Skin Conductance as an *In Situ* Marker for the Degree of Concentration in a First Person Shooting Training Game: Some Preliminary Findings

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ABSTRACT

It is known that varying degrees of concentration could lead to the change of body property such as skin conductance level. Through our experiments in the present study, assuming concentration related to skin conductance level, we use skin conductance variety detected using a compact and wearable galvanic skin response (GSR) sensor to investigate the possible link between the degree of concentration and the level of skin conductance for college students involving one of the most favored daily activities—game playing. In our experiment, four adults (four men) completed a specific mode of web-based game requiring a certain degree of concentration. Mixed results had been obtained. Preliminary results revealed that when players are concentrated (exhibited by relatively low level of skin conductance value), their performance tends to be better. Our results also showed that such pattern might vary as a function of both internal and external factors; no conclusive results can be obtained on whether skin conductance can be used a reliable *in situ* marker for the degree of concentration. Despite these, our study serves as a preliminary yet promising one down the research path.

CCS Concepts

• **Human-centered computing → Field studies**

Keywords

Galvanic Skin Response; electrical conductance of the skin; Concentration; Aimbooster

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1. INTRODUCTION

GSR, or galvanic skin response, is the property of the human body that causes continuous variation in the electrical characteristics of the skin and these continuous variations could be detected and recorded by GSR sensor [10]. Previous studies revealed that skin resistance varies with the changes of the sweat glands in the skin and sweating, which is regarded as the indication of psychological or physiological arousal controlled by the sympathetic nervous system [6, 12]. Therefore, when an individual's emotional changes, the sweat gland activity would increase which in turn triggers the increasing value in skin conductance. As such, emotion variations and fluctuations could be detected and recorded by measuring skin conductance using GSR sensor [4, 7, 8].

Concentration, on the other hand, an attentional process that involves the ability to focus on the task at hand, can also be defined as the ability of ignoring distractions [13]. Previous studies suggest that the calm an individual is, the relatively lower level of skin conductance exhibits [13, 20]. While an overwhelming number of previous works focused on examining and characterizing emotion fluctuations via GSR (among many, some recent ones including [5, 14, 17, 18], relatively fewer focus on establishing the link between skin conductance level and the degree of concentration, especially the challenges brought by the use of such technology of employing devices on individuals when they are involved in daily activities [3]. However, thanks to the recent technological advances, wearable and compact sensors have gained much attention and success in obtaining reliable data in the study of psychological states and processes [3].

Driven by these previous works, in the present study, we intend to investigate the possible link between skin conductance level and the degree of contraction for individuals involving in daily activities---game-playing. The present study intends to investigate the role of skin conductance level in the degree of concentration. To this end, a web-based game called Aimbooster (http://www.aimbooster.com/), which used to train professional first-person shooting games players is adopted to help testers concentrate. The game would record the accuracy, targets hits, the maximum of the targets per second in the settled time period. By analyzing the graph of target hits per second with the time provided

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by Aimbooster, a relative degree of concentration of the player would be generated. The quantitative analysis was based on the understanding of the relationship of degree of concentration and the varying skin conductance level. Besides, GetData Graph Digitizer (http://getdata-graph-digitizer.com/) and SPSS were applied to scan the graph in order to obtain the numerical data and SPSS statistics was also used to further analyze the numerical data obtained and quarry the correlation between them. Meanwhile, feature scaling was applied to standardize the numerical data to further examine the quantitative relationship in the data, although obtained results did not reveal any significant patterns.

The organization of this paper is as follows. In the next section, we will present some previous works to inspire readers of our study. In Section 3, we describe our study setup and preparation, followed by study results and analysis. In Section 5, we showed the limitations of our study. We conclude this paper in section 6.

2. RELATED WORK

Aggag and Revett [1] revealed that player's performance can be influenced by the affective state of the players. It introduces and analyzed a basic study on whether GSR can be utilized to collect information on the affective state of players when they are playing a first-person shooter (FPS) game. In order to research the latent relationship, Ahmed and Kenneth make use of GSR to obtain the affective state of the players [1].

