Affective Computing for Game User Research

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This study examines the spatial and emotional experience facilitated by immersive gaming environments and detected by wearable technologies. We designed, implemented, and tested a serious board game involving simulating the urban networks of the trade routes of the past. We recorded the traces of the players' collective movements using a ceiling-mounted video camera to record the positions of the markers, and a video camera facing the players to record the players' behaviors. Wearable devices enabled the recording of players' emotions during their decision-making process. We captured their emotions with three tools: a GSR to capture participants' emotional state and arousal level, an EEG to record the changes in their brain activity; and a think-aloud protocol to understand their conscious decisions. Finally, we analyzed the gamers' measured "feelings" and compared these with the expressed feelings. The longer-term goal is to explore architectural design with special attention to feelings experienced within it by means of affective computing methods such as wearable technologies and biosensors, as well as gamification.

Keywords: *Wearable Sensors, Game User Research, Affective Computing, Decision-making, Digital Heritage, Gamification.*

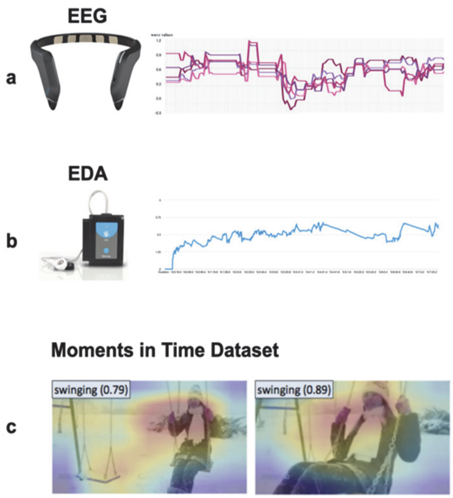


Figure 1
Affective computer data collection methods; (a) EEG (Electroencephalogram), (b) GSR (Galvanic Skin Response), (c) video capture devices and Moments in Time computer vision algorithm.

INTRODUCTION

Recent development in medical technology has brought affordable wearable sensors for monitoring the state of our body, including EEG (Electroencephalogram), and GSR (Galvanic Skin Response). Also, computer vision algorithms and data sets allow large datasets for recognizing and understanding actions in videos, and conventional game user research methods allow scientists to collect and analyze users' data (see figure 1). Through these technologies, conscious and unconscious behaviors and reactions can be collected and analyzed. This paper discusses whether, and if so, how these wearable sensors, computer vision algorithms, and user research methods can benefit architectural history, especially within the context of game environments. What are people's feelings in a particular game environment, and what features of its design cause these? How are rational and irrational decisions made? Is it possible to use games, not only as a learning tool for gamers, but as a way to learn from the gamers themselves?

This study examines the spatial and emotional experience facilitated by immersive gaming environments and detected by wearable technologies. This serious game employs gamers' collective intelligence to test the hypothesis of architectural history. We designed, implemented, and tested a serious board game involving simulating the urban networks of the trade routes of the past. Using real-life topography, we abstracted several layers of GIS data for the game board design. In the game environment, we simulated the movement of trade while the players, as agents, simulated the possible intercity networks (Varinlioglu et al, 2022b). Tracking their movements and behaviors allows us to collect user data for spatial analysis and user behavior. We record the traces of the players' collective movements: a ceiling-mounted video camera records the positions of the markers and a video camera facing the players records the players' behaviors. Wearable devices allows us to record players' emotions during their decision-making process. We record their emotions: using a GSR, we capture a participant's emotional state and arousal level; using an EEG, we trace the changes in brain activity; using a think-aloud protocol, we gain insight into their conscious decisions. Finally, we analyze measured "feelings" to compare with the actual feelings expressed by the gamers.

LITERATURE REVIEW

The study consists of research on three topics: affective computing, user experience, and immersive gaming environments of a board game on a digital heritage. It examines the spatial and emotional experiences facilitated by immersive gaming environments and through wearable technologies. We explore the serious gaming environment with special attention to the feelings it creates via affective computing methods such as wearable technologies and biosensors, as well as traditional psychological methods.

