SynKin: A Game for Intentionally Synchronizing Biosignals

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Abstract

Inter-individual synchronization of motor activity, such as gestures, posture and speech rhythm during face-to-face interaction is a well-established phenomenon. Recent investigations have revealed that similar synchronization during interaction also occurs in brain activity and autonomous physiology. However, it is not known to what extent this synchronization emerges during computer-mediated interaction and whether its absence contributes to the widely acknowledged problems of online communication. We suggest that measuring the synchronization of biosignals is meaningful for assessing emotional capacity of computer-mediated communication systems, and intentionally increasing synchronization could improve understanding between people. As a proof-of-concept an interactive real-time system to quantify and visualize the synchronization of facial expressions, ECG, EEG and EDA of two players was piloted and results are presented in this paper.

Author Keywords

Biosignals; EEG; ECG; GSR; EDA; facial expression; synchronization; physiological computing

ACM Classification Keywords

H.5.3 [Information interfaces and presentation (e.g., HCI)]: Group and Organization Interfaces: Evaluation/methodology

Introduction

During interaction, individuals synchronize their body movements, gestures, and speech rhythm, often unintentionally [12, 13]. Studies have shown that the extent of motor synchronization between individuals is connected to ratings of affiliation [7, 16], and that individuals perform better in a task requiring joint action after synchronous, but not asynchronous, movement with another, e.g. rocking together in rocking chairs [16]. This suggests that synchronization may play a functional role in interaction, facilitating cooperative ability and a sense of connection. Along these lines, in a previous study, an ambient display was used to increase gestural synchronization and to amplify rapport [1].

Investigations in the relatively new field of two-brain neuroscience [10] have shown that inter-individual synchronization of brain rhythms occurs during interaction [4, 9] and increases as a result of cooperation, but not competition [3]. In addition to brain rhythms, synchronization of other biosignals, such as breathing and heart rate [17], also takes place during interaction.

Preliminary evidence suggests that coherence on the level of brain activity [15] is connected to better understanding. However, it is not known whether synchronization of brain rhythms or other psychophysiology is related to understanding and affiliation between individuals or success of interaction. It is possible that alongside synchronization of motor activity, also synchronization of psychophysiology has a meaningful role in the emergence of successful interaction.

In addition to face-to-face encounters, computer-mediated interaction is an increasingly important form of communication in society. Recent investigations have revealed that functional online cooperation requires empathy [6], but that empathy declines when individuals interact online in comparison to face-to-face situations [2]. One reason for this may be the problem proposed by the field of affective computing: digital systems are not designed to take emotional processes into consideration. As a result, digital interaction environments permit the transfer of text well, but not of emotion-related information which would be vital for understanding of the true intended meaning in communication as well as for the emergence of empathy [18]. Furthermore, it is not yet known whether inter-individual synchronization of movements or psychophysiology occurs during computer-mediated interaction. It is possible that a lack of synchronization contributes to the decline of empathy witnessed online.

Measurement of psychophysiological responses is one way to accumulate and possibly make available emotion-related information about the counterparts of interaction. Greater availability of this information during interaction would help overcome the current limitations of digital environments. Several projects have explored this possibility before, and especially heart beat has been used successfully in creating feelings of togetherness and social presence [14]. Assessing the effectiveness of physiological displays in communication has previously been done by questionnaires and behavioral observation, and simply hearing a pre-recorded heartbeat, believing it to be of a partner in a virtual environment affects both ratings of intimacy and the behavior of participants [8].

Our solution

We propose that to assess and design advanced computer-mediated communication systems, psychophysiological synchronization between interacting individuals is a meaningful measurement and optimization target. Additionally, building systems that attempt to drive users into a synchronized state could prove useful for better inter-individual understanding and collaboration both online and offline.

Figure 1: Setting up the electrodes for a participant. Photo by Valeria Gasik.

Figure 2: The setup with two participants sitting in rocking chairs facing each other and a display in the background. Photo by Valeria Gasik.

We decided to use several emotionally relevant psychophysiological measures to gauge the emotional state of our users. Instead of trying to extract one single emotion from each user, we used similarity metrics for each measure independently to assess the total amount of synchrony in the users' emotional states, while they were interacting with each other.

