

Development of Integrated GreenVec Biofeedback Game with Galvanic Skin Response Sensor

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Abstract. GreenVec Biofeedback Game (GVBG) is a biofeedback game-based application that able to measure the skin conductivity of the player with the integration of Galvanic Skin Response (GSR) sensor. The measurement of the skin conductivity is crucial as an indicator for human meditation improvement in terms of stress control. In addition, GVBG spread awareness on global green technology issues specifically about the Electric Vehicles (EV) issue to all users throughout the game process. The measured Skin Conductivity Level (SCL) corresponds to the player's awareness level about the green EV. During the development, Spiral Methodology is applied for a smoother and clearer development processes. GVBG is mainly developed by using Microsoft Visual Studio 2008 with XNA Framework 3.1 and Adobe Photoshop CS6. By playing GVBG, the user will be able to learn more about the proper way to reduce stress while gain awareness on the green technology issues related with Electric Vehicles.

Keywords: GVBG, electric vehicles, galvanic skin response sensor, SCL, biofeedback.

1 Introduction

Biofeedback was first discovered in the 1960s (M.B. Eric, 2008). Since then, it was rapidly developed as an unconventional medical treatment by researchers, meditators, and healthcare clinicians. Biofeedback comes from two different root words; Bio and Feedback. Bio means life while feedback denotes giving back (Rizk, 2006). Thus, biofeedback is the process of feeding back information about life responses. The

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Association for Applied Psychophysiology and Biofeedback (AAPB) and the International Society for Neurofeedback and Research (ISNR) defined biofeedback as “a process that enables an individual to learn how to change physiological activity for the purposes of improving health and performance”(AAPB, 2008, “What is Biofeedback,” para.2). Green technology is a long term solution which resolves the problem in many life aspects including public transportation, reduces the dependency on petroleum and diesel in the country, lowering the amount of carbon emitted daily, free Malaysia from the problematic fuel subsidy issues and eventually saves the world from a worsen climate change (“Green Technology: Accelerating a sustainable transportation system”, 2012). More importantly, Electric Vehicles (EVs) technology is part of the alternative of this green solution.

In fact, Malaysian still lack in the exposure about the right green technology concept especially on the existence of Electric Vehicles (EVs) technology in their living environment. Only minority of Malaysian are fully exposed to this newly introduced technology and its benefits towards a better future while the rest are still ignoring this issue due to lot of misconceptions. With a strong society in Malaysia, biofeedback game is reflected to many new generations (Biofeedback Lab, 2011). Due to its popularity, biofeedback game fits the purpose as a medium to expose the right Electric Vehicles (EVs) concept among the Malaysian. Besides that, the biofeedback game also teaches player proper relaxation practices throughout the game process and consequently improves their meditation techniques as a whole. Biofeedback may still consider “high-technology” therapy that may be used to engender a relaxation response, thus treating the stress response itself (Everly *et al.*, 2002).

GreenVec Biofeedback Game (GVBG) is a biofeedback game which integrates Galvanic Skin Response (GSR) sensor in its game. The game is based on the theme around University Malaysia Pahang. The player controls an electric car in a virtual track environment of University Malaysia Pahang. During the game process, player is required to avoid obstacles while approaching the end of the map. The player needs to collect the electrical power along their journey to maintain their car’s life’s span. The GSR sensor functions to measure the human skin conductivity and provides an indication of changes in human sympathetic nervous system (SNS) (Shi *et al.*, 2007). The skin conductance data collected will be analyzed and be presented in a simple report form by the end of the game. The report corresponds with the player’s performance throughout the game.

