

GREENVEC GAME FOR SKIN CONDUCTIVITY  
LEVEL (SCL) BIOFEEDBACK PERFORMANCE  
SIMULATOR USING GALVANIC SKIN RESPNOSE  
(GSR) SENSOR

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## ABSTRACT

The increasing fame of biofeedback game has brought convenience to human life. More and more people rely on biofeedback game as an alternative medical treatment to overcome stress problems. Practitioners, meditators, healthcare clinicians and patients are among the most common people who use this biofeedback method to handle their stress in a better way. Basically, biofeedback game integrates biofeedback device in their therapy. Different biofeedback devices have unique way to patterned user's physiological response towards the game. Biofeedback game implements the virtual game to collaborate with these biofeedback devices. Global issues such as the Electric Vehicles (EVs) issue which are part of the green technology solution are rarely found in the existing biofeedback virtual games themes. Therefore this project, GreenVec Game for Skin Conductivity Level (SCL) Biofeedback Performance Simulator using Galvanic Skin Response (GSR) Sensor or mainly known as Green Vehicle Biofeedback Game is a biofeedback game-based application that able to measure SCL of the player with the integration of GSR. The skin conductivity level corresponds to the player's awareness level about the green Electric Vehicles (EVs) issues. The biofeedback game will also create a short report on the player's skin conductivity level based on the GSR sensor data and the game data by the end of the game. From the end result, it shows that when the SCL is high, the awareness on the electric vehicles issues is high. While the SCL is low, the awareness on the electric vehicles issues is low.

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**LIST OF ABBREVIATIONS**

IGVBG:	Integrated GreenVec Biofeedback Game
EVs:	Electric Vehicles
GSR:	Galvanic Skin Response
SCL:	Skin Conductivity Level
SCR:	Skin Conductivity Response
AAPB:	Association for Applied Psychophysiology and Biofeedback
ISNR:	International society for Neurofeedback and Research
GreenVec:	Green Vehicle
UMP:	Universiti Malaysia Pahang
EDR:	Electrodermal responses
EEG:	Electroencephalography
EMG:	Electromyography
HRV:	Heart Rate Variability
BVP:	Blood Volume Pulse
LED:	Light Emitting Diode
RFID:	Radio Frequency IDentification
ADC:	Analog to Digital Converter
USB:	Universal Serial Bus
S.M.A.R.T:	Self-Mastery and Regulation Training
NASA:	National Aeronautics and Space Administration
SNS:	Sympathetic Nervous System
PNS:	Parasympathetic Nervous System

- IBI: Interbeat Interval
- AI: Artificial Intelligence
  
- RL: Reinforcement Learning
- ANN: Artificial Neural Network
- GA: Genetic Algorithm
- SDLC: Software Development Life Cycle
- RUP: Rational Unified Process
- XGP: Extreme Game Programming
- IBM: International Business Machine
  
- MATLAB: Matric Laboratory
  
- ADD: Attention Deficit Disorder
- ADHD: attention deficit hyperactivity disorder
  
- EDR: Electro Dermal Response

# CHAPTER 1

## INTRODUCTION

This chapter briefly discussed about the overview of this research. Overall, there are five sub sections for this thesis. The first section is the brief introduction, which briefly describes the project's background. The second section describes the problem statement of the project. The next section which is also the third section is the project goals or research objectives. This is followed by the fourth section which defines the scopes or limitation for project and users. Lastly is the thesis organization which briefly describes the sequences for each chapter of this thesis.

### 1.1 Background of the Project

Biofeedback refers to the process of getting feedback from various functions of an individual body. Biofeedback focuses on the control of diversity of bodily processes. Few common forms of biofeedback sensors are galvanic skin response (GSR), pulse sensors, temperature sensors and many more. By becoming aware of the ambiguous changes of the body, we can learn methods to control them and able to improve one's health. On parallel with that, focus-training game is a game that emphasizes on the focus level of the players.

Generally, the project with title GreenVec Game for Skin Conductivity Level (SCL) Biofeedback Performance Simulator using Galvanic Skin Response (GSR) Sensor or mainly known as Green Vehicle Biofeedback Game (GVBG) is a biofeedback game-based application with a theme around University Malaysia Pahang. In this game, the player controls an electric car in a virtual track environment of University Malaysia Pahang. Player is required to avoid obstacles while moving approaching the end of the map. The car's life depends on its battery power, which is decreasing while moving. The faster the car speeds, the more battery power will be drained. Player is required to collect the electrical power in a form of a battery along their journey to maintain their car's life's span. The game is

designated to have three different levels; the first level with less obstacles, more batteries and more time, second level with moderate obstacles, moderate batteries available and moderate time, and third level with many obstacles, less batteries available and less time. Marks are given based on player's remaining battery life, and also remaining time. In essence, we try to test player's focus level from the aspect of speed. First, the obstacles and the amount of battery life's span primarily functions to test how fast students can make a spontaneous decision under uncertainty. This uncertainty can evoke emotional arousal which consequently affects their level of focus and lead the students to do an irrational decision making. Secondly, the three different speed phases aim to speed up the player's cognitive process. And thirdly, the virtual environment of University Malaysia Pahang is to examine player's ability to adapt with environment changes. This is because, not many people can easily focus when dealing things in an unfamiliar environment. This is due to different level of adaptability among various people.