To this end, we created a two-person system that allows the parallel measurement of brain activity with electroencephalogram (EEG), heart rate with electrocardiogram (ECG), electrodermal activity (EDA) as well as the detection of emotions from facial expressions. We decided to measure EEG, ECG and EDA as these are some of the most emotionally relevant electrophysiological signals that can be measured with electrodes placed on parts of participants bodies that are easily accessible while wearing normal clothing [11]. Capturing basic emotions with the help of a camera and a computer vision algorithm provided an easy way to obtain information about the basic emotional states expressed by the faces of individuals [5].

The system was presented in the form of a two-player game where the participants were shown a visualization of their physiological signals and the conclusions that could be made on their affective states based on the raw signals. The participants were instructed to synchronize their psychophysiological states and an index of this synchronization was calculated and visualized. Briefing of participants included information that rocking together in the same rhythm, looking each other in the eyes and listening to music together (headphones and music were provided on request) could increase their synchronization.

Methods

EEG was measured with the OpenBCI 32-bit system using two passive gold-plated cup electrodes approximately positioned in the Fp3 and Fp4 positions according to the international 10-20 electrode positioning system. The left and right mastoids were used for ground and reference electrodes. All the electrodes were attached to the skin using conductive electrode paste. The radio receivers for the OpenBCI devices for both participants were connected to one computer, which was used to process the raw EEG data and send it over a local network to the host computer. Alpha power was obtained for each electrode by applying a short-time Fourier transform and summing the 8-13 Hz frequency bands. The total alpha activity was then extracted by taking the mean value for both electrodes. EEG lateralization was extracted from the difference in alpha power between the two electrodes.

ECG and EDA were measured with a device fully designed and implemented by the second author. The analog front end of the hardware consisted of two bio amplifiers matched to work together in a challenging environment (including external noise and quick preparations). Two adhesive and disposable electrodes were used to measure ECG on the arms of the player. EDA was measured with two Ag/AgCl electrodes attached on the first phalanx of the index finger and the middle finger of the non-dominant hand with velcro bands. The digitizing of the analog signals were done with 16 bit resolution and with a sampling rate of 80 Hz. Two of the described devices were configured wirelessly onto a local network and the analyzed inter-beat interval data for ECG and the raw data for both ECG and EDA were sent to the host computer for further processing.

For analyzing facial expressions for each participant, a Raspberry Pi 3 fitted with Raspberry Pi Camera Module V2 was used. Pictures were taken with a 0.5 second interval, and sent to the Microsoft Cognitive Services Emotion API as HTTP requests. The Emotion API returned coordinates for each face in the picture, as well as emotional ratings on 7 axes: happiness, sadness, surprise, anger, fear, contempt, disgust and neutral. The original image was cropped to only include the largest, i.e. the nearest face to the camera. The cropped image and the emotional ratings for this particular face were sent over a local network to to the host computer.

Emotion	Mood
Anger	0
Disgust	0.15
Contempt	0.3
Fear	0.45
Sadness	0.6
Surprise	0.8
Happiness	1

Table 1: Basic emotions were translated into mood-values according to the mapping described in this table.

Physical setup

The installation consisted of two rocking chairs facing each other and equipped with electrophysiological sensors (Figures 1 and 2). Cameras were hung from the ceiling and pointed towards the chairs. All the other measurement devices were embedded to the back of the rocking chairs, and electrodes could be replaced between measurements. All the analyzed data variables were referenced to short 30 seconds – 1 minute windows during the installation. Due to these design decisions, the setup allowed for quick preparations of the electrodes and only a very short calibration was needed in order to start playing. Two or three game hosts were present throughout the installation period to apply and remove electrodes and to restart the game for participants.

On one side of the chairs, approximately three meters away a 50" wide screen display was installed so onlookers and participants could follow the game. The host computer received data from the EEG sensors, ECG and EDA measurement devices and the facial cameras as described in the previous section. The host computer was connected to the display and was used to further process and visualize the data.

Game and visualization

The display was divided into three sections. The red and blue players' data visualization were placed according to the players' physical position, on the left and right sides of the screen. Information about the synchronization score and variables was placed in the middle. The interface is shown in Figure 3.

Player data visualization was divided into two sections. The top part included a cropped picture of the player's face and bar graphs to represent the amount of basic emotions detected in the facial expressions of the player. The bottom part contained the raw electrophysiological data for EEG, ECG and EDA, visualized unconventionally as top-to-bottom scrolling time series.

