Responses in oscillatory brain activity and electrodermal activity to interpersonal space intrusion

Birgit Nierula, Mustafa Tevfik Lafci, Andrej Prescher, Sebastian Bosse

Fraunhofer Heinrich-Hertz-Institute, Vision and Imaging Technologies Department, Interactive & Cognitive Systems Group
Einsteinufer 37, 10587 Berlin

Background

- The near-body space is a key component of social and object interaction. In the social context interpersonal space (IPS) defines the comfort distance for interacting with other persons and violations of IPS lead to arousal or discomfort (Hayduk, 1978).
- Besides situational and individual factors, the expansion of IPS is influenced by social cues, such as the facial expression of an intruder (Ruggiero et al., 2017) and social norms and values (Iachini et al., 2016).
- A recent study investigated discomfort-related responses and electrodermal activity (EDA) across multiple interpersonal distances (Tootell et al., 2021) and shows that similar responses can be induced with human-like avatars in an immersive virtual environment.
- In the present study we underpin these findings with electroencephalography (EEG) to identify neural correlates of IPS intrusion that may serve as real time measure.

Methods

- N=5 (from an ongoing study with N=20)
- Immersive VR
- gender-neutral human-like avatar
- 2x2 within-subject design
- **Factors:**
  - Avatar distance: with vs without personal space intrusion
  - Facial expression: angry vs neutral avatar face
- Four experimental conditions consisting of 15 trials each
- 64-channel EEG and EDA were recorded at a sampling rate of 500 Hz using wireless amplifiers (LiveAmp, BrainProducts)
- Individual personal space boundary was identified via the stop-distance procedure
- Each **experimental trial** started with the avatar standing for 5 seconds at a baseline distance of 8m to the participant. Next, the avatar started walking towards the participant and stopped at varying distances with or without IPS intrusion and with angry or neutral facial expression (depending on the experimental condition) for another 5 seconds. The experiment was conducted in 4 blocks of 15 trials each and conditions were presented in random order.
- Participants were standing during experimental blocks; opportunities to sit and rest were provided during short breaks.
- **Analysis:** After pre-processing the data for artifact removal (regression of eye moment), we focused in a first analysis on the relation between alpha oscillations (maximized via SSD (Nikulin et al., 2011)) and avatar distance using Source Power Comodulation (SPoC) analysis (Dähne et al., 2014).

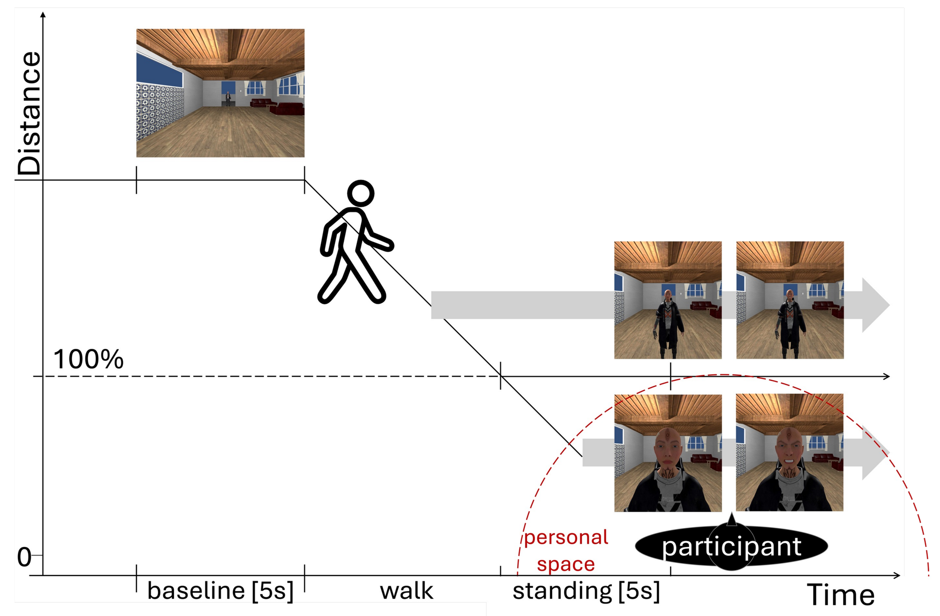

Figure 1. Experimental design

Results

Preliminary analysis indicate an increase in EDA when the avatar entered participants' personal space, which is visible in the individual and averaged EDA response over all participants (Figures 2 and 3).

