Cardiac Arrest: Evaluating the Role of Biosignals in Gameplay Strategies and Players' Physiological Synchrony in Social Deception Games

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ABSTRACT

Social deduction or deception games are games in which a player or team of players actively deceives other players who are trying to discover hidden roles as a part of the win condition. Included in this category are games like One Night Werewolf, Avalon, and Mafia. In this pilot study (N=24), we examined how the addition of visual displays of heart rate (HR) signals affected players' gameplay in a six-player version of Mafia in online and in-person settings. We also examined moments of synchrony in HR data during critical moments of gameplay. We find that seeing signals did affect players' strategies and influenced their gameplay, and that there were moments of HR synchrony during vital game events. These results suggest that HR, when available, is used by players in making game decisions, and that players' HR can be a measure of like-minded player decisions. Future work can explore how other biosignals are utilized by players of social deception games, and how those signals may undergo unconscious synchrony.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in collaborative and social computing**.

KEYWORDS

Deception; Wearables; Biosignals; Synchrony

ACM Reference Format:
Cathy Mengying Fang, G. R. Marvez, Neska Elhaouij, and Rosalind Picard. 2022. Cardiac Arrest: Evaluating the Role of Biosignals in Gameplay Strategies and Players' Physiological Synchrony in Social Deception Games. In *CHI Conference on Human Factors in Computing Systems Extended Abstracts (CHI '22 Extended Abstracts), April 29-May 5, 2022, New Orleans, LA, USA.* ACM, New York, NY, USA, 7 pages. https://doi.org/10.1145/3491101.3519670

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CHI '22 Extended Abstracts, April 29-May 5, 2022, New Orleans, LA, USA

ACM ISBN 978-1-4503-9156-6/22/04.
https://doi.org/10.1145/3491101.3519670

1 INTRODUCTION

Social deception games are a common pastime for college students, streamers, and board game enthusiasts. In these games, players take on a hidden role and try to discover their teammates to uncover the players on the opposition and vote them out. These games are often played in person with cards or a narrator dealing out roles and keeping the game on track. These games allow players to do actions they normally would not do, such as engage in intentional deception. However, in light of the COVID-19 pandemic, many board game players would have had to move their gaming sessions to online environments like Zoom or Discord. This movement led us to wonder how those online game interactions could be boosted by wearables that allowed players to display their HR or other signals to their fellow players.

In this study, we had participants wear an Empatica E4, a wristband that collects biosignal and physiological data on HR, electrodermal activity, temperature, and other signals, while playing two games of Mafia in either an in-person or online game setting. In these games, players could either see signal information or not, and we measured how this affected their gameplay through surveys, interviews, and the analysis of their HRs over the course of the games, drawing on previous work done with HR and social interactions in gaming [4]. Here, we examine a six-player version of Mafia and how players interpreted the signals as an extra, complex piece of information in their decisions. Our main research questions are:

1. How does the information of players' biosignals affect gameplay mechanics in deception-focused games?

2. Do players on the same team experience unconscious synchrony in their biosignals in both in-person and online settings?

In this paper, we describe the set-up of a six-player version of Mafia, how we collected biosignals from participants, and the analysis of in-game choices through surveys and analysis of biosignal data. We also propose future research that could be done on the effect of biosignals on gameplay.

2 RELATED WORK

2.1 Biosignals in Social Deception Games and Other Communication Types

Sharing biosignals has been explored as a way of connecting people. Liu et al. developed an app that connected to a wristband that captured the heart rate (HR) and prompted users to decide whether to share their heart rate or not [10]. They deployed the app to investigate how users would interact with a system that allows sharing one of their physiological signals in real-time. They found that these interactions could be a playful form of communication that provide updates on their lives with others. At the same time, some participants were reluctant to share their HR as it was seen as too intimate or they were worried about showing outward signs of stress. Other work has shown a similar finding where HR can be used for connection with others and as a piece of information sharing [15]. In that work, participants set up their own poker game in which they shared HR throughout the game to add an extra layer of challenge.

