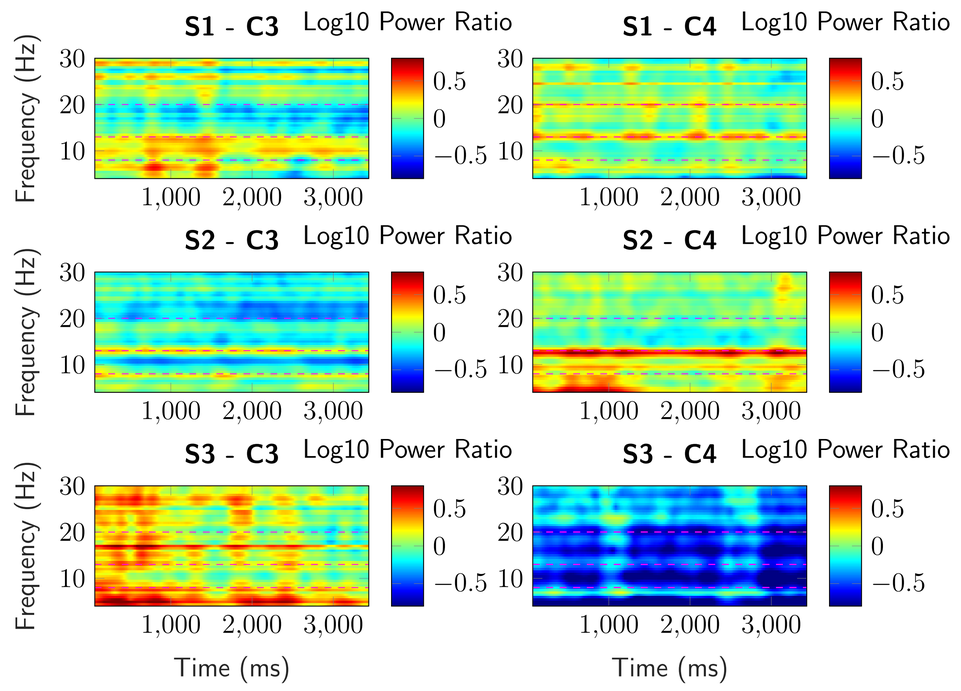


**Figure 2:** ERSP of C3 and C4 channel of 3 participants averaged across all conditions, which is the time-frequency presentation of log10 power ratio relative to baseline for the stimuli epoch. The onset of the video stimuli is at 0 ms. Pink dashed lines indicate the analyzed frequency ranges, including mu (8-13 Hz) and beta (13-30 Hz).

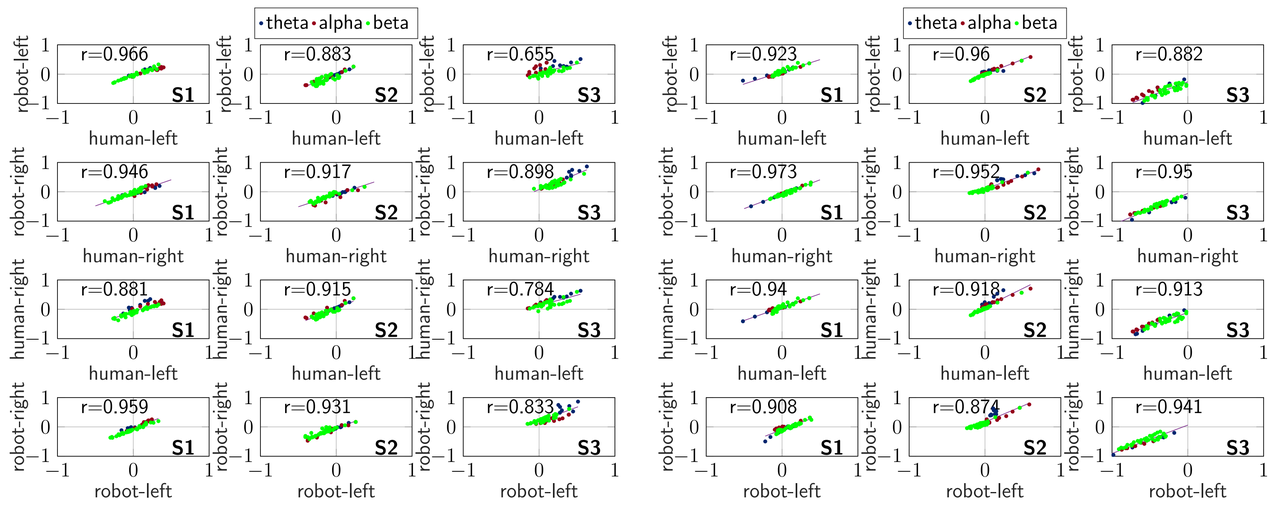


**Figure 3:** Correlation scatterplot of the log10 power ratio at each frequency in 4-30 Hz range between pairs of conditions for each participant at C3 electrode **(Left)** and C4 electrode **(Right)**. Least squared lines illustrate the linear trend between the EEG power ratios of the paired conditions, with the correlation coefficient displayed on the plot. Points denoting values of frequency within each of three frequency bands have different colors.

## Conclusion and Future Direction

- This study shows that EEG can be used to explore how the brain reacts to watching actions performed by both humans and robots.
- Expected patterns of brain activity (ERSP) were observed in the mu-alpha and beta frequency bands for all participants, consistent with previous EEG studies [2],[3].
- Strong positive correlations in ERD were found across different conditions, suggesting similar brain processes when observing both human and robot actions.
- Future research should focus on more detailed analysis methods and larger studies to better understand the brain's response to human-robot interactions, especially for stroke rehabilitation.

## References

[1] Borges, Lorenna RDM, et al. "Action observation for upper limb rehabilitation after stroke." Cochrane Database of Systematic Reviews 8 (2022).

[2] Oberman, Lindsay M., et al. "EEG evidence for mirror neuron activity during the observation of human and robot actions: Toward an analysis of the human qualities of interactive robots." Neurocomputing 70.13-15 (2007): 2194-2203.

[3] Urgen, Burcu A., et al. "EEG theta and Mu oscillations during perception of human and robot actions." Frontiers in neurorobotics 7 (2013): 19.

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