

# EEG Hyperscanning: An ecological evaluation of brain synchronization in co-operative tasks

Nathan Shields<sup>1</sup> and Alejandro Lopez Valdes<sup>1</sup>

<sup>1</sup>Trinity College Dublin, The University of Dublin; School of Engineering, GBHI, TCIN and TCBE, Dublin, Ireland

## Introduction

### Motivation

- Evaluate **group dynamics** based on **real-life cooperative** group settings to further the knowledge **Inter-Brain Synchronisation (IBS)**.
- Knowledge of **IBS** in **social cognitive neuroscience** remains limited.
- Explore **IBS** settings and its potential use in **clinical settings** [1].

### Research objectives

- To evaluate the effect that **cooperative** and **adversary** group dynamics can have on the **IBS** levels within the group.
- To assess and compare **IBS** levels within a **successful** and **unsuccessful** group (passed vs. failed trials).
- Our **Hypothesis** is that successful performance will exhibit higher levels of **IBS** compared to failed or adversary conditions.

### Experimental measures

- Inter-Subject Correlation (ISC)** [2]
- Correlated Component Analysis (CorrCA)**
- Bandwidth Dependent Analysis**

## Methods

### Participants

30 young, self reported healthy adults from the student body of Trinity College Dublin were recruited and divided randomly into **10 groups of 3 participants**. All recruits were on a voluntary basis and the project outline was approved by Ethics prior to recruiting. Participants had low to no levels of familiarity with one another before testing. Participants were asked to refrain from drinking alcohol, smoking tobacco, consuming caffeine or applying product to their hair 12 hours before the trial commenced. No remuneration was provided for participation.

### Study Design

The experimental design for this project consisted of 7 EEG recorded trials:

**Control Trial x1** – Participants carried out individual puzzles as a control condition (e.g., sudoku, crossword, wordsearch).

**Cooperative Trial x3** – Participants worked together to complete The Mind card game. They completed this task without speaking to each other to promote neural synchrony amongst the group.

**Adversary Trial x3** – A player at random was selected, without the knowledge of the other two participants, to play against the other two group members (i.e., sabotage the game).

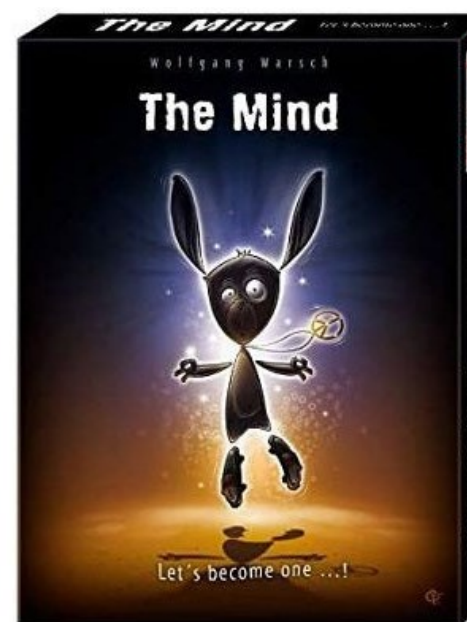
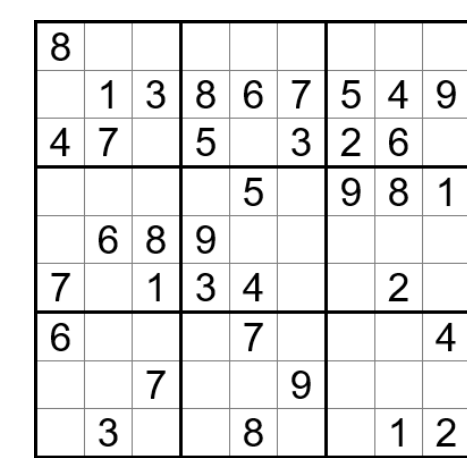


Fig.1: Sudoku and The Mind.

