Multimodal synchrony predicts team performance

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Synopsis

We show that in contrast to what is generally expected, high team performance in a semi-realistic drone control task is associated with low synchrony in physiology and facial expression. We explain this through the notion that in this task, successful team members focused more on their individual tasks than less successful teams. Our study highlights the need to relate synchrony measures to team performance at the level of task phase, corresponding to required shared and distributed attention.

Background

Physiological synchrony refers to the degree to which physiological signals of multiple individuals uniformly change over time. In previous work, we and others have repeatedly shown that physiological synchrony is a reliable indicator of shared attention among groups of individuals (Stuldreher et al., 2020).

We here extend previous work to a team setting. Several studies examined physiological synchrony in team tasks before (e.g., reviewed by Kazi et al., 2021). The premise usually is that high synchrony coincides with better team performance. However, in most real-life team tasks, team members should focus on independent team task aspects most of the time rather than shared aspects, and the opposite can be expected.

Whereas most studies focus on single physiological measures instead of multimodal paradigms (Kazi et al., 2021), synchrony in multiple measures may be complementary to each other (Stuldreher et al., 2020). We here investigate to what extent physiological synchrony in participants' electroencephalogram (EEG), electrodermal activity (EDA), heart rate (HR), gaze direction and, facial expressions are predictive of team performance in a drone control task.

Methods

The study was approved by the Radboud University Ethics Committee Social Sciences (ECSS) under reference number ECSW-2024-031. All participants provided written informed consent. Fifty pairs of 'navigator' and 'pilot' participants performed eight 5-minute blocks of a semi-realistic drone control task (more elaborately described in Zhecheva et al., 2024). Participants sat back-to-back in the same room (Figure 1a) and viewed similar screens (Figure 1b). The navigator verbally instructed the pilot on which drone should be guided to what location, while avoiding hazard zones. When a drone arrived, the navigator could start searching for a target in an image sent by the drone. The main responsibility of the pilot was to guide drones to coordinates as instructed by the navigator. Important events (e.g., a drone arrived at its location) were accompanied by distinct sounds. In addition, call-signs were auditorily presented, and every other block, the pilot was instructed to mentally keep count of how often one of these call-signs was presented. Team performance was quantified per 5-minute block, represented by "total team score" being, the numbers of drone locations reached plus targets found in the image

search, minus number of hazard zones hit. Team performance was also continuously presented to the team on the screen.

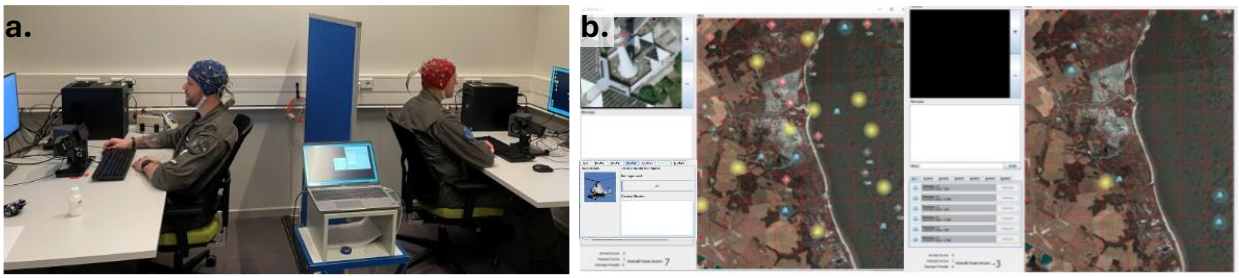

Figure 1. a. Overview of the experiment setup. b. The screens as seen by navigator (left) and pilot (right)

EEG, ECG, and EDA were recorded using a BioSemi ActiveTwo system with the hyperscanning option. Data were preprocessed to reduce artifacts and to obtain heart rate (HR) and phasic EDA activity over time. Gaze direction was recorded using an Eyelink 1000 system and averaged across the two eyes. OpenFace 2.2.0 (Baltrusaitis et al., 2018) was used to extract facial expressions (defined by activity in 17 Action Units or AUs) according to the Facial Action Coding System from footage recorded by a Logitech C920 webcam.