Closer to our work are those that present biosignals to players in co-located social deception games. Prior work looked at how players interpret and utilize biosignals in social play [3] and how biosignals affect players' experience and social interactions [4]. In the latter work, the Social Presence in Gaming Questionnaire (SPGQ) was used to determine how behavioral engagement, empathy, and negative feelings change when participants played the game under different conditions where access to biosignals changed [2]. We used the same questionnaire in our study to examine the social connections player experience during their gaming experiences.

We draw on prior work on how biosignals can be used to alter communication between people in their daily lives and in social deception games. More specifically, we focus on a game that involves both collaboration and competition, in addition to deception. We also evaluate the use of biosignals in online games, where compared to in-person games, players have restricted social cues.

2.2 Physiological Synchrony

Interpersonal autonomic physiology (IAP) describes the relationship between people's physiological dynamics. In particular, physiological synchrony (PS) is the phenomenon where the physiological activity between two or more people becomes associated or interdependent [13]. Physiological synchrony has been found in scenarios such as a conscious engagement of a narrative stimulus [14] and can be both negative (e.g., an argument between a couple [9]) and positive (e.g., a therapy session [11]). IAP typically uses measures from the autonomous nervous system (ANS), the body's unconscious, involuntarily controlled response to stimuli, reflective of one's state of arousal [8]. PS has been found to be predictive of the outcome of interpersonal social interactions, namely team performance in gaming [6] besides the aforementioned scenarios where PS were found. In a group setting, working a joint task can lead to PS [5].

Most related to our work is the investigation of PS in multiplayer games. Chanel et al. found that PS was an indication of social presence and PS was higher in competitive versus cooperative play [1]. Similarly, Mitkidis et al. showed that PS could be a good proxy of trust in a cooperative game. [12]. In a turn-based game that involved a dyad and an artificial agent, Järvelä et al. found that the presence of the virtual agent led to a diminished PS between the dyad [7].

Our work looks for potential PS among players in a game where the players engage in an activity that requires high cognitive load and high interpersonal interactions. Different from prior studies, our work require players to consciously lie or defend themselves to persuade others in order to advance in the game. In addition, we hope to compare IAP in an in-person setup versus an online setup, where in the latter condition, the interpersonal interactions are limited and there would be more exposure to distractions from the digital interface.

3 EXPERIMENT DESIGN

3.1 Conditions and Experimental Setup

To test our hypothesis that players would use HR to make decisions and that they may experience HR synchrony, we use the classic social deception game Mafia. In this game, players take on the role of either a mafia member or a civilian (including the special roles: Doctor and Police) and try to vote off or kill off the other team. This game has several phases in which participants close their eyes and become unaware of certain players' actions, making this a game of imperfect information which means we can examine acts of intentional deception. In our six-player version of the game, we had two mafia members, two pure civilian roles, one doctor, and one police. We chose a six-player version of the game instead of a more typical game with eight or more players to allow for shorter rounds. Participants completed two games of Mafia in each condition and roles were randomly assigned to participants.

We had four conditions in this study to examine the effects of being able to utilize HR information in the first or second game in our in-person and online conditions (Figure 1). HR information was collected from Empatica E4 wristbands [1] that were connected to six smartphones that displayed participant HRs through the E4 Realtime app. Two studies were conducted in person and two online. In each study, participants played two games where their HR was either visible or hidden; the order of HR visibility was counterbalanced within the environmental condition.

For the in-person condition, participants sat around a table and were able to see the HR displays of the six players on a screen in front of them and projected on a screen in the testing room (Figure 2 top). For the online condition, players logged into a Zoom room where a facilitator's computer shared the HR information of the six players during the game (Figure 2 bottom). In both conditions, players wore clear masks, allowing their smiles and facial expressions to be seen, and wore E4s on their dominant wrists.