Physiological Game Evaluation using Affective Computing

All humans experience emotions. Ekman (1992) lists sadness, pleasure, fear, anger, disgust, and surprise as the six types of fundamental, innate, and culturally independent emotions. These categories are useful to understand emotions; however, while we are aware of the nature of emotions, it is extremely difficult to define them objectively and qualitatively (Ozkan and Oguz, 2021, p.1). Emotions are physical, emphasizing their bodily component, while also being cognitive, stressing their mental component. The leading indication of emotion is a sensation of physical changes, such as your heart beating faster or your hand perspiring (Picard, 2000, p.22). Additionally, there is mounting evidence that emotions can be distinguished by their physical characteristics (Picard, 2000, p.23). How can emotions be created, recognized, and expressed by computers? If a computer is attempting to identify or comprehend your emotion, it should be able to do so by analyzing your voice, your movements, and evaluating your current context (Picard, 2000, p.23). Also, is it important to determine whether it is possible to detect and quantify emotions through devices.

Affective computing is a field of study that focuses on developing systems and technologies that can detect, interpret, and respond to human emotions. EEG (electroencephalography) and GSR (galvanic skin response) are two of many physiological measures commonly used in affective computing research (see figure 1).

Galvanic Skin Response (GSR) or Electrodermal Activity (EDA)

Galvanic Skin Response (GSR), also known as Electrodermal Activity (EDA), is a gauge of the skin's passive electrical conductivity (Boucsein, 1992). It tracks the variations in skin conductance brought on by alterations in emotional arousal. The sympathetic nervous system's activation of the sweat glands in the skin in response to emotional arousal is the physiological process underlying GSR. It has been employed to examine emotional reactions in a variety of circumstances, including mental stress, anxiety, and emotional regulation. Overall, GSR is a helpful tool in numerous research projects, providing a non-intrusive and objective measure of emotional arousal. EDA measurements are associated with the fingers, palms, and toes, which are more likely to respond to parasympathetic nervous system (PNS) alterations (Nacke, 2015).

Electroencephalography (EEG)

Electrical patterns called brain waves can be detected on the scalp utilizing EEG. EEG has a millisecond temporal resolution, which makes it a highly precise method of measuring brain activity. However, it may present difficulties when analyzing signals from areas of the lower brain, such as the basal ganglia (Nacke, 2015). Gamma, beta, theta, and alpha are the four main categories of brain waves, and each is associated with various mental and emotional states. Beta waves are associated with being awake, attentive consciousness, thinking, and enthusiasm, and gamma waves, with enhanced perception, learning, and problem-solving activities. Theta waves are associated with diminished consciousness, deep states, dreams, creativity, insight, and deep meditation.

Both EEG and GSR can be used to develop affective computing systems that can detect emotional states in real time. These systems can be used in a variety of applications, such as improving human-computer interaction, developing emotion-aware technologies, and assisting with mental health diagnoses and treatments. In numerous contexts, it has been demonstrated that the psychological state of immersion, which is characterized by awareness, presence, and flow, improves learning and engagement. Furthermore, emotional and cognitive states can be indicated to a significant degree by bodily manifestations such as heart rate and skin conductivity. Also, an individuals' actions, facial expressions, and cognitive assessments can reveal their subjective experiences, and can be used to assess the success of interventions aimed at eliciting particular psychological states.

Non-physiological Game User Research

Game User Research (GUR) is an emerging field that ties together Human-Computer Interaction (HCI) and game development. Game user research commonly makes use of non-physiological research methods, such as the traditional methods of behavioral observation, think-aloud protocol, interviews, heuristic evaluation, focus groups, surveys and questionnaires, and game metrics. (Nacke, 2015). These traditional methods remain the industry standards, but more recent methods use combinations of user testing methods (Mirza-Babaei et al, 2013). Unfortunately, in game user research, emotions expressed in the consciousness of the user through interview and observation methods leads to ambiguity, as it is difficult for individuals to express mixed emotions unequivocally (Plutchik, 2001). The feeling of emotion or the psychological changes that accompany emotion is a fictitious problem. Emotion is complex, and can be seen as a series of events connected by feedback loops, and feelings and behavior can both influence behavior, and can both influence cognition, while cognition can also influence feelings (Plutchik, 2001). A valid data collection method is the verbal expression of the user through psychological tests conducted with the user's consent.

Behavioral Observation and Interviews

This method can range from basic, i.e., watching over players' shoulders while they are immersed in the experiment, or as sophisticated i.e., high-definition video recording of players from various angles in a natural gaming environment. Behavioral observation is straightforward and produces practical results and thus, is the most valuable GUR technique. The researcher should record observations but refrain from drawing hasty conclusions (Nacke, 2015). Interviews provide insights into the game from players' perspectives through qualitative subjective research. Interviews enable more in-depth examination of a player's viewpoints, feelings, and responses (Nacke, 2015).