### Test Setup

Each participant was fitted with a 24 electrode mBT Smarting EEG cap [3], and was seated evenly around a table with the cards placed in the centre, as seen in Figure 2. The EEG signals were recorded using three android devices, each individually paired via amplifiers to the EEG caps. The android devices were strapped to the weaker arm of each participant (i.e., the arm not placing cards) to increase signal strength and limit motion artifacts. The three android devices, recording laptop and video camera were synchronised using a WLAN router so that events throughout the experiment could be recorded using the LSL protocol [4]. All devices were connected via the 5GHz WLAN channel to reduce noise and dropped data packages. Triggers were implemented to annotate the EEG recordings into: baseline, passed trials, failed trials and the end of recording for analysis.

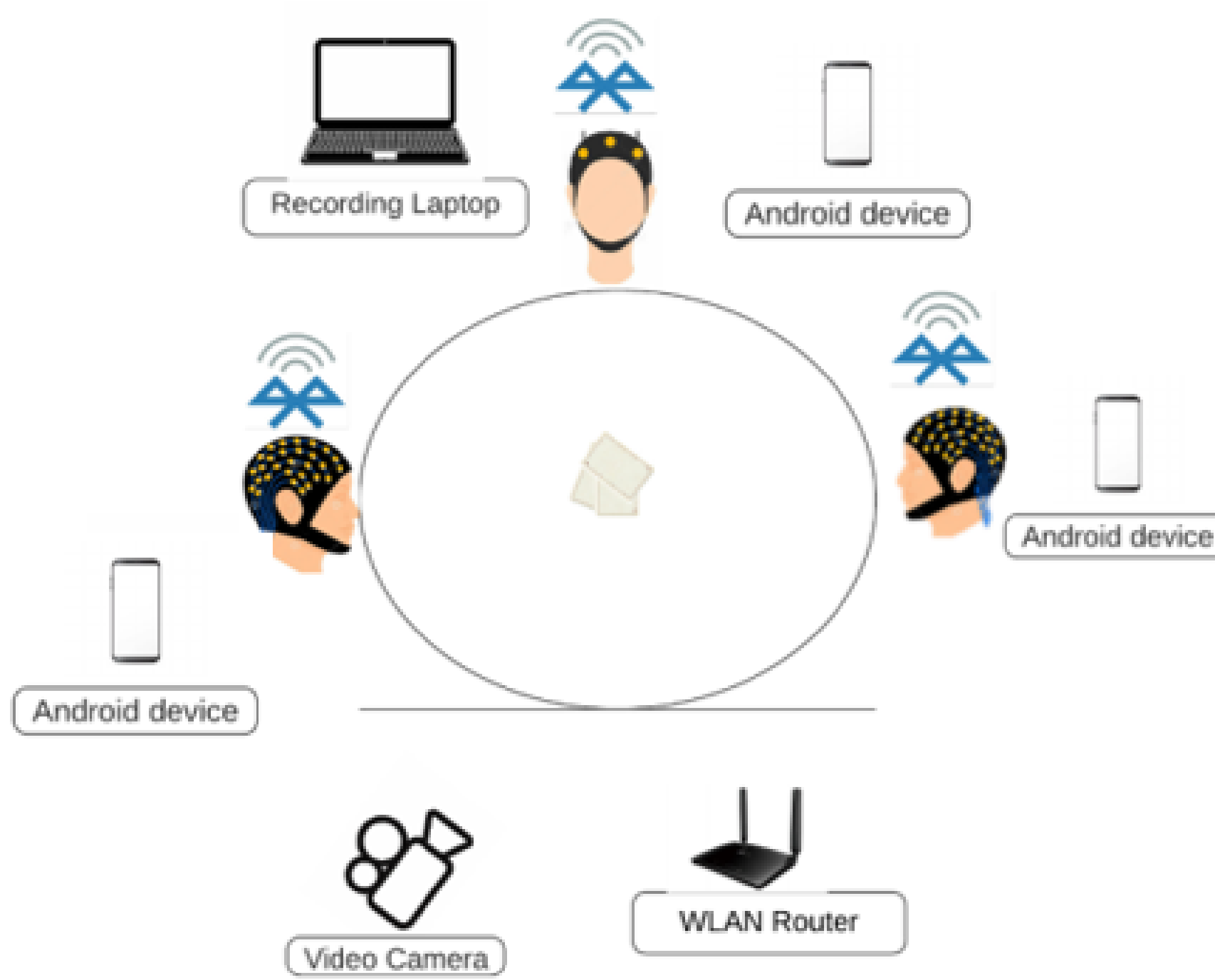


Fig.2: Physical Test Setup.