3.2 Participants and Study Procedure

We recruited 24 participants (average age = 19.8, SD = 2.5) through our university mailing list. There were three non-binary, ten female, and ten male participants, with one participant declining to self-identify. Our participants consisted of undergraduate and graduate students who reported previous experience with social deception

[1] https://www.empatica.com/research/e4/

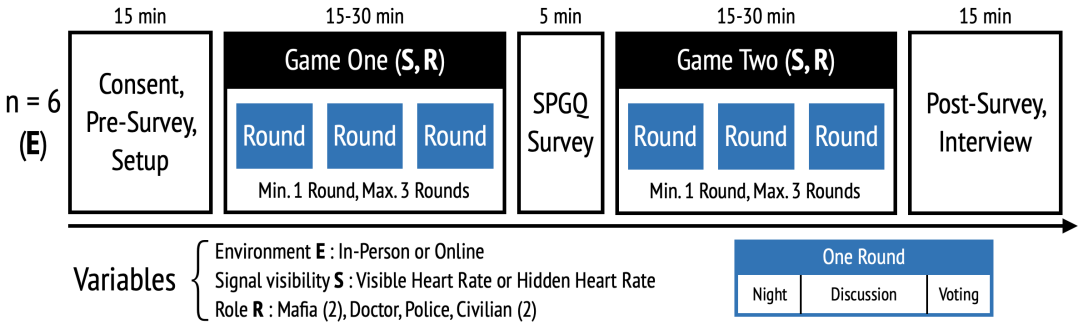

Figure 1: User Study Procedure.

games. Participants had an average experience of 5.2 (1-not at all, 7-a great deal) in Mafia gameplay. The study lasted around 60 minutes, and the participants were compensated with $15 in the form of a gift card upon completion of the study.

Participants were asked to complete pre-study surveys before beginning play. These survey questions asked participants about their emotional state, their experience with social deception games, and their gameplay style. The facilitators asked participants to wear the devices, set up the wearable devices (that record the biosignals) for each participant, and showed how their biosignals will be displayed on a screen. The participants were randomly assigned to four conditions (two games, first with no signals, then with signals in person; two games, first with signals then with no signals in person; two games, first with no signals then with signals online; two games, first with signals then with no signals online). The facilitators then explained how the game worked and answered any questions the participants had and set up video cameras to record the game play. In groups of six, spaced apart for COVID-19 safety, participants began the game play. After the first round of game play, the participants answered the Social Presence in Gaming Questionnaire (SPGQ)[2], and then played the second round. After the second round, players answered the SPGQ questionnaire again and completed a post-survey. In the post-survey, we asked participants how seeing the physiological signals influenced their gameplay and how nervous they were in games where they could and could not see HR. Finally, the participants took part in a semi-structured post-interview as a group about their gameplay experience and feelings of connectedness. In this debrief, we asked the following questions on how signals influenced their gameplay.

(1) How did you feel when you were seeing your own physiological signals?

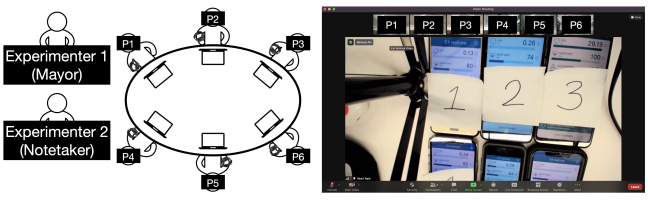

Figure 2: Experimental setup.

(2) What were your gameplay strategies when you could see other players' physiological signals?
(3) Did you feel more or less connected with other players on your team when you were playing the game remotely when you could see everyone's physiological signal (remote condition only)?
(4) Did your strategies differ when you could see the signals? How or how not?
(5) Did you find the signals to be accurate and understandable?
(6) Were the signals meaningful to your gameplay?

3.3 Data Acquisition

The physiological data were recorded using an Empatica E4 worn on the participant's dominant hand. The Blood Volume Pulse (BVP) was sampled at 64 Hz and was used as the input signal to compute the inter-beat-interval (IBI) timings and HR (HR). The resulting HR was recorded and saved at 1Hz. The Electrodermal Activity (EDA) was measured by a pair of silver (Ag) plated electrodes in contact with the wrist and was sampled at 4 Hz [2]. During each gameplay, an average of 40-minutes of physiological data was continuously recorded. The participants were asked to sit still for 3 minutes, where the data during this resting period were used to calculate the baseline physiological data for each participant. The participants press the button on the sensor to timestamp the recording in between each round of Mafia. In addition to the physiological data, the survey responses were collected online, and we recorded the video and audio of each participant using a video conference platform.