In each of these (3 physiological, 1 gaze, and 17 facial AU) measures, we computed synchrony between members of the dyads by computing inter-subject correlations. For EDA, heart rate, gaze direction, and AUs, correlations were computed using a 15-second sliding window with 1-second increments across the data, and the resulting correlations were averaged, following our previous work (Stuldreher et al., 2020). For gaze position, correlations were first determined separately for horizontal and vertical directions, and subsequently averaged. For EEG, correlated component analysis (CorrCA), was used to find the linear combination of channels with the highest correlation between members of the pairs. Inter-subject correlations were computed after applying this spatial filter, following our previous work (Stuldreher et al., 2020).

We investigated whether and to what extent synchrony in each of these measures relates to team performance. To do so, we used linear mixed models (LMMs) with random intercept and fixed slope, where team performance is the dependent variable, synchrony in each variable – the predictor, and dyad – the grouping factor. We report the variance explained by the fixed effect ($R^2_{marg.}$), the slope of the fixed effect (β; the number of units team performance changes with one unit increase in synchrony), and the p-value of the fixed effect. Each variable that showed a significant or near-significant fixed effect ($p < .100$) was added to a second multivariate LMM to study the variance of team performance explained when combining modalities.

Results

Table 1 depicts the statistical parameters of the LMMs for EEG, EDA, heart rate, gaze direction, and AUs. It shows a significant negative relationship between AUs 7 (lid tightener), 10 (upper lip raiser), 12 (lip corner puller), 14 (dimpler), 26 (jaw drop) with team performance, and a near-significant relationship between EDA and HR with team performance.

Adding all modalities with a (near-)significant fixed effect to a multivariate mixed linear model (Multim. in table) resulted in a marginal R^2 of .092, higher than any of the models based on a single variable.

Discussion

Overall, team performance decreases (or shows a trend in that direction) with increasing synchrony in EDA, HR and five facial AUs. None of the studied measures show a positive

relation, or a trend towards it. The results of the multivariate model suggest a benefit of combining measures from different modalities.

Our findings contrast with the general premise that team performance tends to increase with physiological synchrony. We explain this through the link between physiological synchrony and shared attention. Higher levels of physiological synchrony point towards higher levels of shared attention and may thus indicate that team members monitored information that was relevant for their teammate, rather than focusing on their own task.

Table 1. Statistical parameters of the LMM describing the relation between synchrony in different modalities and team performance. **Bold** = significant fixed effect, *Italics* = near-significant fixed effect.

Mod.	**$R^2_{marg.}$**	**β**	***p***	**Mod.**	**$R^2_{marg.}$**	**β**	***p***	**Mod**	**$R^2_{marg.}$**	**β**	***p***
EEG	.000	-1.9	.943	AU06	.003	-1.82	.383	AU20	.007	-12.5	.119
EDA	*.007*	*-4.6*	*.058*	**AU07**	**.025**	**-12.9**	**.012**	AU23	.004	9.5	.232
HR	*.013*	*-5.7*	*.055*	AU09	.005	-12.1	.179	AU25	.003	-5.24	.387
Gaze	.000	7.0	.558	**AU10**	**.036**	**-11.5**	**.002**	**AU26**	**.014**	**-15.7**	**.026**
AU01	.002	-6.4	.444	**AU12**	**.053**	**-13.6**	**<.001**	AU45	.002	-11.3	.356
AU02	.000	-1.2	.904	**AU14**	**.043**	**-18.6**	**<.001**	**Multim.**	**.092**		
AU04	.006	-9.6	.143	AU15	.001	5.3	.566				
AU05	.000	2.0	.869	AU17	.006	9.6	.171				

While our results thus suggest that overall, participants had better team performance when they focused more on their own task, there is no doubt that during certain task phases it is important to have high shared attention. In upcoming work, we aim to identify independent vs shared task phases (operationalized through the moments where the navigator instructs the pilot), and test whether good team performance is associated with relatively high synchrony in those shared compared to independent work phases.

Disclosures

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