Yoon et al [19] introduced a new and lightweight device to monitor the psychological stress level of both patients and non-patients. Multimodal physiological data analysis was adopted. What's more, the special lightweight and customized design allows the the patch simple, tiny, and comfortable, which thus made it more comfortable for wearing [19]. The experiment results showed that external temperature was not the dominant factor. [16] built a stress sensor based on GSR and controlled by Zigbee to detect the different state of stress. Relaxed and stress state will be generated after comparing the threshold and the input data. Different tests were conducted to verify the behavior of the GSR sensor and a cross-validation method was used to evaluate the different results.

In [9], an overall wearable sensor layout is built to establish a GSR emotion predicting system which can analysis state transition. Meanwhile, this system can help researchers find out the correlation between GSR signals and emotions [9].

While more overwhelming number of previous works also focused on examining and characterizing emotion fluctuations via GSR among many, some recent ones including [5, 14, 17, 18], fewer examined some physiological states which might trigger emotion (i.e. physiological precursors) including concentration and attention which motivates the present study. In particular, in this study, we described our small-scale study to examine the latent association between the levels of concentration and galvanic skin response, in the context of a first-person-shooting game.

3. STUDY DESIGN

3.1 The Study Environment

A web-based flash game, Aimbooster, which allows users to test their mouse click speed and positioning accuracy is chosen due to its inherent simple design, which provides a light yet stable study environment (see Figure 1). When the game starts, the user's accuracy and speed will be displayed in the top of webpage. Many First Person Shooting Game (FPS) had been adopted as a training tool. It allowed customized settings, such as target behaviors, grid, gimmicks and so on, for specific scenarios. Certainly, it provides eight designated modes of training which also drives us to choose it as our testing environment.

3.2 The Apparatus

A highly affordable GSR sensor from Grove[2] was used in our study due to its wider availability in China. It is not a medical device and includes finger straps for electrodes to detect the conductance of skin.

3.3 The Study Design and Preparation

Eight undergraduate students (four male and four female) were selected to be the experiment volunteers. All of them are from computer science major, so the experimenters have highly computer-related background.

The "auto balanced" mode of Aimbooster was used to trigger players' degree of concentration (Figure 1 displays the autobalaced mode). The experiment used a within-subject design. The independent variables were the degree of concentration (measured by the data from the wearable GSR sensor). The "autoblanced" mode with target size 70px, grid size 600*420px are chosen as the defaulting setting; we only changed it to one-minute per game in advanced setting of that mode. Also, we allowed players to choose their favorite DPI (Dot per inch) of mouse; in additions, 500/1000/1500/2000/3000/4000 are also available. DPI was not limited and player can choose their favorite one so that their degree of concentration can be less influenced by irrelevant variables.

In the initial testing, the GSR sensor was wore on the index and middle finger on the dominant hand, but later on, we find out that the connecting line of GSR sensor is clumsy and easy to broken since users need to make quick actions. Therefore, the GSR sensor was later put on the non-dominant hand during the experiment. For each time, after a player wear the GSR sensor, a ten-second relaxing window (for the player to calm down or adjust to the wearing of the sensor) is applied to prevent from initial data fluctuation which might affect data accuracy. After it, the player is required to play the game for one minute. After finishing the game, the player is given another 30 seconds' relaxing and adjusting time. In total, all players play three times. Figure 2 shows the actual playing scenario.