2 Related Works

There are few important elements that are related to the development of this proposed system. Skin conductance or also known as Galvanic Skin Response (GSR) is one of several electro dermal responses (EDRs). EDR are changes in the electrical properties of a person’s skin caused by an interaction between environmental events and the individual’s psychological state (“The Galvanic Skin Response (GSR) and emotion”). The skin conductivity startle response is one of the most robust and well-studied physiological responses (H. Jennifer, 1999) because skin conductance reflects

more than one physiological process due to its properties that change on the relatively short time scale of seconds. Skin conductance serves as indicators of processes as attention, habituation, arousal and cognitive effort in many different subdomains of psychology and related disciplines (Figner, B & Murphy, R.O). Basically, skin conductance can be divided into two types; tonic and phasic skin conductance. Tonic skin conductance is the baseline level of skin conductance, in the absence of any particular discrete environmental event, and is generally referred to as Skin Conductance Level (SCL). Tonic skin conductance levels vary over time in individuals depending on his or her psychological state and autonomic regulation (“The Galvanic Skin Response (GSR) and emotion”). Another type of skin conductance is Phasic skin conductance which changes when the events take place. Discrete environmental stimuli will evoke time related changes in skin conductance. These are generally referred as Skin Conductance Responses (SCRs) (“The Galvanic Skin Response (GSR) and emotion”).

Commonly, skin conductance reactivity is monitored using the feedback instrument such as Galvanic Skin Response (GSR) sensor. GSR sensor has two built in electrodes which will automatically send the small electric current to pass through the body of the test subject to measure conductivity. The GSR reflects sweat gland activity and changes in the sympathetic nervous system and measurement variables (F.D. George, 1977). The measurement is taken from the subject’s fingertips, where changes are monitored in the relative conductance of small electrical current between the electrodes. The activity of the sweat glands in response to sympathetic nervous stimulation (increased sympathetic activation) results in an increase in the level of conductance (F.D. George, 1977). There is a relationship between sympathetic activity and emotional arousal although one cannot identify the specific emotion being elicited (F.D. George, 1977). Although well correlated with emotional events in studies, the skin conductance response is still not entirely predictable (H. Jennifer, 1999).

Journey to Wild Divine, Relax to Win Game, Mind Balance Game, and emWave Desktop Stress Relief System are the current existing biofeedback games. Journey to Wild Divine is a biofeedback video game system promoting stress management and overall wellness through meditation, relaxation exercises, and mindfulness training. Founded by Kurt R. Smith and Corwin Bell in 2001, The Journey to Wild Divine is widely spread and highly rated as the world’s best computer program for stress relief and stress related health issues. Besides of its biofeedback method as an alternative healthcare, this system also unique in its gameplay, where players are allowed to use thoughts, emotions, and breathing to complete the mind and body training events (Wild Divine Inc, 2012).

Relax to Win game is a game developed by MIT Media Lab in the US (Marjaana Lehtinen, 2012). It is a game in a form of a race between two dragons. Relax to win game implements a competitive gameplay where two players have to relax to determine the speed of the dragon. In a race against stress, a winner is the player who manages to relax the most during the course of the game (“Relax to Win – A New Game for Mobile Phone”, 2006). Competitive games usually brings player to a certain level of increased tension, but in Relax to win game, the player must discover to override this tendency, learn not only to relax , but to relax in a stressful environment (“Relax to Win – A New Game for Mobile Phone”, 2006). The game takes place in a

virtual 3D world set aboard a starship in space. The environment is designed to immerse the player and attract their attention to make the feedback process is more effective (“Video Games to Help You Relax”, 2002). This is due to a fact that people’s focus and adaptability level is varies with each other, thus an effective environment designed is a design to affect player’s attention better.

Mind Balance was the first application developed by the MindGames group as part of ambitious collaboration with researchers at University College Dublin to implement new brain-computer control interfaces. The game concept is easy where a participant must assist a tightrope-walking behemoth known as the Mawg, by helping him balance as he totters across a cosmic tightrope (‘Mind Balance’). There is no joystick, any mouse and not even a camera, but only a cap that non-invasively measures signals from the back of the head (“Mind Balance”). The cap which known as The Cerebus hardware device used for the game relies on an electroencephalogram (EEG) metric and the wireless technology Bluetooth to create a control mechanism. Instead of measuring the ratio between alpha and beta waves, The Cerebus monitors the occipital lobes at the back of the head to detect artifacts from the electrical signals produced by the brain’s visual processing (“Cross-Country Olympic Mind Games”). Currently, one of the biofeedback instruments above is used and available at Biofeedback Lab at Gambang Campus, University Malaysia Pahang (UMP). It is known as emWave Desktop Stress Relief System. The emWave Desktop system is a scientifically validated software/hardware system that collects pulse data through an ear or finger sensor which plugs into your computer. The system translates the information from your heart rhythms into interactive graphics displayed on your monitor screen (IP Home LLC, 2011). The game system offers four challenges level to help user sharpen their coherence building skills. Additionally, the system incorporates an accumulated coherence scoring display so you can track your progress during a session and save and review their sessions over time (Tools for Wellness, 2012).