4 RESULTS AND DISCUSSION

4.1 Survey and Interview Analysis

Participants reported high previous experience with the game Mafia (AV = 5.2, SD = 1.2 on a seven-point scale). When asked about their most common Mafia strategies, a majority (n=14) stated that they prefer to take an analytical stance - written on the survey as "I like to keep track of what people say or do over the course of the game." The next most popular strategy was a defensive one (n=11)—"I try to keep suspicion off of me no matter what."

[2]https://support.empatica.com/

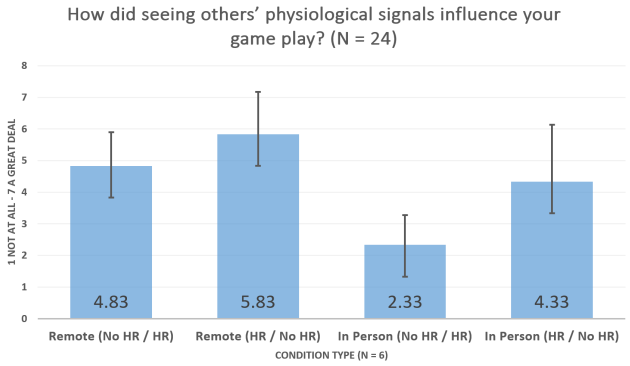

Figure 3: Average (bars) and standard deviation (lines) of the reported influence of biosignals on gameplay.

As every participant played two consecutive games of Mafia and may have been influenced by order effects, as we saw that the average Engagement scores from the SPGQ went up in the second game played no matter the condition, we present the SPGQ scores only from the first game that every participant completed instead of both game scores. There are three sections of the SPGQ that are evaluated on a scale of 0 to 4 — empathy, negative feelings, and behavioral engagement [2]. On the SPGQ-Empathy section, there were only slight differences between all four conditions, but higher empathy was reported in games where players could see HR information and was higher in in-person games. For scores on SPGQ-Negative Feelings, there were the most negative feelings reported in the online condition, but also in games where players did not have access to HR information. In SPGQ-Behavioral Engagement, there was slightly higher behavioral engagement in both games where players could see HRs and in the online conditions.

Overall, participants were more relaxed when they could not see the HR displays of themselves and other players (AV=4.25, SD=1.36; 1—extremely nervous, 7—extremely relaxed) than when they could (AV=3.88, SD=1.90). During the post-interview, participants reported feeling "extra nerve wracking, being the Mafia and having [their] heart rate on display." On average, participants stated that the signals did affect their gameplay somewhat (AV=4.33, SD=1.84; 1—not at all, 7—a great deal). More specifically, some participants used an increase in HR as a supporting argument for identifying the "mafia", such as pointing out when a player's HR is higher than usual, especially during the beginning of the game when few cues are provided. One participant stated "It tells them they're nervous because you're so focused on the heart rate that you don't really look at, like, how they react in other ways." Looking at the breakdown by condition, those in the Online HR|No HR (AV=5.83, SD=1.34) and Online No HR|HR (AV=4.83, SD=1.07) conditions stated that seeing biosignals influenced their gameplay more than those in the corresponding in-person conditions of HR|No HR and No HR|HR (AV=4.33, SD=1.80; AV=2.33, SD=0.94) (Figure 3). Additionally, those in the condition where they played the first game with HR and the second game without, reported that the HR was more influential to their gameplay. Between the Online (No HR|HR) and In-Person (No HR|HR) conditions, this difference (AV=2.33 and