[2] https://www.seeedstudio.com/Grove-GSR-sensor-p-1614.html

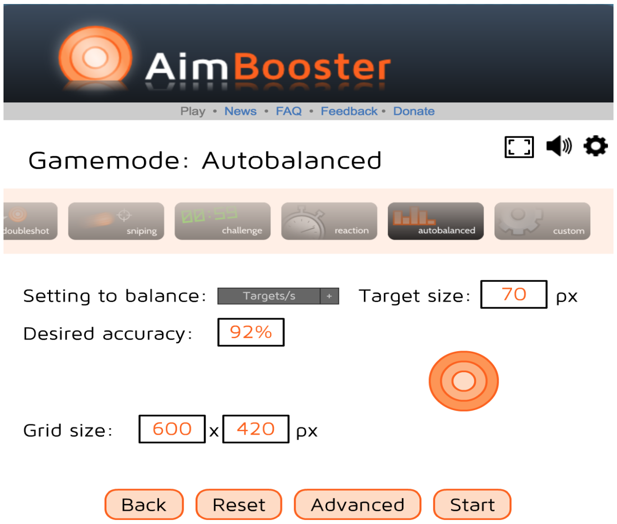


Figure 1. Aimbooster Configuration

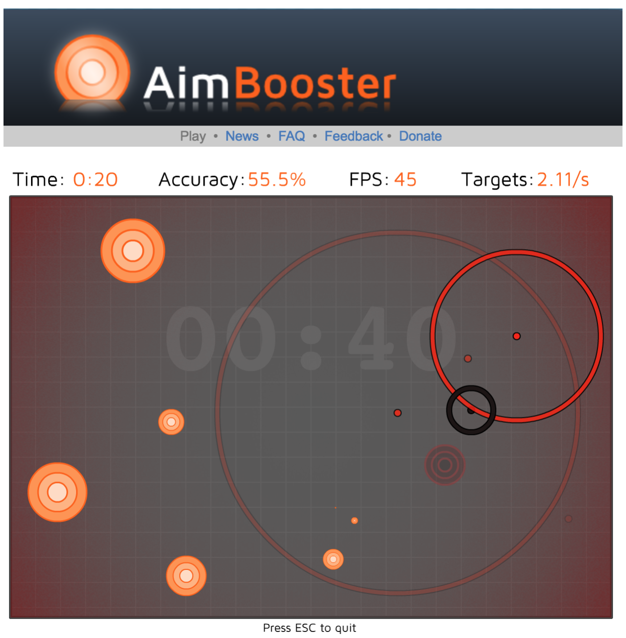


Figure 2. The Game Screenshot (Aimbooster)

3.4 *Evaluation Protocol*

Data were collected from two resources, one was from aimbooster in-game data, another one was from the wearable GSR sensor. We collected the accuracy, targets hit (per second), maximum target moving speed (per second) and average target per second from the aimbooster game data as indicators of players' performance. The game generated the average target change in time line chart automatically. As for the data from GSR sensor, after we obtained the raw data, we reported the mean of it for simplicity without comprising our study. Figure 3 captured one of the testing moments when the player was wearing the GSR sensor while playing the game.

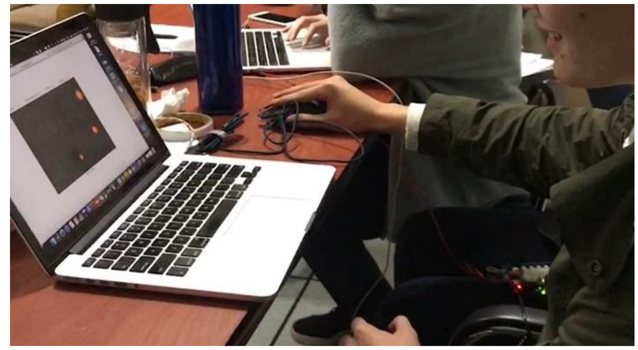


Figure 3. One of the Testing Moments

4. STUDY RESULTS AND ANALYSIS

4.1 *Data Preprocessing*

We have conducted three continuous tests in order to study the linear relationship between continuous working with high concentration. And we invited 4 male players and 4 female players to help us to complete experiment.

According to our experiment setup, each player engaged in the game for 60 seconds and the GSR record time limitation was 100 seconds. What's more, we first wore on the GSR sensor for 30 seconds to make sure the GSR recorder was stable then started the 60-second experiment. In addition, 30 seconds were set between each experiment to avoid the delay of the record and make adjustment. Taken together, the corresponding part of the experiment time from 30s to 90s on the GSR Data Collection chart was from unit 200 to 1400. Our data analysis and visualization had been based on the retrieval data during these time slots.

Since the original numerical data from the game cannot be obtained directly, we utilized GetData graph digitizer digitize scanned graphs and obtain the original coordinates by setting the data for every second interval in the line chart graph. And there are about 60 datasets which are akin to the amount of target hit per game. In that case, the 60 datasets are corresponding to the max target per second in this 60-second game time. In order to be consistent with the 60-second time frame for data analysis, we cut out the 200-1400 area from the GSR Data Collection chart. Therefore, there are a total of 1200 units which are corresponding to the 60-second game time. Then we calculate the data that average of 20 units GSR collection data from 200-1400 (1 second will produce 20 GSR data output.) Finally, we processed all players' GSR output and max target per second into one figure respectively.