The resulting data for each player was visualized as an evolving hexagon, where each corner would move between the center of the shape (0%) and the edge (100%). The two hexagons, red and green, were overlaid on top of each other, so that the overlapping area represented the total synchronization between players. Each corner of the hexagon represented a distinct variable:

Pulse – Heart rate extracted from the ECG signal, normalized between 40 and 120 beats per minute.

Arousal – EDA level normalized to the minimum and maximum values of the signal within the last 30 seconds.

Activation – Inter-beat interval normalized to the minimum and maximum values of the last 10 intervals.

Mood – A smoothed value extracted from the facially expressed basic emotions based on the most prominent emotion and mapped to an emotional valence based value according to Table 1.

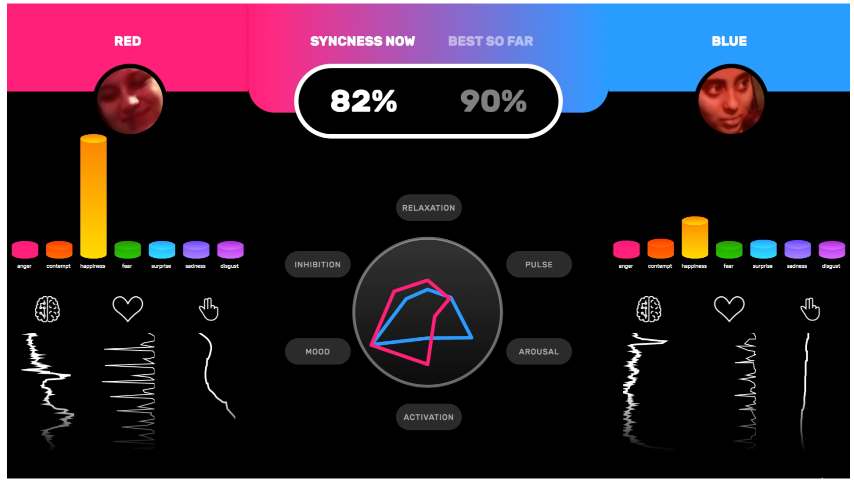

Figure 3: The interface was divided into three sections, one for each player and a middle section to visualize the amount of synchronization.

Inhibition – Lateralization value extracted from the EEG signal, normalized to +/- two standard deviations of the signal values within the last 60 seconds.

Relaxation – Total alpha value extracted from the EEG signal, normalized to +/- two standard deviations of the signal values within the last 60 seconds.

The *Synchness* score was generated by taking the average of the distance between these six values for the participants. The score was also smoothed, so that participants needed to remain in a synchronized state to be able to increase their score.

Results

The game was initially presented at Slush conference[1] to showcase the measurement devices and the understanding of players' psychological states that could be gained based on biosignal measurement. Because the game was not intended for data collection, but more for proof-of-concept and to serve as a discussion opener, data was not collected during the installation. The game hosts estimate that approximately 80 individuals took part in the game during the two days.

While biosignal recording units can be relatively cheap and portable, the meaningful analysis and usage of these signals are often hard for practitioners. During the conference, a significant amount of interest was given towards using subconscious data both in evaluating and building products.

[1] Slush 2016, Nov 30 – Dec 1, Helsinki, Finland.

Especially game developers and people working within mental health approached the game hosts enthusiastically about integrating biosignals in their products.

Feedback from participants was overwhelmingly positive, with the most enthusiastic players trying for 30 minutes to break the high score. Several spectators and participants started to spontaneously call the installation the *"Friendship Game"*. Towards the end of the conference such a long line had formed that not everyone was able to try the system.

Future Development

One line of development will focus on possible uses of biosignal synchronization in real-life cooperative situations. Our ongoing lab experiments are focusing on the relation between inter-brain synchronization and success of joint learning. In the case that biosignal synchronization is related to the quality of cooperation, encouraging it with the help of visualization e.g. in virtual team work environments can be beneficial. Additionally, synchronization could then be used to evaluate the quality of cooperative virtual environments.