### Data Analysis

**Inter-Subject Correlation:** ISC computes the neural functional responses in groups of multiple people correlated in consistently in time [5]. The ISC scores analysed were in the range of -1 to 1. Scores close to 1 represent high correlation and scores close to -1 denote anti-correlation.

**Bandwidth Dependent Synchronisation:** ISC scores for each of the five different EEG frequency bandwidths were calculated and compared. Delta (1-4Hz), Theta (4-8Hz), Alpha (8-12Hz), Beta (12-30Hz), and Gamma (30-100Hz) bands.

**Cooperative vs Adversary Analysis:** ISC scores of participants that had cooperative and adversary roles during the experiment were evaluated to investigate whether either behaviour had any effect on ISC scores.

**Inter-Group Synchronisation:** EEG data from the participants were redistributed to artificially form 10 new groups where neither of the 3 members actually carried out the task together. This was to examine whether or not IBS can occur even when the participants are not physically working together but are still completing the same task in the exact same environment.

## Results

### Inter-brain synchronisation across all events

(Fig.3)

Figure 3 shows a clear difference between the ISC scores of the passed vs failed trials, with the passed achieving over two times the ISC score of the failed. The negative correlation shown during the control and baseline trials demonstrates that no synchronisation occurred between the participants during these events. There was a significant difference in ISC scores across different conditions (Kruskal-Wallis,  $p$ -value = 0.0452). A planned comparison between the ISC of passed and failed trials showed a significant difference between the events (Mann U-Whitney,  $p$ -value = 0.0460).