Electrodermal responses

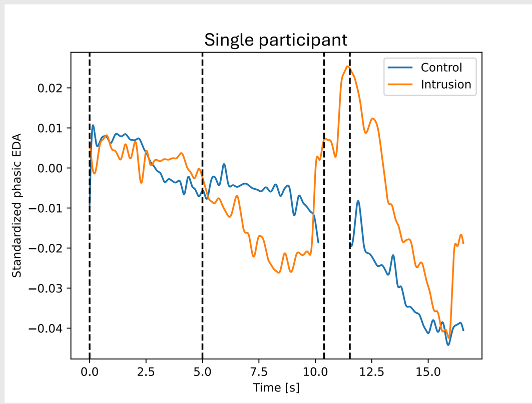

Figure 2. Single subject EDA response averaged over treials with and without personal space intrusion.

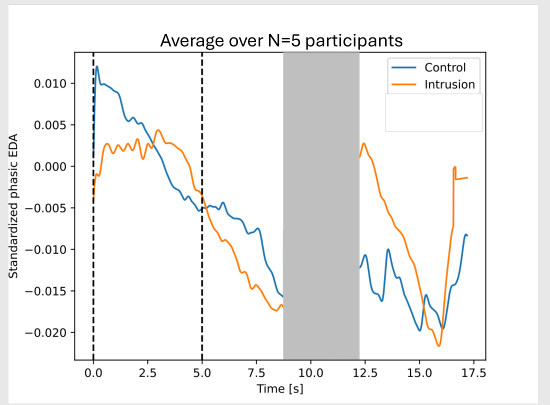

Figure 3. Grand average EDA response (N=5) over experimental trials with (orange trace) and without (blue trace) personal space intrusion. The x-axis displays the timeline of, starting with the standing period at the end of the room from 0s to 5s (baseline), followed by the avatar walking towards the participant and ending with another standing period of the avatar directly in front of the participant. The gray bar indicates the different time points for PS instrusion.

In a first EEG analysis we looked at the relation between avatar distance and alpha oscillations using all EEG channels (Figure 4) and subsets over sensorimotor (Figure 5) and parietal brain regions (Figure 6), where we expected responses due to attention processes or sensorimotor preparation.

Small relation between distance and alpha oscillations over all EEG channels

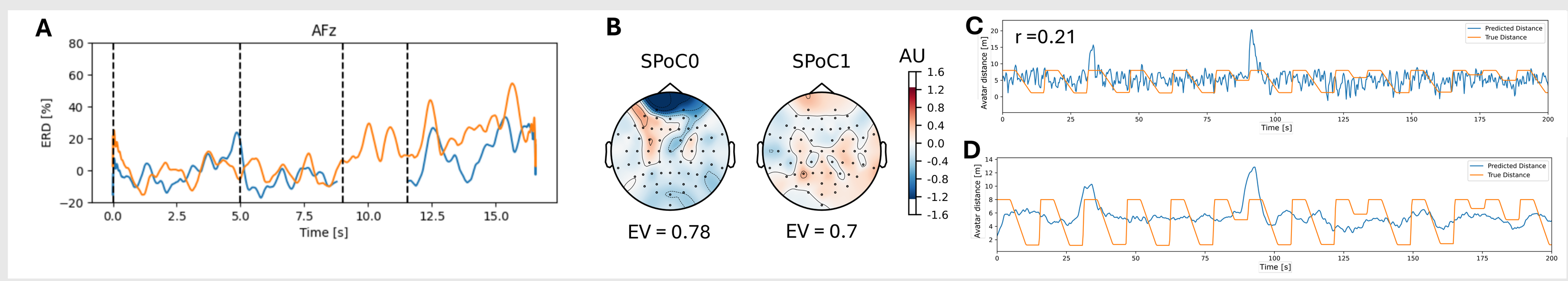

Figure 4. (A) Single subject event-related desynchronization (ERD) at channel AFz (baseline: 0s-5s). (B) 1st and second spatial filter of SPoC analysis. (C) Correlation between actual and predicted distance using the first SPoC comonent. (D) Panel C with moving average.