Figures 3 to 6 show GSR data and the corresponding average target change (line chart) generated by the game.

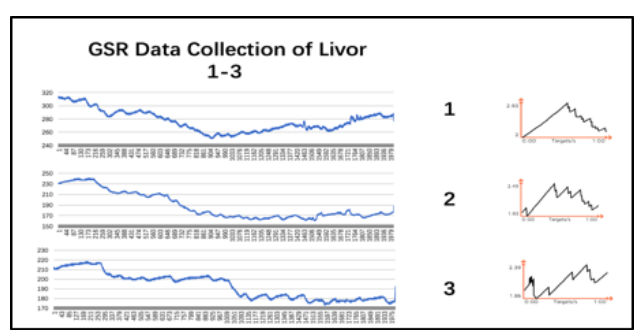
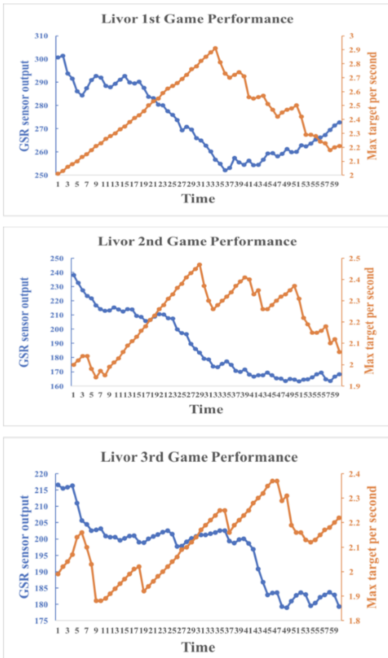


Figure 4. GSR Data Collection Chart 1-3 & Average Target Change in Time Chart 1-3 of player Livor



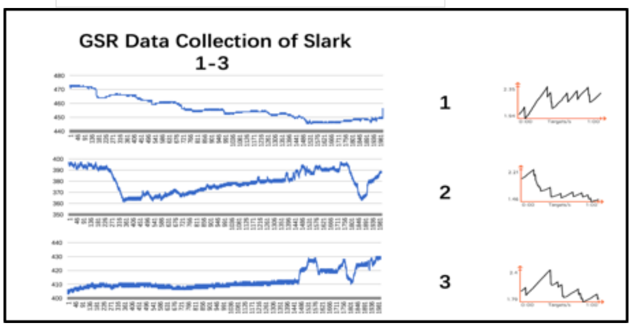


Figure 5. GSR Data Collection Chart 1-3 & Average Target Change in Time Chart 1-3 of player Slark

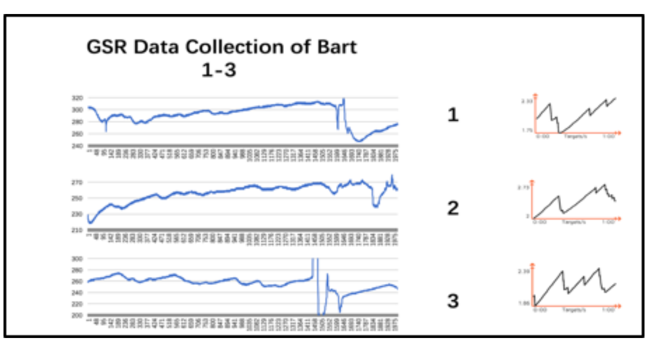


Figure 6. GSR Data Collection Chart 1-3 & Average Target Change in Time Chart 1-3 of player Bart

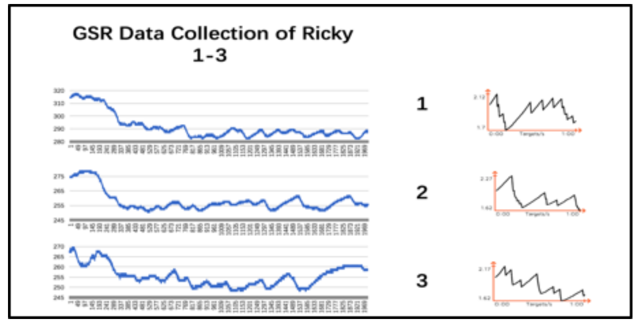


Figure 7. GSR Data Collection Chart 1-3 & Average Target Change in Time Chart 1-3 of player Ricky

4.2 General Observations and Analysis

Figures 8 to 15 show the GSR sensor value and the max target per second in the game playing session for each player. We speculated a correlation between the two, since the target moving speed could affect players' emotion (i.e. anxiety, nervousness) which might in turn have some impact on their concentration.