Video Recordings

Video recording offers an unbiased and in-depth account of a user's experience while playing a game, and is a crucial tool for video game user research. Researchers can observe a participant's actions, facial expressions, and physiological reactions on camera, with data including heart rate and galvanic skin response, which can reveal important information about emotional states and levels of participation. Moreover, video recordings can help locate gameplay concerns like difficulty spikes or usability flaws, information which could aid developers in optimizing the game's design.

The automated analysis of recorded video data using computer vision algorithms is a recent advancement in video recording for game user research. One such method is the Moments in Time algorithm (Monfort et al, 2019), which employs computer vision techniques to pinpoint and examine significant gaming moments, such as those involving annoyance, engagement, or perplexity. Examining these moments can bring insight into the player's mental state and gameplay experience, and this information can be used to enhance the game design and user experience.

In conclusion, video recording is a crucial tool for gaming user research since it gives a thorough and unbiased assessment of a player's experience. Researchers can automate the study of video recordings by employing computer vision algorithms, giving them the opportunity to learn important details about the player's feelings, and gameplay experience. This can assist game designers in creating more captivating and engaging games.

Serious Game in Digital Heritage

Gamification has gained popularity as a way to preserve, display, depict, and spread cultural heritage. The systematic application of gamification in the field of cultural heritage interpretation seeks to elicit or trigger changes in people's attitudes, actions, and thoughts about cultural heritage, according to Karahan and Gul (2021). According to Aydin and Schnabel (2016), gaming acts not only as a vehicle for sharing knowledge about cultural legacy, but also as a platform for the creation of this legacy using modern media technologies. Serious games -games designed for educational objectives- in many areas including cultural heritage, are a new tool aiming to increase engagement with cultural content. It can be concluded that gamification is a useful instrument for preserving and sharing cultural legacy that has the capacity to positively influence people's attitudes, actions, and thoughts.

Context

In the light of previous studies on game users, this study used player interaction and the gamification of digital heritage as a research tool to address these challenges (Varinlioglu et al, 2022a). Gaming sheds new light on the topic of cultural heritage, and, particularly, uses players' collective intelligence to mimic the growth of ancient networks by utilizing players' decision-making abilities (Varinlioglu et al, 2022b). The study gathered user data for geographical analysis, game statistics, and user behaviors by tracking players' movements and behavior, and the position of markers using a ceiling-mounted video camera. The research shows how gamification has the potential to aid in the preservation and study of cultural heritage; in this case, the game's ultimate objective was to learn the gamers' strategies to find their path through visiting waypoints.

STUDY
The purpose of the study is to understand the impact of gamification on how people decide and perform in-game environments (see figure 2).

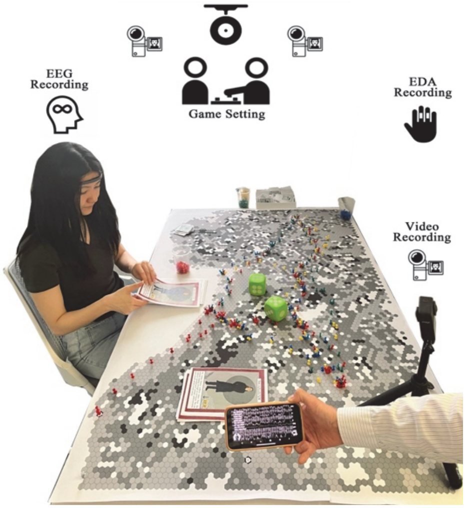


Figure 2
Game and experimental setup of one game session with two participants.

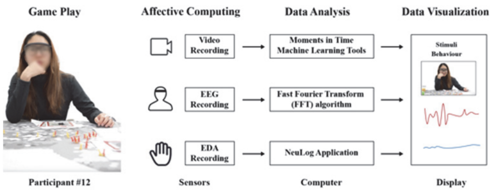


Figure 3
Tools and algorithms used in the analysis and the study pipeline.

Game Setup
This strategy game uses a board generated from the real topography and chance cards specifically designed to reflect the historical setup. The game also employs playing cards, divided into chance and trade cards, which are used to determine a player's movement and score. The chance cards may lead to a positive or negative outcome, leading the player either to proceed and gain money, expressed as trade cards, or to lose properties and move backward.

The game involves pathfinding through visiting waypoints to reach the main nodes. The aim is to score as many points as possible and return to the starting point as quickly as possible. The rules are designed to motivate players to visit as many waypoints as possible. Briefly, the game involves using pathfinding via waypoint visits to reach the main nodes, scoring as many points as possible and returning to the starting point as quickly as possible.