The overall player's skin conductance data will be collected by the GSR sensor and a simple report of the player's performance will be generated by the end of the game. Hence, the game not only functions as an aid to improve the focus level but it indirectly exposes player on the newly introduced green technology of an electric car.

## **1.2 Problem Statement**

Nowadays, biofeedback games is highly demanded as an alternatives cure to treat stress related problems. However, there is still no Malaysian customized biofeedback game invented in Malaysia. And usually, buying the biofeedback game from other countries is high in cost. This becomes the root factor on why less Malaysian prefers biofeedback games. Only research institutes buy these biofeedback games and devices for study purposes. Another problem is related with green technology exposure. Malaysian still has a low level of awareness on the existence of green technology in their living environment. One of the latest green technologies is the electric vehicles (EV) which are now rapidly built by many exclusive companies to lessen the dependencies on the fuel consumption. Not many people realize on the importance of this newly introduced technology towards a better future.

### 1.3 Objectives

Several objectives of the research are defined as follows:

- i. To develop a prototype of green vehicles biofeedback games using Galvanic Skin Response in order to give awareness about the Electric Vehicles (EV) concept to the player
- ii. To measure the player's Skin Conductivity Level (SCL) through this biofeedback game
- iii. To generate a report summary of the player's skin conductivity via this biofeedback game.

### 1.4 Scopes

The scopes of this project are:

- i. System Functionality
  - The game gives awareness about the green vehicle technology concept which applied in electrical vehicles (EV) in Malaysia
- ii. System User
  - This biofeedback game is available for users from all ages
  - Not for user who suffer from Hyperhidrosis medical condition; a person who sweats excessively and unpredictably
- iii. Data
  - Skin Conductivity Level (SCL) using GSR sensor
- iv. System Architecture and Platform
  - The game generates report summary of player's Biofeedback Performance based on Skin Conductivity Level (SCL) using Galvanic Skin Response (GSR) Sensor and GreenVec Game Simulator

## **1.5 Thesis Organization**

This thesis consists of seven (7) chapters. Chapter 1 Introduction will shortly introduce the research study. This chapter will comprise the problem statements, objectives, scopes and the summary of each chapter in the thesis. Chapter 2 Literature Review will explain in details the overview of the project flow. In this chapter, the project concepts, technology applied for the system, the manual system, and the existing systems which are related to the case study will be reviewed. This chapter will also review on the methodology of the project research concisely. In Chapter 3 Methodology, further and deeper reviews of the overall approach and framework will be deliberated. This chapter also covers the details for the method, technique, hardware and software during the research process. Chapter 4 Design will explain the wireframe and framework model of the research.. Chapter 5 Implementation will elaborate in details the work flow of the research. Data analysis, data gathering processes, and further explanation on the selected algorithm applied for this project will also be discussed in this chapter. Chapter 6 Results and Discussion will explain the end result of the project research based on the data analysis in the prior chapters. Supposedly, result analysis is expected to be parallel with the research objective. This chapter also covers on the research constraints. Lastly, Chapter 7 Conclusion will summarize the research findings as a whole, and discussed for any future enhancement for the research topic or technique. References and appendices will be added to the last part of this project.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

In this chapter, it will briefly discuss about the literature review of GreenVec Game for Skin Conductivity Level (SCL) Biofeedback Performance Simulator using Galvanic Skin Response (GSR) Sensor or mainly known as Green Vehicle Biofeedback Game (GVBG). There are several main parts in this chapter. First part of this section is the introduction of the literature review. Then, the next section discussed on the concepts existing in the project development. The following section deliberates on the technology used and applied technologies within the project. After that, the manual of the system for the project will be discussed. The last part concerns on the review of the existing systems and followed by methodologies used throughout the game development.

#### **2.1 Introduction**

Literature review is a review of the critical analysis of a segment of a published body of knowledge through summary, classification, and comparison of prior research studies, reviews of literature and theoretical articles. Also, a literature review can be interpreted as a review of an abstract accomplishment. Literature review functions as a framework to give a clearer view for the project flow. In this project, the literature review is divided into few sections which review on the concepts used, methods, and technologies.