Basically, the emWave Desktop system determines the degree of coherence found in user’s heart rhythm patterns and displays changes in real time. When stressed, user’s heart rhythms will produce an incoherent pattern and vice versa. All of these changes of heart’s rhythms patterns are displayed on the user’s computer screen. By knowing the visual change on the screen and associating it with a more peaceful, calm internal state, user will be able to manage stress and maintain a state of physiological coherence and balance (IP Home LLC, 2011). Figure 1 below shows the comparison of heart’s rhythms pattern in a contrast coherence state.

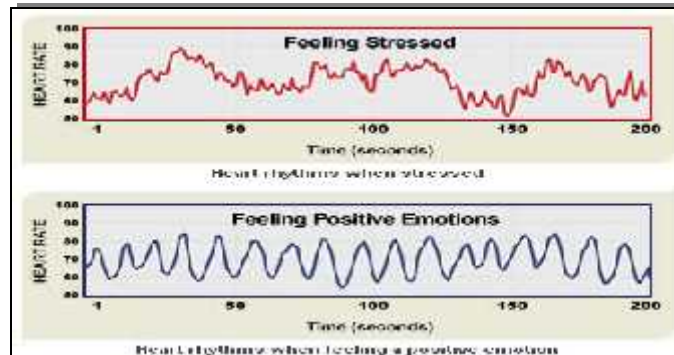


Fig 1. Comparison of Heart's Rhythms Patterns with emWave Desktop Stress Relief System

3 Methodology

During the development, Spiral Methodology is applied for a smoother and clearer development processes. Figure 2 shows the Spiral Model as a whole. The Spiral Methodology involves iteration processes which starts at a center of the spiral and continuously loop until customer's requirements are satisfied. There are six phases exist in the Spiral Methodology starting from Customer Communication, Planning, Risk Analysis, Engineering, Construction and Release, and lastly Customer Evaluation.

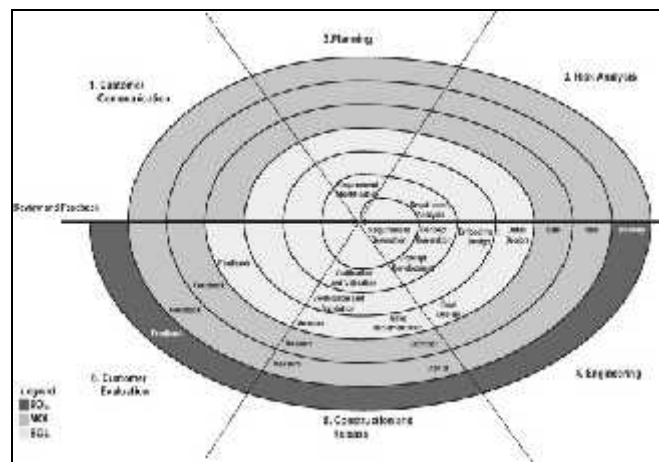


Fig 2. Spiral Methodology

Spiral Methodology is an iterative lifecycle model which is favored for large, expensive, and complicated models. Integrated GreenVec Biofeedback Game

(IGVBG) using GSR sensor is not a large or expensive system yet it is truly complicated in its development processes. Plus, the integration of this biofeedback game with the external device which is the Galvanic Skin Response (GSR) sensor makes it to be more complex for data analysis and design phases.