Figure 8. The GSR sensor output and max target per second in the 60-second game performance of Livor

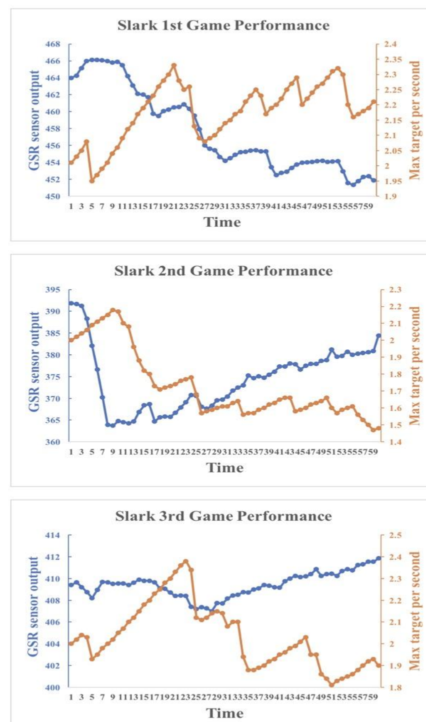


Figure 9. The GSR sensor output and max target per second in the 60-second game performance of Slark

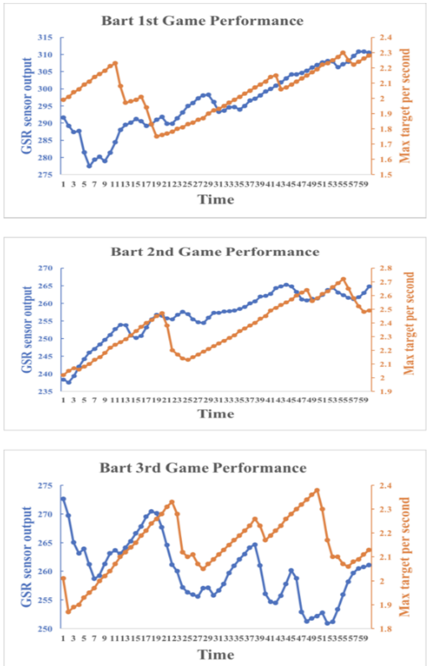


Figure 10. The GSR sensor output and max target per second in the 60-second game performance of Bart

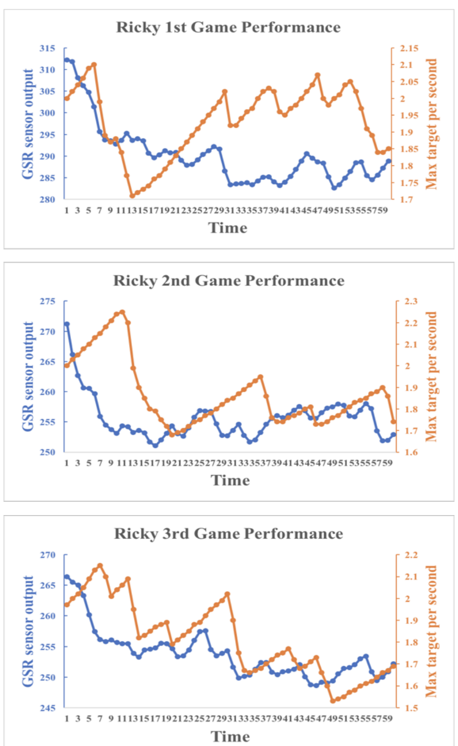


Figure 11. The GSR sensor output and max target per second in the 60-second game performance of Ricky