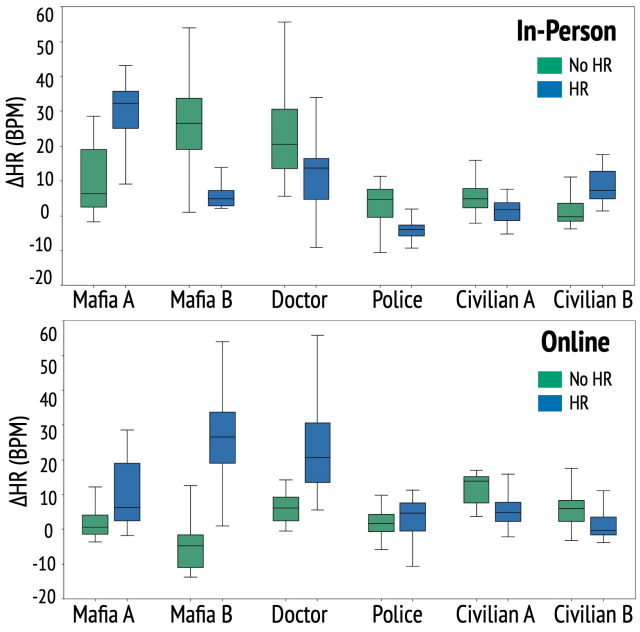

Figure 4: Boxplots of all the participants ΔHR during the first round of the game for the In-Person (top row) and the Online (bottom row) conditions.

AV=4.83) is significant at p<.05 using a one-way ANOVA test and Tukey's HSD Test for multiple comparisons. Other group comparisons did not reach a level of significance.

In the semi-structured interview, participants stated that they found signals to be meaningful to their gameplay, specifically to those in the conditions where they played a game with HR followed by a game without. These players lamented the loss of this data point and stated that they relied on it significantly. Additionally, participants stated that they found the signals to be accurate and understandable. Participants also mentioned that sharing their HR with others did feel very intimate as other players would often call out what they perceived as suspiciously high or low HRs. One player commented, "[The heart rate signal] looks pretty understandable because when you [referencing a Mafia player] went for the Police, it jumped up like 30 beats per minute," highlighting how players integrated this additional data point into their deductions about other players' motivations.

4.2 Quantitative Analysis

The HR (sampled at 1Hz) was upsampled to match the sampling rate of EDA (sampled at 4Hz). The EDA data was cleaned using a Low-Pass Filter with a cutoff frequency of 20Hz using a 4th Order Butterworth method. Since each person has a different baseline HR/EDA, we used the mean of the signal during the rest period as a baseline for that participant's data. We then subtracted the number from the baseline to show the change relative to the person's baseline HR/EDA. We found the indices of the beginning and end of data during each round from the timestamps and then segmented the signal into rounds one and two. Due to sensor failure, the EDA