Experiment Setup
The experiment was designed to analyze the user experience of playing a board game collectively. The setup involves EEG and GSR readings, gesture analysis, and questionnaire with a think-aloud protocol. After gamers give their consent, the study coordinator provides an overview of the game, its features, and rules. Participants sit facing a camera with a microphone and wearable devices. They follow a protocol to neutralize their emotional state by watching a one-minute video.

The main activity of the experiment involves 20 minutes of game playing, which is recorded through video and audio. The participants' behavior and emotional state are also recorded through EEG and GSR devices. Participants are encouraged to play the game for the full period, but have the option to terminate the task at any point. After the game, participants answer survey questions or follow the think-aloud protocol with the coordinator, which may be audio or video recorded.

The experiment is conducted in six sessions, with two people in each 20 minute- session. The total time for the study is around 30-45 minutes. The study is conducted in an office setting. Participants are allowed to ask questions before and after the EEG and GSR devices are activated. The use of consent forms, questionnaires, and think-aloud protocols ensures that the experiment is both conducted ethically, and also accurately captures the user's feedback.

ANALYSIS
The study uses a Muse 2 as EEG device, NeuLog NUL-217 as GSR device, GoPro and mirrorless cameras for video recordings (see figure 3). The EEG signal from

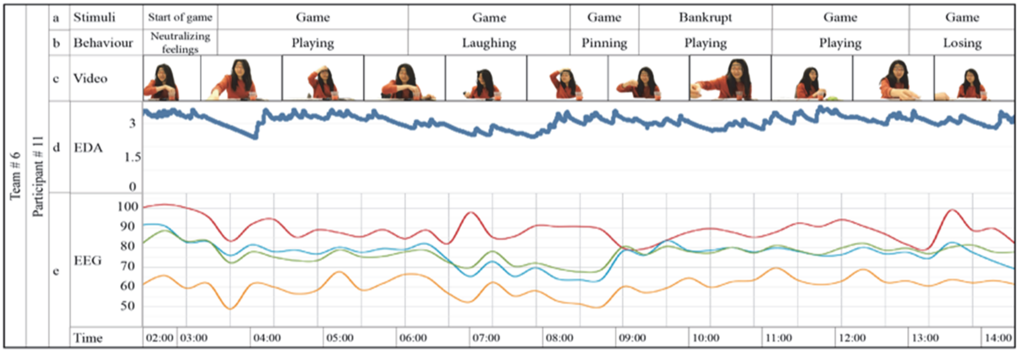


Figure 4
A sample dataset of two participants during a game session: (a) stimuli in the game environment; (b) gamer's behavior driven from the Moments in Time dataset; (c) video samples used in the Moments in Time dataset; (d) the GSR graphs displaying the galvanic skin response; (e) EEG graphs displaying the delta channel of the brain waves.

the Muse 2 headset is recorded using the Muse Monitor mobile app. The absolute signal undergoes a Fast Fourier Transform (FFT) algorithm in Muse to compute the power spectral density of each frequency range (i.e., for Alpha channel 9-13 Hz) on each channel. Basically, the signal from each channel shows the amount of each frequency present in a one-second interval. The raw data are given on a log scale, in units of Bels, for further analysis.

The signal is cleaned in terms of the number of non-informative elements and errors (e.g., missing data, non-numeric values, poor signal quality obtained from a particular electrode, eye blinks and jaw clenches annotation data, dropped samples, etc.). Then, we visualize the absolute band power of the five oscillations for each participant, for later comparisons.

The EDA signal from NeuLog NUL-217 GSR sensor was collected from each participant. Sudden talk, game stimuli, decision-making, and sounds are among the factors that trigger these conductivity-changing emotions. The sensor measures the conductivity of the skin, especially between the fingers; the skin response time from the sudden effect is between 0.1 to 0.8 seconds. The level of the response changes dramatically across individuals--to measure this, users must place their hand on a table, chair, or lap and keep completely still.

We use cameras to record the stimuli, behaviors, and facial expressions that users receive during the game. The users' behavior was analyzed by the pre-trained machine learning model, Moments in time (Monfort et al., 2019). Finally, the stimuli, behaviors, EEG data, and GSR data received by the user are visualized simultaneously (Figure 4).