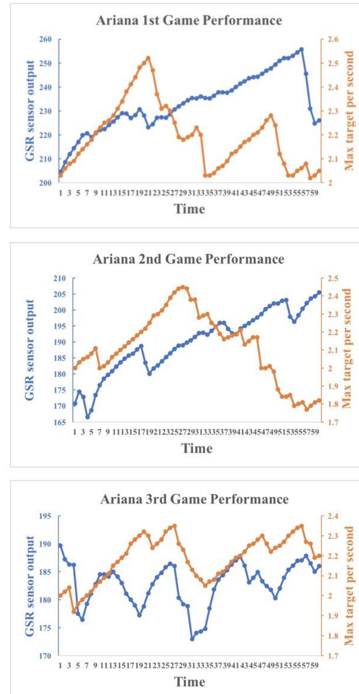


Figure 12. The GSR sensor output and max target per second in the 60-second game performance of Ariana

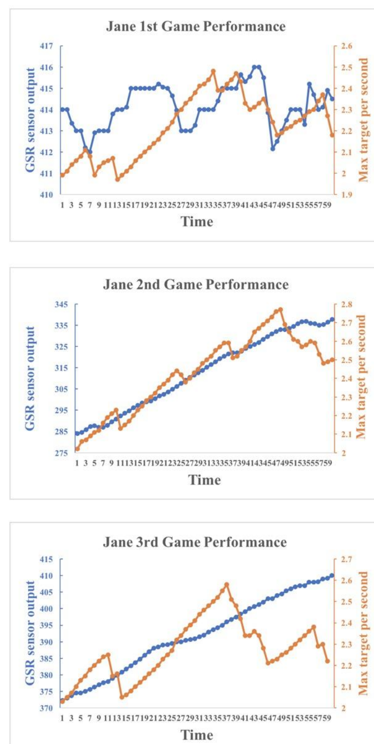
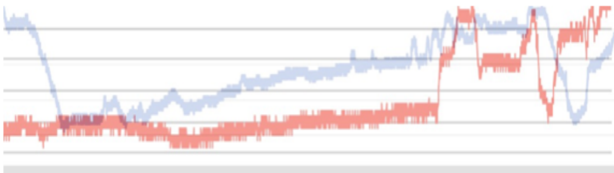


Figure 13. The GSR sensor output and max target per second in the 60-second game performance of Jane



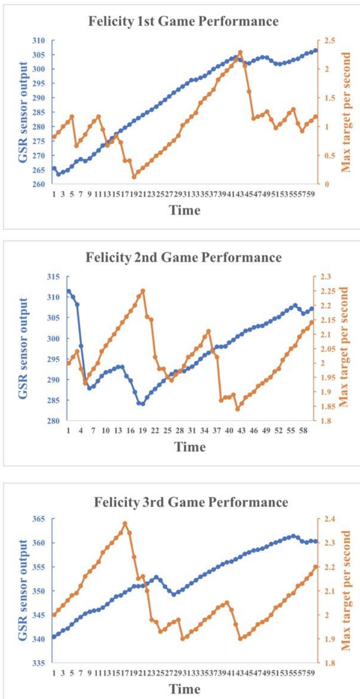


Figure 14. The GSR sensor output and max target per second in the 60-second game performance of Felicity

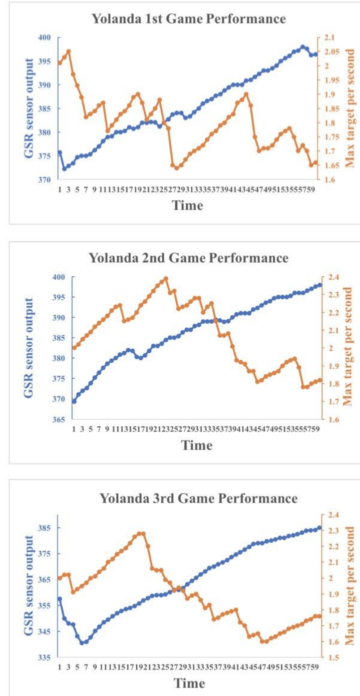


Figure 15. The GSR sensor output and max target per second in the 60-second game performance of Yolanda

Figure 16. Comparison of line graphs for Slark's second and third experiments

Previous studies indicated that there is a strong correlation between the stress level and the GSR value [11, 15, 16], although these studies had been carried out in different contexts from ours. Figure 7 and 8 demonstrated that the general tendencies of GSR value and max target per second of player Livor and Slark are not similar to each other. The blue lines (GSR) and the orange line (max target) are more like a mirror-image relation, which might indicate a negative correlation. However, if we compare Bart and Ricky, the same relationship failed to show up (see Figure 10 and 11). Hence, due to the limited data available in our experiment, no conclusive correlation can be drawn.