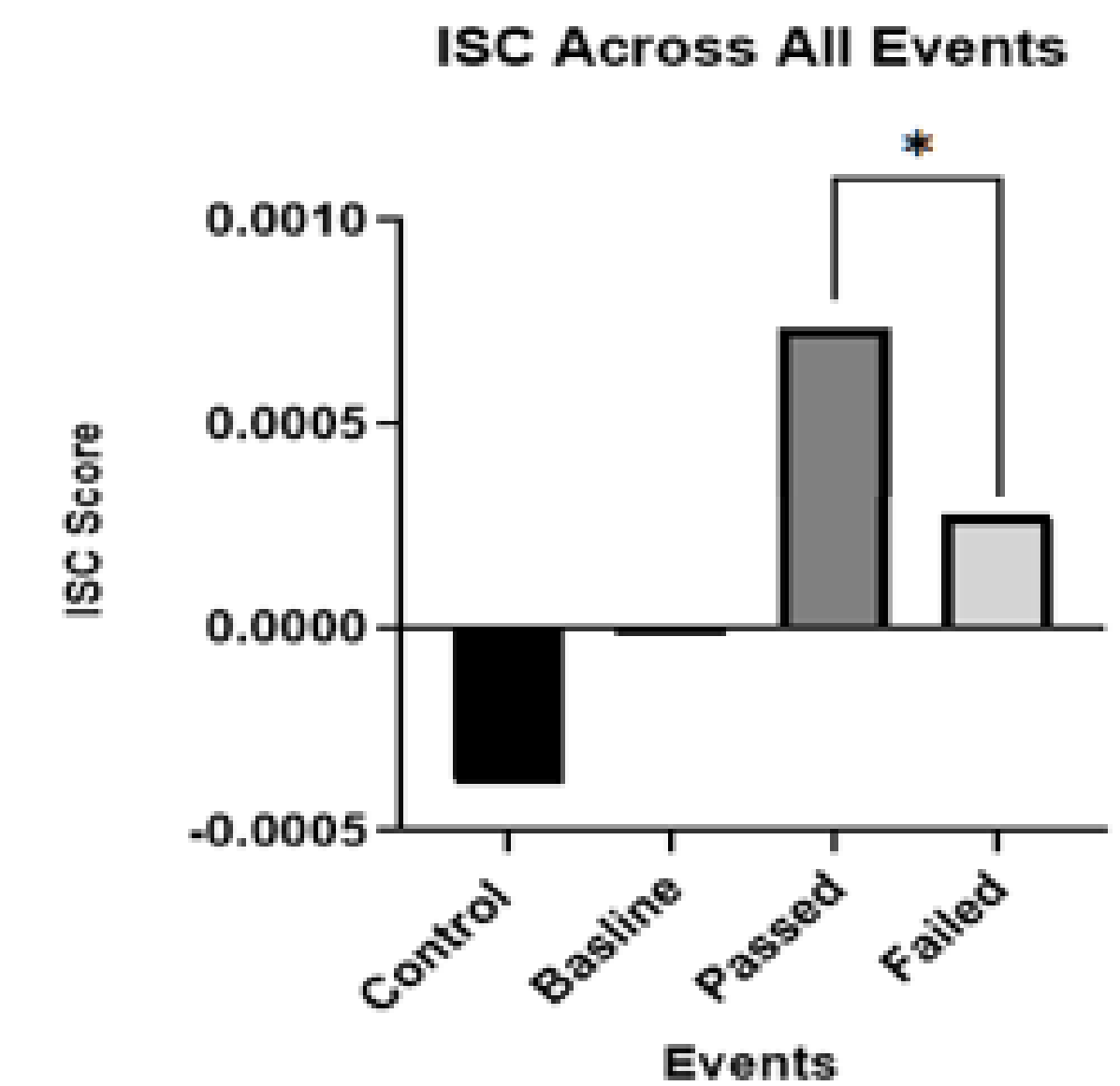


Fig.3: ISC scores across all events.