RESULTS

The game included 12 participants, divided into six teams of two for the game sessions. Due to the malfunctioning of the devices, the data from four participants in two sessions were excluded from the results. During the analysis phase, we synched EEG and GSR data of 8 participants in 4 sessions with the camera recording to be used for computer vision analysis using Moments in Time datasets (see figure 5).

The initial results of the study displayed a rise in the stimuli of all players during the course of the first 15 minutes of graphs; this was EEG and GSR graphs, some parallel results, especially the average of Delta brainwave, the red one, (1-4Hz) of channel TP9, AF7, AF8, and TP10 in the EEG. This Delta channel data indicates the unconscious mind and occurs in deep sleep, revealing any feelings of boredom during the gameplay.

EDA floats up in the last half as displayed in the graph in blue. For example, Participant #1's EDA floats up after observing her opponent obtain a chance card. This shows that in the second half of the game, this player is very focused to avoid loss of

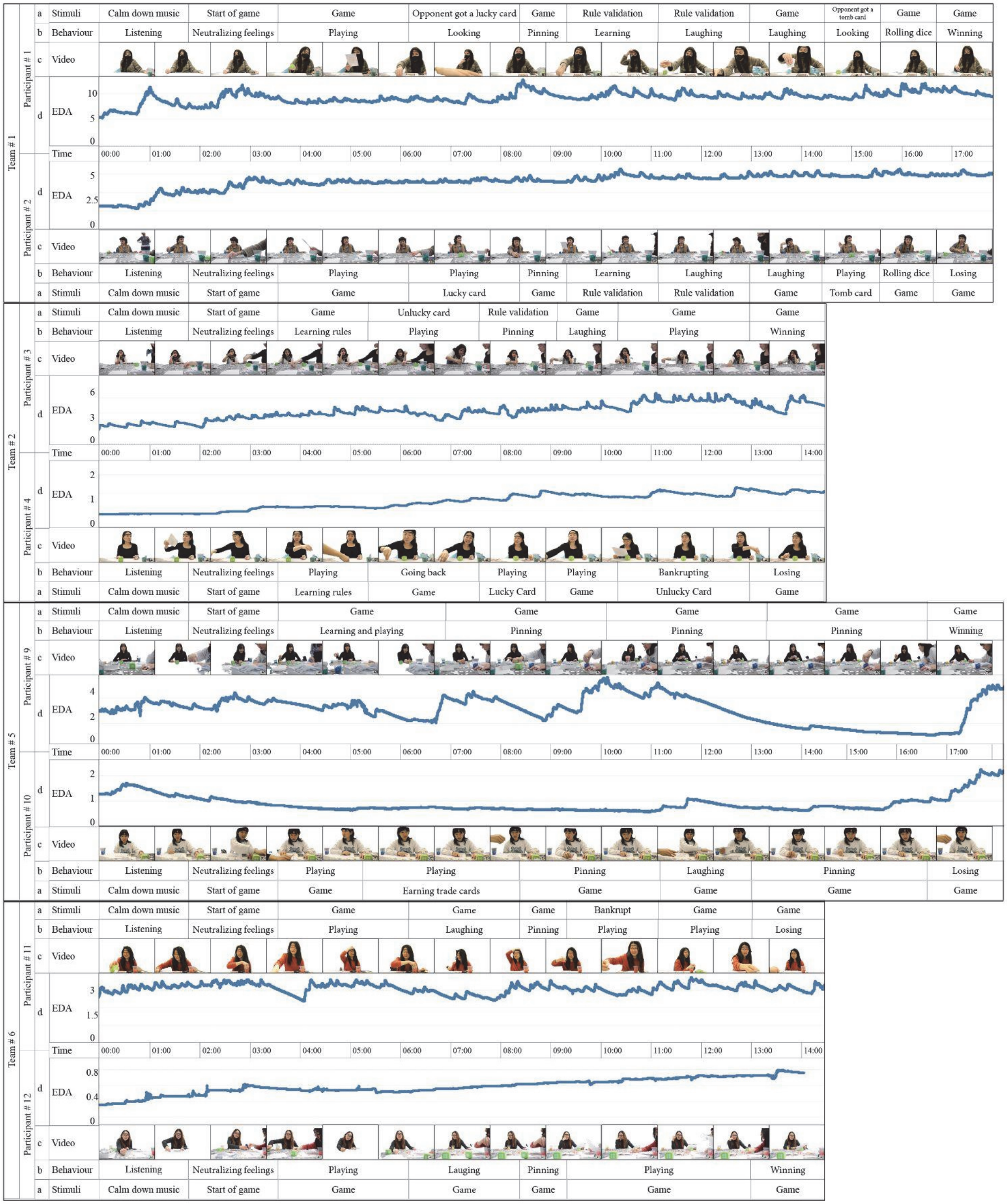


Figure 5
GSR data correlated with the video captures and behaviors of 8 game participants in teams of 2.

concentration. Most players rise in the middle and second half of the GSR, after becoming familiar with the rules, and during the important decision-making process.