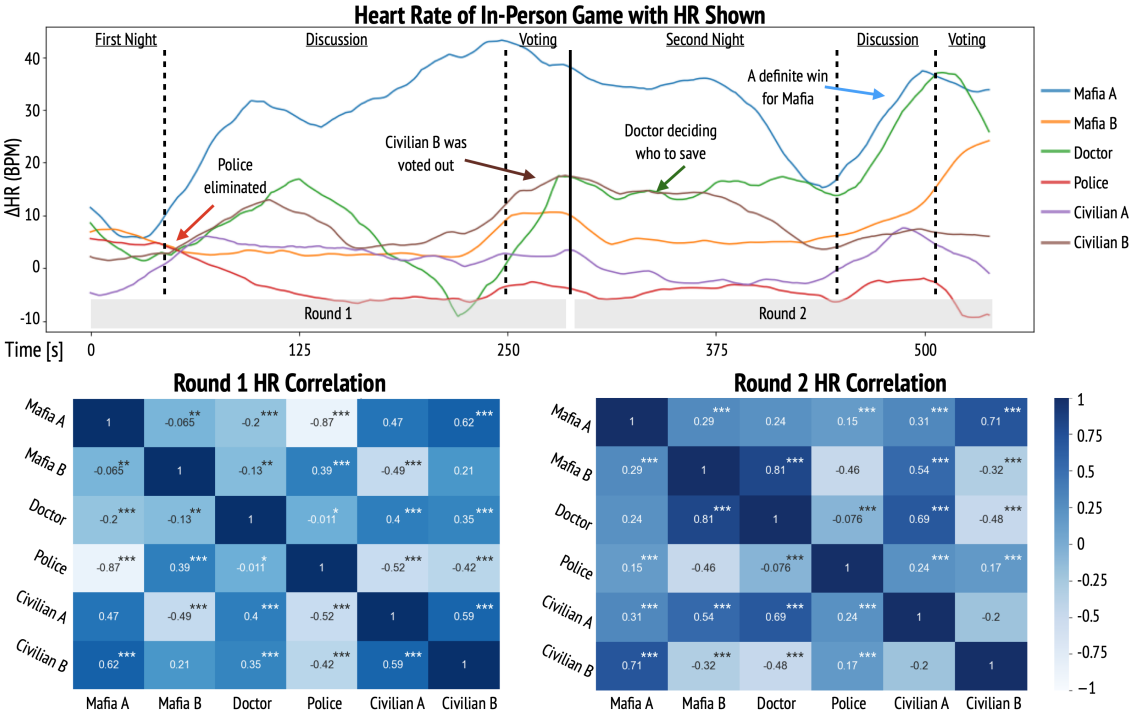

Figure 5: Top: Time-series graph of players' HR during an in-person game where signals were visible. Bottom: Correlation matrices of players' HR during each round. *: p<.05, **: p<.01, ***: p<.001

of at least one player was not captured properly during each round of the game. Thus, we decided to focus our efforts on analyzing the HR and hope to investigate other biosignals in future work.

For the following analysis, we used normalized HR (ΔHR) data across participants (i.e., the change in a player's HR relative to the mean of their baseline HR). To see if any of the experimental variables – environment (in-person vs online), biosignal visibility (visible vs hidden HR), and role in game (mafia, special characters – had any effect on the participants' HR, we performed an ANOVA on the median ΔHR for each factor. Although we did not find any statistically significant effect of the factors on the median ΔHR (Environment: F=.038, p=.848; Signal visibility: F=1.201, p=.292; Role: F=2.514, p=.108), the gameplay role had the most influence on the HR followed by signal visibility. We represented each player's signal with a boxplot (Figure 4), and indeed some roles, namely the mafia and the doctor, showed greater variability in HR than others. In addition, under the same environmental condition, the influence of signal visibility on the overall HR was more salient for the mafias and the doctor. Considering the group as a whole, the overall change in heart rate in the online condition was greater when the signal was visible, whereas the effect of heart rate visibility is less salient for the in-person condition. Indeed, this was supported by participants' comments and the survey results, where seeing each others' HR when the game takes place online had a stronger influence on their gameplay strategy and induced a greater sense of nervousness.

We also plotted the players' HR on a time-series graph to investigate potential subconscious physiological synchrony. We initially set out to investigate the potential synchronization of the two mafia players during each round, as these two players work cooperatively and are the only players that know the real identity of someone else in the round. However, the HR data exhibit overall group synchronization (i.e., most players' HR peaked or dipped around the same time). We matched those moments with gameplay events and found several insights, which we illustrate with an example game.

The top of Figure 5 shows an in-person round of Mafia where the players could see each other's HR. The players' HR lowered during the night and slowly increased as they opened their eyes for discussion. When a player is eliminated or voted out (e.g., Police – red line and Civilian B – brown line), their HR decreased and stayed flattened throughout the rest of the game. This was expected, as they could no longer actively engage in the game, thus resulting in a decrease in arousal. During other key game moments, some players' HR significantly increased, indicating an increase in arousal (e.g, when the Doctor had the critical role to save the right person and when the mafia knew it was a definite win).

To quantify the level of synchrony of the physiological signals, a correlation matrix for each round was computed where 1 indicates perfect synchrony. We found that strong correlation (positive synchrony) happened between the mafia (e.g., Figure 6 Bottom left, Mafia A–Mafia B: correlation coefficient=.65) and also between other pairs, for example, Mafia B and Doctor (Figure 5 Bottom Right Round 2; correlation coefficient=.81) or Mafia A and Police (Figure 7 Bottom Left Round 2; correlation coefficient=.96). We suspect that a high level of synchrony was likely a result of active participation (e.g., self-defense or accusation) during the discussion.