Based on these two coincident curves obtained in Livor, Slark and Yolanda, we might infer that the lower the value of the GSR, the higher the success rate, which indicated that the calmer the player, the higher score he/she could obtain. And there is a certain coincidence between the line graph of the GSR and the number of max targets hits per second. Because individuals can concentrate better in relatively stressful situations, which might lead to higher successful target hitting rate. This finding is consistent with the statement in the official document of the GSR sensor: the lower the value obtained by the GSR, the higher the person's nervousness.

From graphical analysis of the trend lines of GSR output and max target per second, there exhibited a positive correlation in Bart Ricky, Ariana, Jane and Felicity we further performed a correlation analysis of the data and the results confirm such correlation; however, no correlation was found in player Ricky and Bart. We cannot rule out the possibility that some inherent and delicate factors might lead to such findings, for example, some people might show a higher skin conductance level when being attentional and concentrated; everyone might have a different baseline [20].

Thus, our small-scale study supports some findings in previous works [11, 15, 20]. In the next section, we will offer fine-tuned pattern analysis on the possible link between skin conductance fluctuations and the errors players tend to make in each experiment.

Although we focused on the analysis of the male data, by combining the GSR sensor output data of men and women, we found that women have a smoother and fewer fluctuations GSR sensor output. What's more, almost all the female players' GSR sensor output lines have an increasing tendency while those of the males are irregular. However, from an overall perspective, both genders presented similar results that players' output data would have fluctuations more or less with the occur of errors, which can be easily observed from graphs.

4.3 Further Analysis on Concentration Fluctuation and Errors

When examining closer at each player's performance data (in terms of the errors made), we uncovered that the last fluctuation of each experiment had the minimum vibration amplitude (see Table 1). The values of the fluctuations obtained by the GSR sensor can reflect changes in the human sense of tension. Therefore, the curve of the result of the whole experiment can roughly reflect the experimenter's variation of degree of concentration in the experiment. Because the number of changes in the number of GSR values for the last experiment in each set of data were the smallest, we speculated that the change in the mood of the last experimental experimenter in each set of experiments was minimal.

Table 1. Experimenter errors and fluctuations vary with the number of experiments

Livor(M)	**1**	**2**	**3**	**Average**
Fluctuation times	5	6	5	5.33
Total Errors	11	11	9	10.33
Slark(M)	**1**	**2**	**3**	**Average**
Fluctuation times	5	9	3	5.67
Total Errors	7	8	12	9
Bart(M)	**1**	**2**	**3**	**Average**
Fluctuation times	2	5	0	2.33
Total Errors	6	6	8	6.67
Ricky(M)	**1**	**2**	**3**	**Average**
Fluctuation times	11	11	8	10
Total Errors	11	15	13	13
Ariana(F)	**1**	**2**	**3**	**Average**
Fluctuation times	6	8	10	8
Total Errors	10	7	8	8.33
Jane(F)	**1**	**2**	**3**	**Average**
Fluctuation times	8	1	1	3.33
Total Errors	6	7	3	5.33
Felicity(F)	**1**	**2**	**3**	**Average**
Fluctuation times	3	4	3	3.33
Total Errors	7	4	8	6.33
Yolanda	**1**	**2**	**3**	**Average**
Fluctuation times	5	3	1	3
Total Errors	11	10	10	10.33

Notice: M represents male and F represents female.

Figure 9 compares the skin conductance fluctuations in Slark's 2nd and 3rd experiments; the wave of the second experiment was much bigger than the third one. We can see that from the third time there was almost no wave (after 1400 was the end of the experiment). In summary, our experimental results supported the view that the smaller the GSR value change, the smaller the emotional change; and with practices, the player would be able to concentrate and calmer.