Spiral Methodology implements iterative steps in its model, where after each of the iteration completed; the prototype is then evaluated by the customer and reiterated based on the requirements needed. This process occurs few times until the prototype satisfy the needs of the customer. In this matter, customer's feedback determines the number of iteration of this methodology. For GVBG, repetitive validation and verification from the customer is essential to get accurate requirements during the design and data analysis phases. Inaccurate data gathered may affect the product's functionality critically. Besides that, Spiral Methodology is also capable to identify potential risk areas at the early stage of the processes. It has built-in critical features for risk mitigation and clarifying requirements. Risks are known as a main factor for high product costing. For GVBG, this is truly helpful because if the risk is accessed regularly, hence better planning can be made and more cost can be saved. Without repetitive and risk mitigation features, the project development has higher possibility for cost problems by the end of the project. These are my justifications of choosing Spiral Methodology as my project framework.

The initial phase which is customer communication involves data collection of user requirement. This is usually done in a two way conversation with the customer to discuss on the user requirements for the project development. This is a fundamental step of getting the right requirements to build the right product for the customer. In this phase, close interview session was carried out with Assoc. Prof. Dr. Nubli, one of the biofeedback researchers in University Malaysia Pahang.

Once the requirements are fully identified and understood, it will be easy for system analyst to proceed with the next step of development process which is planning phase. In this phase, project schedules, costs, resources, objectives and other related information for iteration process is determined. The second phase which is planning phase was done where all the needed resources are allocated, the milestones are well-planned, existing documentation has been done, objectives and constraints are determined, and other relevant information for a better understanding of GVBG using sensor are collected. The emphasis of logical model that is readable and useful for representation the knowledge (N Ahmad, 2010; A. Noraziah, 2008).

The next phase is Risk Analysis phase which is one of the most critical parts of the development. Few risks related with GSR device, game mechanics, game design and GSR raw data graph display are determined and potential solutions are planned as early as possible. The phase is continued with an Engineering phase, the fourth phase of the methodology. This is the phase to build the design and prototype of the GVBG using GSR sensor. All the prior user requirements are converted into a computer-based specification. Based from the user requirements, system flow design, Data Flow Diagram (DFD), Entity Relationship Diagram (ERD), graphical user interface and storyboard are built. The system architecture design is always be the first impression of any system as a whole. Thus, a good architecture design should be simple, user-friendly, ease to use, reliable, supportive and also well-organized. Functional requirements define the expected services of the system purposes, scope and required data structures.

Figure 2 shows overall system flow design of GVBG. Before player enters the game, the GSR sensor must be connected to the player. The game is start when the player enters the Integrated GreenVec Biofeedback Games using GSR sensor. Firstly, the introduction video will be displayed at the beginning of the game. Then, player will be redirected to the home menu. Here, few options are available; player may choose to either access tutorial, access help menu or play the game. In tutorial site, player will be demonstrated with proper way of playing the game. Player will also be guided on how to achieve the game's goal. While in the help menu site only shows the keys for the GVBG game. When player enters the play game site, player will be redirected to the game environment. Here, all the game's score is kept into a database. A simple GSR raw data graph result is shown at the Relax Trace Program. Lastly, the GVBG using GSR sensor ends once player exit from the game.