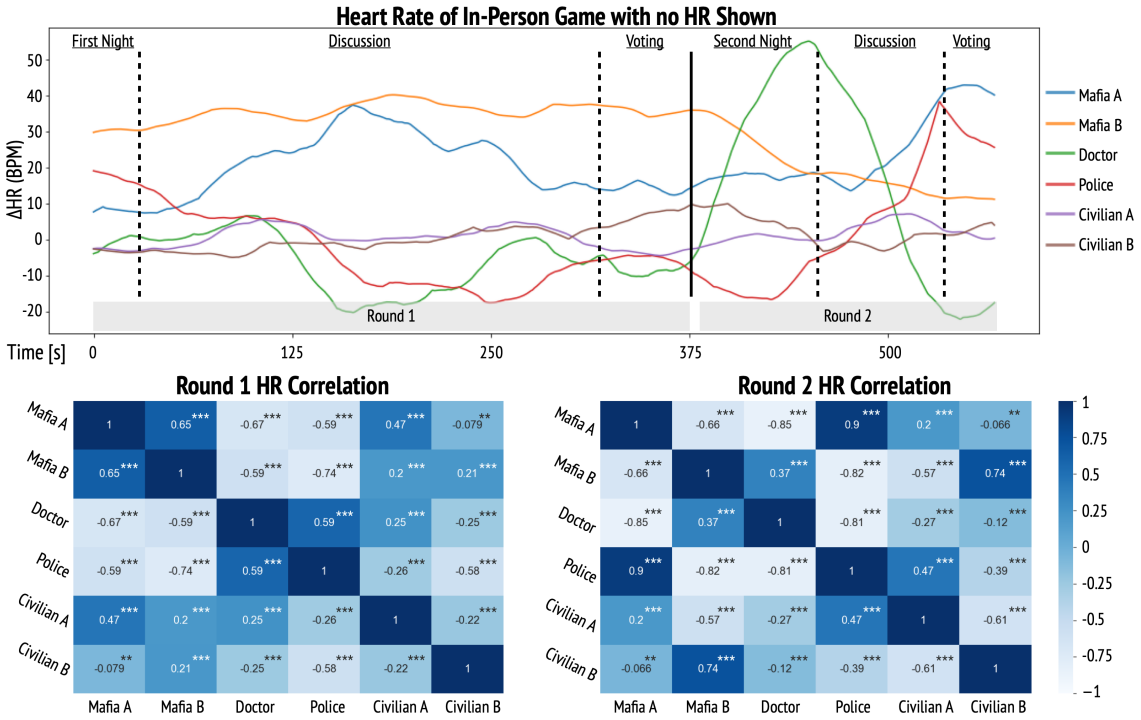

Figure 6: Top: Time-series graph of players' HR during an in-person game where signals were hidden. Bottom: Correlation matrices of players' HR during each round. *: p<.05, **: p<.01, ***: p<.001