Small relation between distance and alpha oscillations over motorsensory brain regions

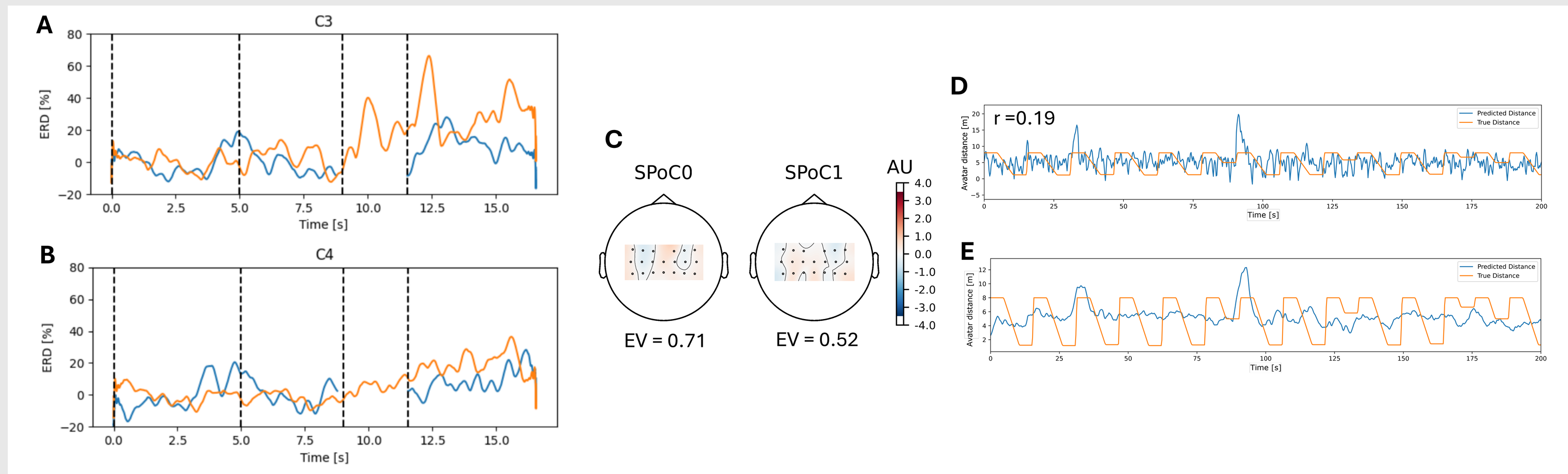

Figure 5. (A+B) Single subject ERD at channels C3 and C4 (baseline: 0s-5s). (C) 1st and second spatial filter of SPoC analysis. (D) Correlation between actual and predicted distance using the first SPoC comonent. (E) Panel D with moving average.

Moderate relation between distance and alpha oscillations over parietal brain regions

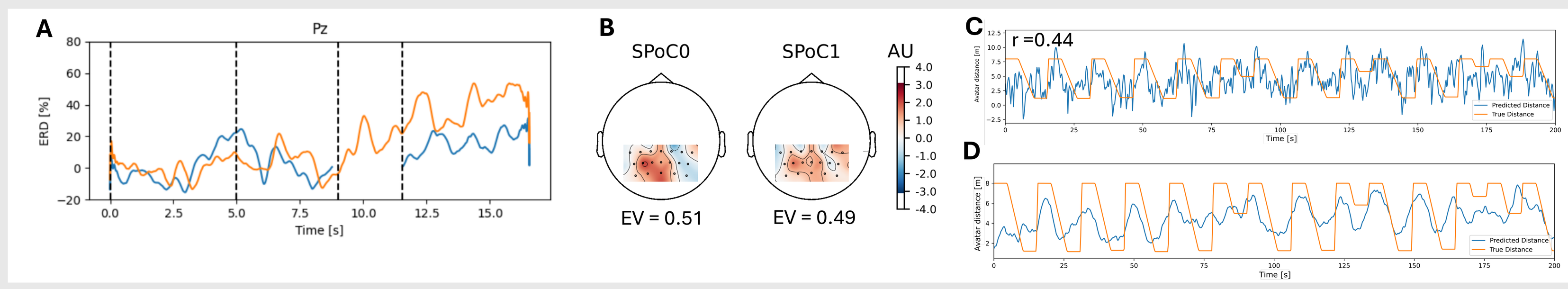

Figure 6. (A) Single subject ERD at channel Pz (baseline: 0s-5s). (B) 1st and second spatial filter of SPoC analysis. (C) Correlation between actual and predicted distance using the first SPoC comonent. (D) Panel C with moving average.

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Discussion

Our findings are a first step towards a novel avenue to objectively identify neural markers in real-time for personal space intrusion in VR. This will have implications for the development of advanced applications that involve social interactions with virtual characters.

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