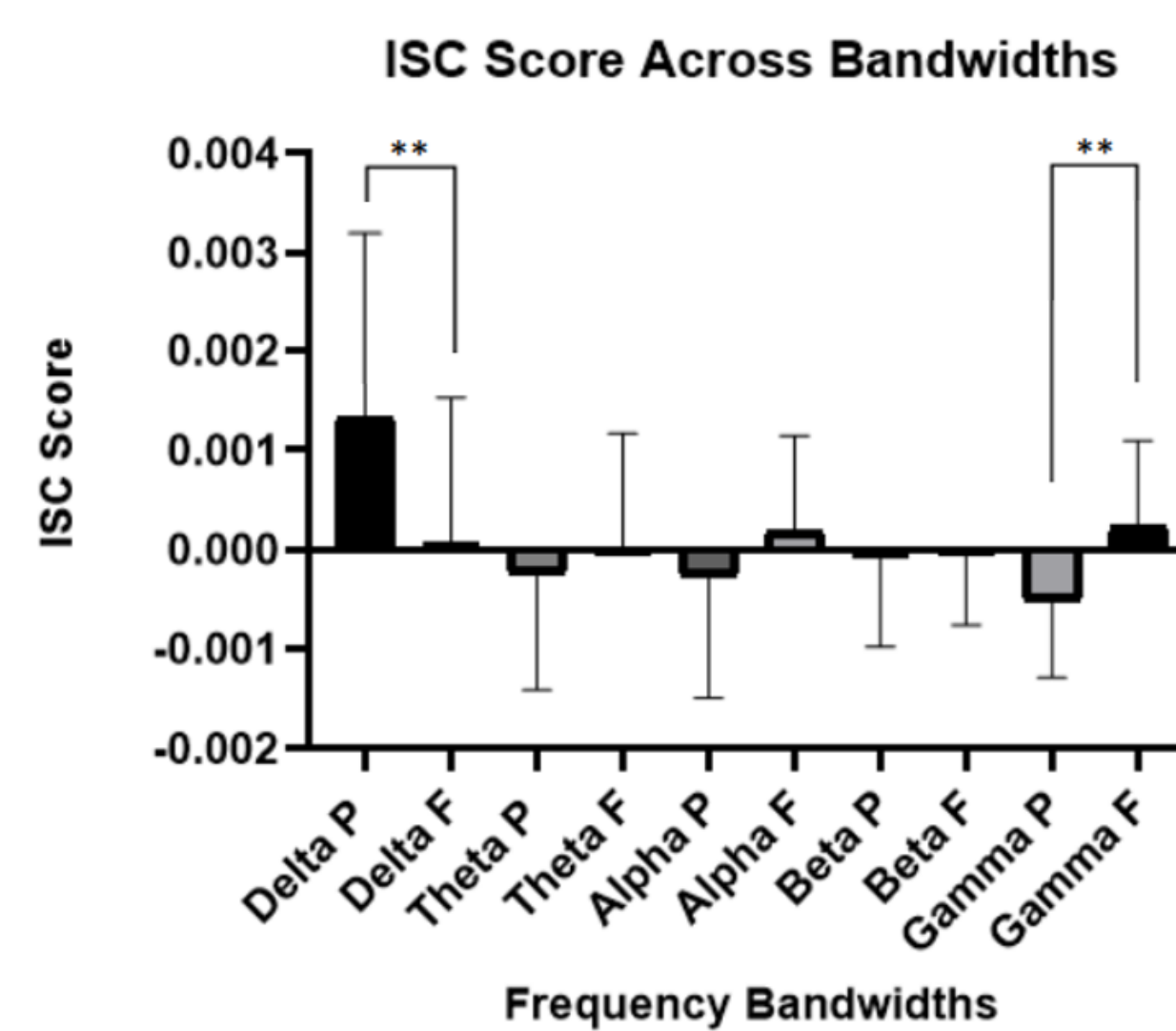


Fig.4: ISC scores for all EEG frequency bands, passed (P) vs. failed (F) trials

### Bandwidth dependent synchronisation

(Fig.4)

Figure 4 shows the ISC scores calculated for each of the five EEG frequency bands and compares the passed and failed trials. The Delta band exhibits the highest ISC score indicating that high levels of synchronisation occurred in this band during the passed trials. There was a significant difference in ISC scores for the Delta band (Mann U-Whitney,  $p$ -value = 0.0092) and the Gamma band (Mann U-Whitney,  $p$ -value = 0.0036).

### Cooperative vs adversary effects on group performance

(Fig.5)

Figure 5 compares the roles of cooperative and adversary behaviour within a participant's dynamic in the group. Synchronisation via ISC scores was significantly higher during cooperative trials than during adversary trials (Mann U-Whitney,  $p$ -value < 0.05).