Psychophysiological signals such as measures of the autonomic nervous system are very sensitive to environmental properties, which is one reason why their usage outside of the laboratory and in naturalistic situations is difficult. Measuring synchronization of biosignals and behavioral measures instead of individual absolute/relative values circumvents the biggest problem in experimental designs targeting real-life applications. In a synchronization setting every change in the environment affects both persons, and the synchronicity measures remain relatively unaffected. This idea will be developed further in order to design more complex scientific experiments in natural settings, and applicability to our other methods, such as magnetoencephalography, functional imaging, and transcranial magnetic stimulation will be investigated.

References

[1] M. Balaam, G. Fitzpatrick, J. Good, and E. Harris. 2011. Enhancing Interactional Synchrony with an Ambient Display. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11)*. ACM, New York, NY, USA, 867–876.

[2] L.M. Carrier, A. Spradlin, J.P. Bunce, and L.D. Rosen. 2015. Virtual empathy: Positive and negative impacts of going online upon empathy in young adults. *Computers in Human Behavior* (2015).

[3] X. Cui, D.M. Bryant, and A.L. Reiss. 2012. NIRS-based hyperscanning reveals increased interpersonal coherence in superior frontal cortex during cooperation. *NeuroImage* 59, 3 (2012), 2430–2437.

[4] G. Dumas, J. Nadel, R. Soussignan, J. Martinerie, and L. Garnero. 2010. Inter-Brain Synchronization during Social Interaction. *PLoS ONE* 5, 8 (aug 2010), e12166.

[5] P. Ekman and H. Oster. 1979. Facial expressions of emotion. *Annual review of psychology* (1979).

[6] D. Engel, A.W. Woolley, L.X. Jing, and C.F. Chabris. 2014. Reading the mind in the eyes or reading between the lines? Theory of mind predicts collective intelligence equally well online and face-to-face. *PloS ONE* (2014).

[7] M.J. Hove and J.L. Risen. 2009. It's all in the timing: Interpersonal synchrony increases affiliation. *Social Cognition* (2009).

[8] J.H. Janssen, J.N. Bailenson, W.A. IJsselsteijn, and J.H.D.M. Westerink. 2010. Intimate heartbeats: Opportunities for affective communication technology. *IEEE Transactions on Affective Computing* 1, 2 (2010), 72–80.

[9] M. Kawasaki, Y. Yamada, Y. Ushiku, E. Miyauchi, and Y. Yamaguchi. 2013. Inter-brain synchronization during coordination of speech rhythm in human-to-human social interaction. *Scientific Reports* 3 (apr 2013), 849–850.

[10] I. Konvalinka and A. Roepstorff. 2012. The two-brain approach: how can mutually interacting brains teach us something about social interaction? *Frontiers in Human Neuroscience* 6 (2012), 215.

[11] S.D. Kreibig, G. Schaefer, and T. Brosch. 2010. Psychophysiological response patterning in emotion: Implications for affective computing. *A blueprint for affective computing* (2010), 105–130.

[12] Z. Néda, E. Ravasz, Y. Brechet, T. Vicsek, and A.-L. Barabási. 2000. Self-organizing processes: The sound of many hands clapping. *Nature* 403, 6772 (feb 2000), 849–850.

[13] M.J. Richardson and K.L. Marsh. 2005. Effects of visual and verbal interaction on unintentional interpersonal coordination. *Journal of Experimental Psychology* (2005).

[14] P. Slovák, J. Janssen, and G. Fitzpatrick. 2012. Understanding heart rate sharing: towards unpacking physiosocial space. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '12)*. ACM, 859–868.

[15] G.J. Stephens, L.J. Silbert, and U. Hasson. 2010. Speaker-listener neural coupling underlies successful communication. *Proceedings of the National Academy of Sciences of the United States of America* 107, 32 (aug 2010), 14425–30.

[16] P. Valdesolo, J. Ouyang, and D. DeSteno. 2010. The rhythm of joint action: Synchrony promotes cooperative ability. *Journal of Experimental Social Psychology* 46, 4 (2010), 693–695.

[17] B. Vickhoff, H. Malmgren, R. Åström, G. Nyberg, S.-R. Ekström, M. Engwall, J Snygg, M. Nilsson, and R. Jörnsten. 2013. Music structure determines heart rate variability of singers. *Frontiers in Psychology* 4 (2013), 334.

[18] J. Zaki and K.N. Ochsner. 2012. The neuroscience of empathy: progress, pitfalls and promise. *Nature neuroscience* (2012).