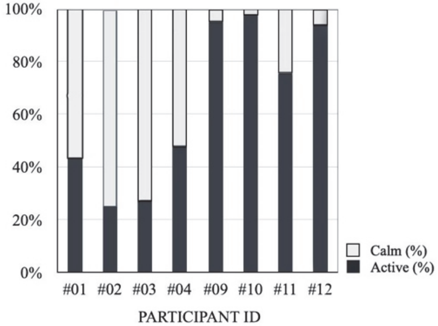
The delta wave of the EEG has the same pattern as the GSR. For all bands, the brain waves for each group were consistent or antagonistic. For each group of players, the winner's red goes up as victory nears victory or down as defeat nears. For example, player 11's EEG and EDA are the opposite. Specifically, after she gets a negative card, EDA rises and EEG delta falls rapidly.

The Moments of Time uses a 4-second interval to run its algorithm and compare with their datasets. After synchronizing with EEG and GSR data, our results show that a 4-second interval was not accurately displaying the behavior of the participants. We therefore used other analysis methods, such as our observations, to analyze the types of stimuli received. For example, a participant received a positive chance card, resulting in a change in their behaviors, which presented some ups and downs in the graphs of specific EDA and EEG. Their physical movements, such as laughing and talking, created noise in the data.

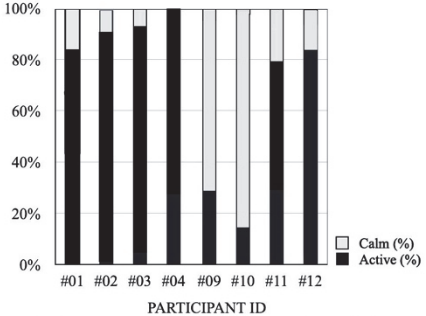
The end results demonstrated that the gameplay had an emotional impact on the participants' decision-making. The chance cards were crucial to this process. However, as the game progressed, the individuals' stimulus increased as demonstrated by the GSR and EEG data. This may have been a result of either group decision-making or general game design. Although generally encouraging, the experiment study's findings regarding the application of affective computing technologies and psychological analytic techniques were not entirely accurate (see figure 6).

CONCLUSION

The purpose of the study is to understand the impact of gamification on how people decide and perform in-game environments. To understand the factors underlying this decision process, the users' and gamers' physical and psychological reactions were examined. The study targeted three outcomes. The first was the exploration of affective computing tools in a serious game environment specifically designed for an architectural heritage research project. The second was to test the efficiency of these devices and their limits and constraints, as well as their potential, in a game environment. The final one was to understand the efficiency of this game as a learning tool, as well as a way to learn from the gamers themselves.



Active and clean label of participants' EEG data.



Active and clean label of participants' EDA data.

Figure 6
Active and clean label of participants' EEG and GSR data.

In the future, we will integrate eye tracking, similar to that employed by Sussman (2021) in her research on urban and architectural setup. In the subsequent stage, we aim to use VR to create a game environment in which the game stimulus is more controllable. More research may be done on how well various EEG frequencies and channels perform in measuring game player emotions. We should also note that we are aware of the limitations of consumer products, and the need for advanced products for better accuracy and precision, leading to more detailed results and analysis.

The long-term objective is to investigate architectural design, with a particular focus on feelings experienced inside the architectural environments using affective computing techniques including gamification, wearable technology, and biosensors. We suggest one possible use case: if a future machine has the capacity to analyze space as humans do, it might be able to play a role in assessing the generated design spaces. This will also open doors to discuss whether, and if so, how these wearable sensors are useful for design research, especially within the context of AI applications, in terms of analyzing and generating human-centered spatial designs. Over the past decade, design science using AI for architecture has made advances in various generative algorithms and optimization techniques. Numerous architectural studies predating the age of computers and emerging psychological research were able to use contemporary sensors. However, even with advances, it is still challenging to provide a data-driven evaluation of humans' senses in the generated space, as well as their feelings when occupying them.

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