4.4 Data Correlation on Skin Conductance Level and Game Performance

We performed the Pearson correlation using the SPSS statistical software to examine the possible link between the skin conductance level and each player's performance (in terms of the maximum number of targets hit). Note that correlation is significant at the 0.01 level(2-tailed).
Results in player Bart's play data reveal that correlation starts to exhibit in the second ($r = 0.812$, $p < 0.01$, two tailed) and third

experiments ($r = -0.046$, $p < 0.01$, two tailed). Player Livor showed in his second ($r = -0.502$, $p < 0.01$, two tailed) and third experiment ($r = -0.511$, $p < 0.01$, two tailed). Slark's data did show significant correlation in first ($r = -0.652$, $p < 0.01$, two tailed) and third experiment ($r = -0.524$, $p < 0.01$, two tailed). Ricky's third experiment demonstrated a strong positive correlation ship between the skin conductance level and the total number of targets hit ($r = .762$, $p < 0.0005$, two tailed). As for women's data, player Ariana showed significant different in second experiment ($r = -0.330$, $p < 0.0005$). Player Jane's data began to suggest in the second ($r = 0.924$, $p < 0.0005$) and third experiment ($r = 0.541$, $p < 0.0005$). Player Felicity's first experiment displayed positive correlation ($r = 0.515$, $p < 0.01$, two tailed). Player Yolanda's all three experiments were all crucial ($r = -0.613$, $p < 0.01$, two tailed; $r = -0.580$, $p < 0.01$, two tailed; $r = -0.810$, $p < 0.01$, two tailed).
The analysis failed to lead to conclusive results regarding the link between skin conductance level and the game performance. However, our results did again support the fact that everyone's base line of skin conductance level is difference [11, 20].

5. Study Limitations

5.1 Study Subject

Only eight subjects participated in our study, and they are students from our campus, in other words, our subjects in the study are young people, which greatly affect the magnitude and validity of our study. In addition, we speculate that subjects' game-playing background might also affect their performance, which might in turn affect our experiment results. Additionally, the more practice a play makes on Aimbooster, the more familiar he/she will become leading to fewer mood swings. Considering about interests, players might be not interested in Aimbooster or they did not devote all their energy to the trail. Therefore, our result brought out has no powerful supports that proves the relationship between one's skin conductance level and degree of concentration.

5.2 The GSR Sensor

The GSR sensor used during the experiment was cheap and not sensitive enough to the skin conductance levels as expected during our initial testing. The value GSR sensor gathered was not immediate, so that it became necessary to record data of 30 seconds before and after to avoid missing the capture of mood swing. Besides, limited by the device, it could only record 2000 values at one time. When the number of values is over 2000, the previous values will be cleaned to make room for more incoming data. Therefore, time of each trial was limited to around one minute. Planning to test under longer time period about the relationship between the degree of degree of concentration and skin conductance level with commercial devices is needed in the future.

6. Concluding Remarks and Future Works

While an overwhelming number of previous works focused on examining and characterizing emotion fluctuations via GSR sensors, relatively fewer focus on establishing the link between skin conductance level and the degree of concentration, especially the challenges brought by the use of such technology of employing devices on individuals when they are involved in daily activities. However, thanks to the recent technological advances, wearable and compact sensors have gained much attention and success in obtaining reliable data in the study of psychological states and processes. Driven by these previous works, in the present study through a small-scale experiment, we investigated the possible link between skin conductance level and the degree of concentration for individuals involving in daily activities---game-playing.
Preliminary results revealed that when players are concentrated (exhibited by relatively low level of skin conductance value), their performance tends to be better. Our results also showed that such pattern might vary as a function of both internal and external factors; no conclusive results can be obtained on whether skin conductance can be used a reliable *in situ* marker for the degree of concentration. Despite these, our study serves as a preliminary yet promising one down the research path.
However, in the future, the primary pattern will be a crucial indicator of statues of esports players. In the NBA, the physical fitness gap is minimal among the top athletes. Therefore, only the data can accurately reflect out of these gaps and become a winning weapon for athletes. With the development of electronic sports industry, more and more elite players compete in the top level in this field. Therefore, the preliminary pattern will build a personal indicator based on e-athletes' concentration and game performance, which obviously reveals athletes' competitive states and help managers to select and train their athletes.

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