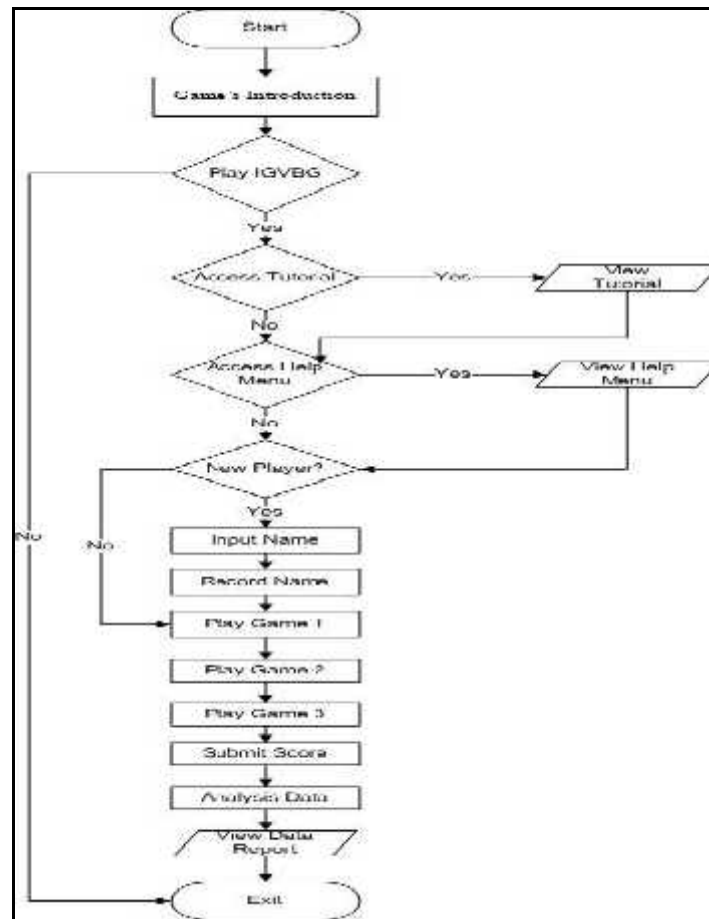


Fig 2. Overall Process GVBG

Figure 3 shows a context diagram of the data flow diagram for IGVBG using GSR sensor. Based from the diagram, player will input name into the IGVB game for data analysis. The IGVB game measures player's skin conductivity level by the help of the sensor device attached to the player. The GSR sensor detects the skin conductivity level which is changing based on the emotional level of the player. By the end of the game, once player submit the score, the skin conductivity level data and the game score will be analyzed and the analyzed data will be generated in a form of graph form together with player's simple report.

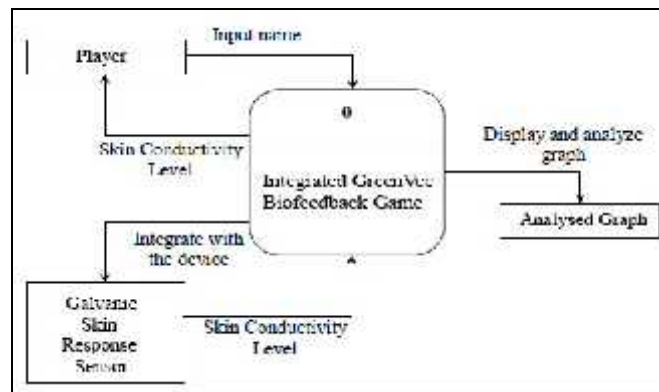


Fig 3. Context Diagram for GVBG

Next, the phase followed with a construction and release phase. The phase highlights most on the implementation of the prototype on the customer's site. The prototype is tested for functionalities, weaknesses, risks or strength to ensure that the prototype fulfills the user requirements. During this process, customer is provided with training user manual and documentation of GVBG as well. The last phase is the Customer Evaluation phase. This is the phase where feedbacks from the customers are taken as new requirements for enhancements in the next spiral process.

4 Implementation

This section presents the implementation of GVBG. There are few concepts that are highlighted for this project, which are biofeedback concept, Green Electric Vehicles issues, Skin Conductivity Level (SCL) data graph, SCL data analysis and summarization of SCL data and Green Electric Vehicles Technology concept.

The system concept was divided into five modules, starting from biofeedback concept module, green electric vehicles issues, skin conductivity level data graph, analysis of SCL and summarization of SCL data and green Electric Vehicles Technology concept. The first module which is the biofeedback concept touches more on the usage of Galvanic Skin Response as a sensor for biofeedback game. Second module which is Green Electric Vehicles issues is the concept which discussed about Green Electric Vehicles Technology concept among Malaysian. This is followed by the third section of the module, which is the skin conductivity level data graph that will display the actual result of human SCL graph. The fourth section, Analysis of SCL data is the technique which needs the assumption of arousal of SCL to generate the report for respective player about awareness on the green electric vehicles issues. And the final section, the summarization of SCL data and Green Electric Vehicles Technology concept is the output section where player will be shown the final summary of SCL about their level of awareness on the right Green Vehicles concept.