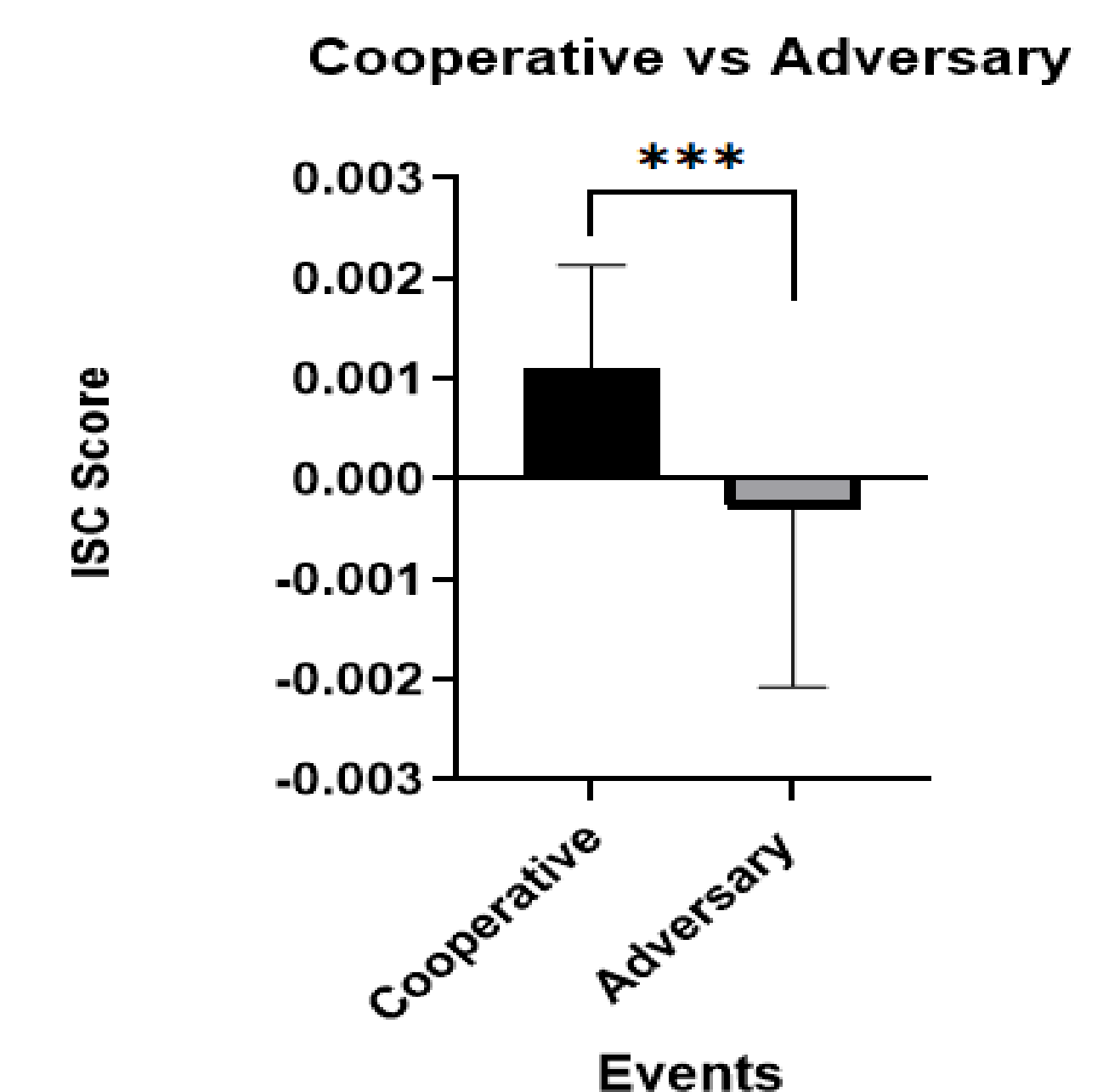


Fig.5: ISC scores for cooperative vs. adversary trials.