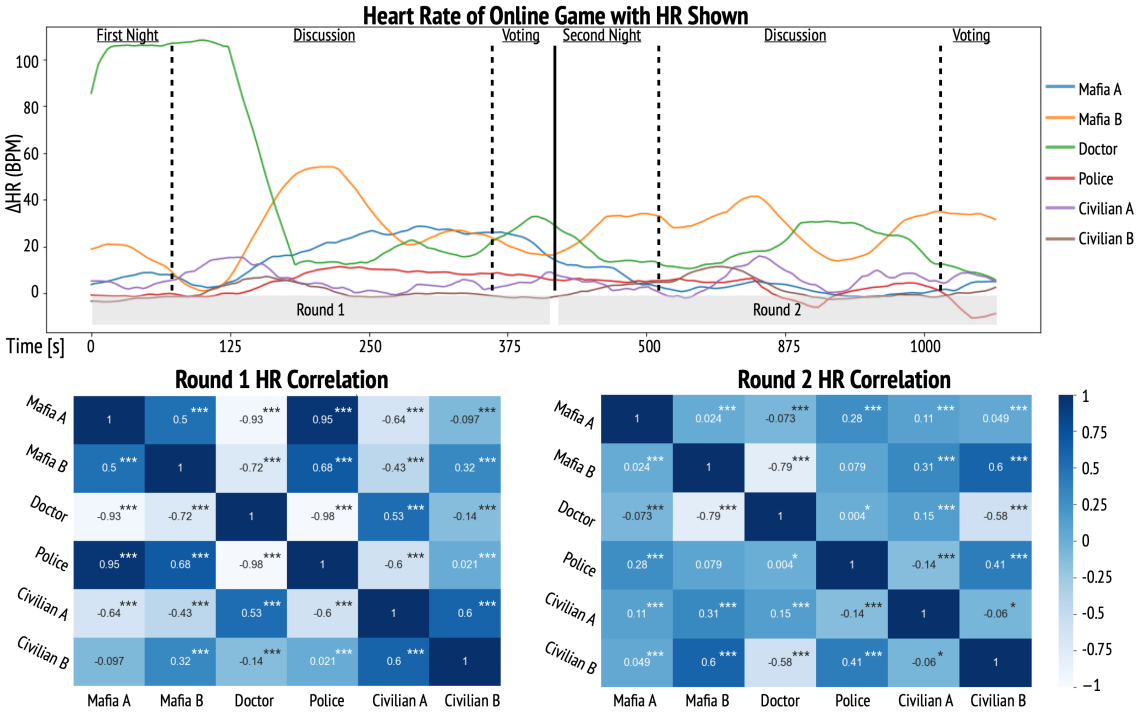

Figure 7: Top: Time-series graph of players' HR during an online game where signals were visible. Bottom: Correlation matrices of players' HR during each round. *: p<.05, **: p<.01, ***: p<.001

5 CONCLUSION AND FUTURE WORK

In this work, we investigated the effect of biosignals on players' gameplay strategy and physiological dynamics in the deception game Mafia. We recognize that this is a pilot study with a relatively small N, but the trends suggest that further study is warranted on how biosignals influence gameplay decisions. Participants stated that seeing biosignals influenced their gameplay across online and in-person conditions, although it influenced online players more, possibly as a substitute for the in-person cues of nervousness a player may normally look for. Additionally, from our interviews, we know that players placed value on seeing HRs of other players and used that information to make critical gameplay decisions, such as voting a player out of the game and casting suspicions on others. For our analysis of HR synchrony, we also found moments of gameplay in which player HRs synchronize in their positive and negative trends, such as when a new round starts or a player is eliminated.

Future work can analyze how players interpret other signals, such as EDA, when making gameplay decisions in social deception games. Techniques like dynamic time warping could be used to further investigate both concurrent and lagged trends in physiological synchrony considering shifts in the temporal alignment. Moreover, we intentionally utilized a six-person game of Mafia in this study to have shorter games that could accommodate a smaller number of participants. However, Mafia is typically played with larger groups of players, and there are many variations with different kinds of special roles. It would be interesting to analyze biosignals in these larger groups where there is more room for players to speculate over many rounds. Additionally, other styles of games could be explored, especially in exclusively cooperative games where players compete against the game and not each other. Overall, this line of work suggests that the integration of biosignals into in-person and online games could add an extra layer of complexity that players enjoy utilizing in their gameplay decisions.

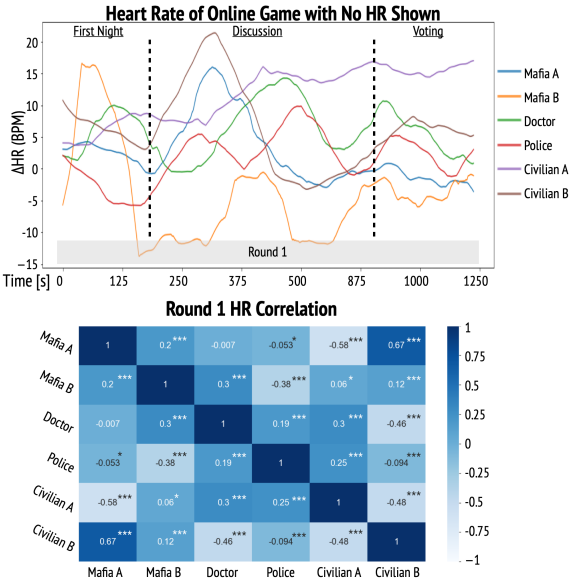

Figure 8: Left: Time-series graph of players' HR during an online game where signals were hidden. Right: Correlation matrices of players' HR during each round. *: p<.05, **: p<.01, ***: p<.001

ACKNOWLEDGMENTS

We want to thank our participants for their invaluable time. The study was approved by the MIT Committee on the Use of Humans as Experimental Subjects (COUHES) under the protocol number 2110000492 - Measuring Biosignals in In-person vs. Online Deception Games for Synchrony.

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