Fig 4. *A GSR Sensor*

Figure 4 shows the Galvanic Skin Response (GSR) Sensor to measure the skin conductivity level of a person. The measurement is based on the amount of current that can pass through our body. The GSR sensor shows how easy (conductance) or how difficult (resistance) it is for the current to pass through our body, and this is based on Ohm's Law. Ohm's Law states that the electrical current flowing through a conductor is always proportional to the applied potential difference to it (voltage) but indirectly proportional to resistance value (Basic Electronics, 2011).

The game design includes the game content, mechanics, and technology used for the game development. The game interfaces are one of the most critical parts of any game development, where it gives the initial impression of the game as a whole. The game interface should be attractive, simple, consistent and relevant with GVBG. Figure 5 shows the main interface of the game. Meanwhile, Figure 6 shows the detail about the game interface, and Figure 7 shows the integration of the game interface with the GSR sensor.

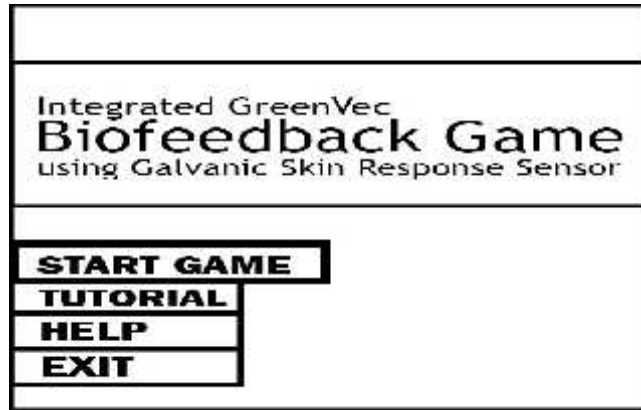


Fig 5. Main Menu of GVBG

Figure 5 is the main menu of GVBG. This is the first screen that will appear where player will have options either to start the game or go through tutorial, or choose help or exit the game. The first option which is Start Game will redirect player to the play screen for game to start. The second option, tutorial will provide player with few basic training before the player can get into the game environment. The third option, Help option provides user with basic configuration setting such as key setting and sound setting.

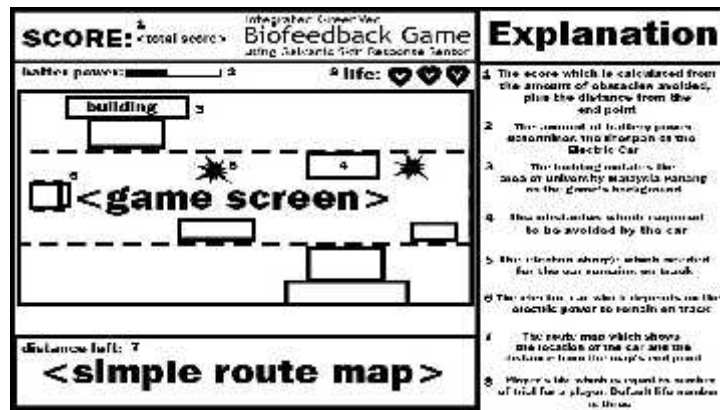


Fig 6. Game Interfaces Detail Explanations

Figure 6 is the game interfaces with detail explanations of GVBG. Player will have options either to start the game or go through tutorial, or choose help or exit the game. The first option which is Start Game will redirect player to the play screen for game to start. The second option, tutorial will provide player with few basic training before the player can start the real game. The third option, Help option provides user with tips, and basic configuration setting such as sound setting, or screen size setting.