### Multi-Subject Synchronisation

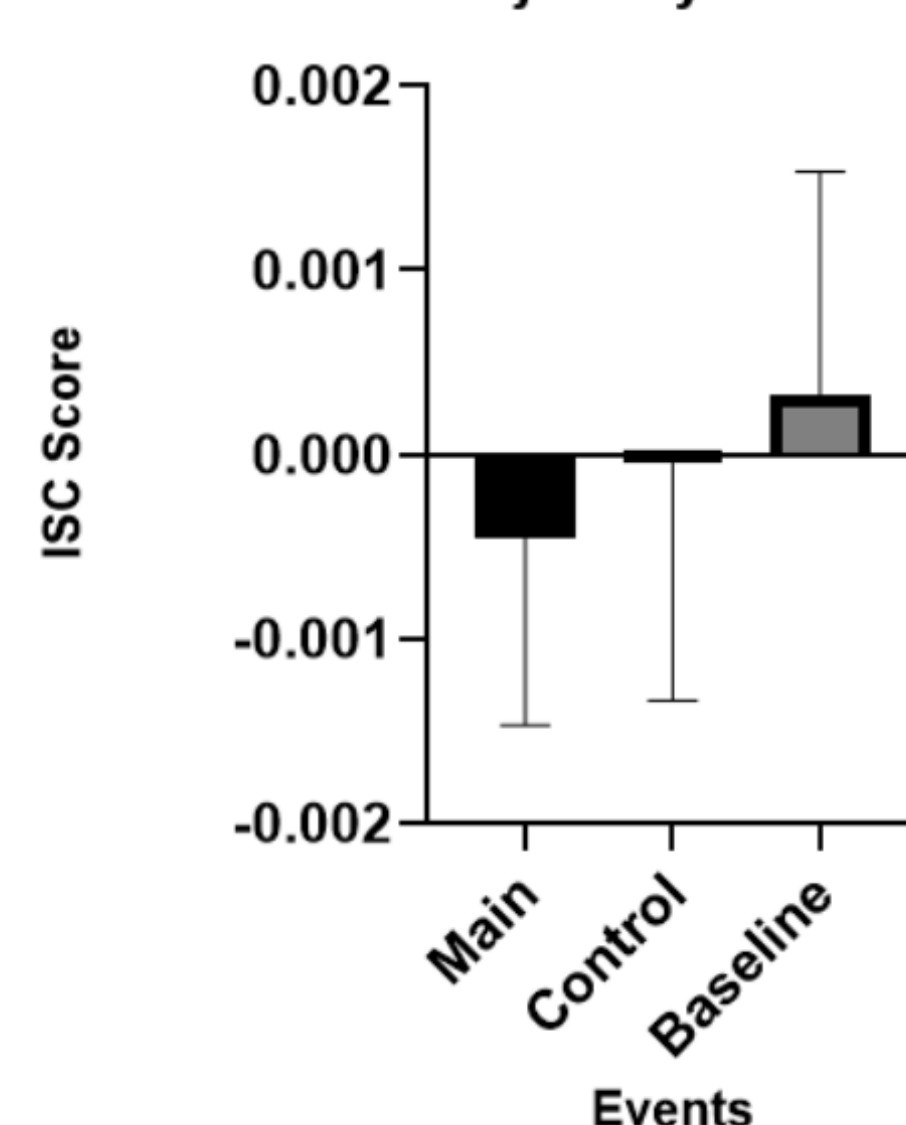


Fig.6: ISC scores for inter-group synchronisation.

### Inter-group synchronisation

(Fig.6)

Figure 6 shows the ISC scores for the main trials, control trials, and baseline all participants' datasets were redistributed into 10 new groups where neither of the 3 original members coincided. No positive ISC scores for the main trial were found, however, the data was not tested for significance.

## Discussion

### Inter-Brain Synchronisation

- The ISC scores calculated across all events show high levels of IBS in the passed trials when compared to the failed trials. This agrees with our expected outcome that successful team performance leads to higher levels of IBS within the group.
- The ISC score range from -1 to 1 allowed a visual representation of the negative correlation that can be seen in the control trial. The negative ISC score can be assumed to be due to the fact that all participants carried out this task individually instead of together as a team as was done during the main trials. This supports our findings that group cooperation promotes IBS among participants.

### Bandwidth Dependent Synchronisation

- Significant synchronisation only occurred in the Delta band of the passed trials. With either low or negative ISC cores computed across the remaining four trials. This effect was no expected and calls for further investigation into the role of Delta activity on IBS.

### Cooperative vs Adversary Analysis

- Cooperative vs adversary trials showed that cooperative group behaviour exhibited positive and higher levels of ISC scores when compared to the negative and lower ISC scores that adversary behaviour produced. This again supports our findings that group cooperation increases IBS among participants.

### Inter-Group Synchronisation

- Redistributing the datasets into 10 new groups showed that although participants completed the same task in the same environment no brain synchrony occurred. Providing further evidence that cooperative groupwork promotes IBS and that it is not task depended but rather environmentally driven.

## References

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