There are few game rules to be followed. The first one is regarding on the player marks. The score for each player is calculated from the amount of obstacles avoided, plus the distance from the end point. The second rule is based on the life span of the player which is based on its battery power. To maintain the battery power throughout the game, player needs to collect the available electric charge as competent as they can. The game requires the player to avoid the obstacles from the front, and the more obstacles they can avoid the higher marks they will get. The car player's character will change its speed from slow, to moderate and eventually fast for every 10 seconds duration. The faster the car moves, the more challenging the game will be.

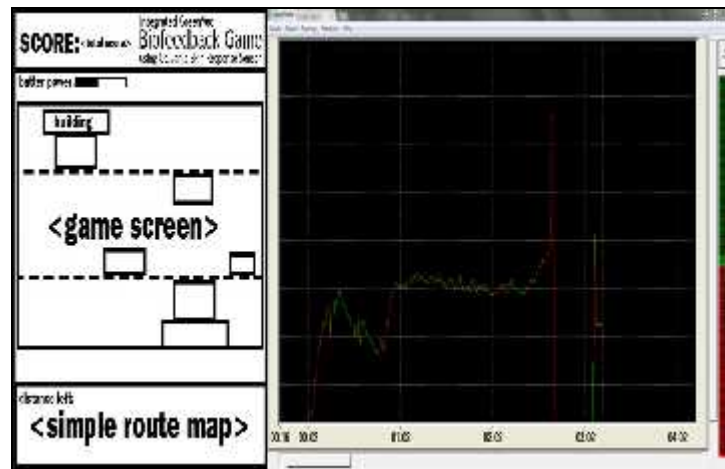


Fig 7. GVBG integrates with GSR Sensor

Figure 7 shows the GVBG interface with GSR real time sensor graph. The left side is the interface of the game for the player while the right side is the GSR real time sensor graph. The GSR real time sensor is corresponding with the player's state throughout the game process. The level of amplitude describes the stress level of the player.

5 Results and Discussion

Summarizations of the analysis for GSR data are:

1. Amplitude of SCL is increased when the awareness of electric vehicles issues is high.
2. Amplitude of SCL is decreased when the awareness of vehicles issues is low.
3. Amplitude of SCL is increased and decreased with balance when the awareness on vehicles issues is balanced.

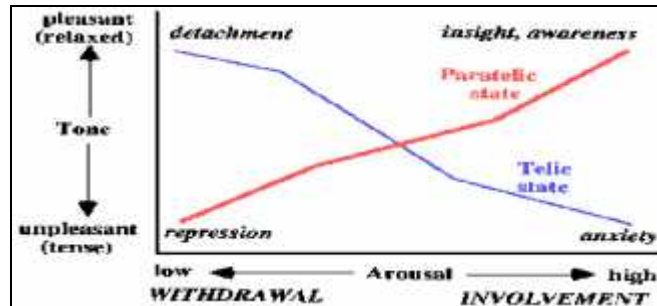


Fig 8. The Galvanic Skin Response (GSR) Meter Psycho-analytical research

The development of GVBG is mainly using Visual Studio 2008 with C# Programming Language and XNA Framework 3.1. The GVBG using GSR Sensor has met all the objective of this project, which are:

1. To develop prototype of green vehicles biofeedback games using Galvanic Skin Response in order to give awareness about the Electric Vehicles (EVs) concept to the player
2. To measure the player's skin conductivity through this biofeedback game
3. To generate a summary of the player's skin conductivity via this biofeedback game

6 Conclusion

GreenVec Biofeedback Game (GVBG) is a biofeedback game which aims to give awareness about the right concept of Green Electric Vehicles (EVs) technology issues among Malaysian which was wrongly interpreted by some people in the older days. GVBG is also integrated with the Galvanic Skin Response (GSR) sensor to measure the skin conductivity level of the player. Overall, GVBG is a unique standalone game because aside from operational as a medium for Green Vehicles concept exposure, it also behaves as an interactive meditation technique to cope the stress level among the players. The GVBG using GSR sensor is hoped to be a medium for pre-education knowledge exposure about the importance of Electric Vehicles (EVs) apart from being a newly meditation techniques for a better future in our society.

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