#### **2.2 The Concept of the Project**

There are few crucial concepts that need to be classified for this project. Firstly, is the concept of the biofeedback, and followed by the concept of the game. The next important concept is the justification of the green vehicle game concept and the combination



concept of both biofeedback and game; biofeedback game is deeply discussed. Lastly, the concept of skin conductance will also concisely discuss in this section.

### **2.2.1 The concept of Biofeedback**

Biofeedback has developed rapidly as an alternative medical treatment since it was discovered by researchers, meditators, and healthcare clinicians in the 1960s (M.B. Eric, 2008). Biofeedback has proven to be a safe and powerful healing process that is increasingly gaining popularity in the professional medical community because of its comprehensive approach to treating a wide range of physical and mental disorders (B. Michael, 2009). Until today, biofeedback has evolved as one of the mainstream methodology for treating certain medical conditions and improving human performance ((AAPB), 2008).

Bio is a single form of word meaning life while feedback denotes giving back (Rizk, 2006). Basically, biofeedback is the process of feeding back information about life responses. The 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). Biofeedback is also defined as a means for gaining control of our body processes to increase relaxation, relieve pain, and develops healthier, more comfortable life patterns (W.E. Stephen, 2004, “An Overview of Biofeedback”, para.7).

Biofeedback returns physiological information to you, not readily accessible without the assistance of the instrument (E.D. Steven, 2011). These biofeedback instruments can monitor muscle tension, galvanic skin response, heart-rate, blood pressure, peripheral blood flow (vasoconstriction), EEG brain waves and other measures. The three most commonly forms of biofeedback therapy are Electromyography (EMG), Thermal biofeedback, and Neurofeedback or electroencephalography (EEG) (E.D. Steven, 2011).

### **2.2.2 The concept of Game**

There are vast amounts of definitions for “game”. David Kelley (1988) defines game as a form of recreation constituted by a set of rules that specify an object to be attained and the permissible means of attaining it. Another definition is given by Katie Salen & Eric

Zimmerman (2003) where a game is a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome. This is further supported by Avedon & Sutton Smith (1981) where, “a game can be defined as an exercise of voluntary control systems in which there is an opposition between forces, confined by procedures in order to produce a disequilibria outcome”. On the other side, philosopher Ludwig Wittgenstein argued that the concept “game” could not be contained by any single definition, but the games must be looked as a series of definitions that share a “family resemblance” to one another. In 2003, Jesper Juul proposed a definition of games, based on the 6 main points where he defined game as a rule-based formal system with a variable and quantifiable outcome, where different outcomes are assigned different values, the player exerts effort in order to influence the outcome, the player feels attached to the outcome, and the consequences of the activity are optional and negotiable.

Basically, game is usually undertaken for enjoyment and sometimes as an educational tool. A good game is a game which presents a series of interesting choices for the player to make (T. Stephen, 2012). For this GVBG using GSR sensor, the game is a simulator that helps to measure Skin Conductivity Level which corresponds to the player’s awareness level about global green technology issues related to Electric Vehicles (EVs). Meanwhile, this biofeedback game also trains player’s state of emotion to deal with different game’s mechanics (time constraint, car’s life span constraint and environment familiarity) in order to enhance their focus level as well.

### **2.2.3 The Concept of Green Vehicle (GreenVec)**

Transportation, public or private, is a topic of much discussion in Malaysia. There is constant talk about the increasing numbers of vehicles on the road, and the subsequent pollution they created. Based on fact, the transportation sector is the second biggest emitter in carbon dioxide after the energy sector in Malaysia. Transportation is closely linked to another solemn problem in fuel subsidy. Thus, one of the best alternatives to fix this problem is by using the green technology alternatives. Green technology is a long term solution which resolves the problem in 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).

To be specific, Electric Vehicles (EVs) is also part of this green technology solution. Electric vehicles are propelled by an electric motor powered by rechargeable battery packs. Electric vehicles bring several advantages over the internal combustion engines in term of energy efficiency, performance benefits, environmental friendly, and also energy dependent reduction (“Electric Vehicles (EVs)”, 2012). In other part of the countries, demands for electric vehicles are increasing. For example in Chicago, electric garbage trucks are built by electric bus manufacturer Motive Power System to collect the garbage’s in a garbage route provided. The electric trucks were expected to reduce Chicago’s garbage truck-related costs from 80 cents per mile to 10 cents per mile (Katherine Tweed, 2012). This is quite a saving compared to the prior garbage trucks costs. Recently in Jakarta, electric bus was introduced by researchers from the Indonesian Research and Science Institute’s Mechatronics and Electric Power Research Center to promote green technology that is hoped will reduce fossil fuel consumption. By using a LifeP04 lithium battery, this electric bus can reduce operational costs by about 50 percent and maintenance costs by about 70 percent (Elly Burhaini Faizal, 2012). Another example can be seen in South Korea, where The Korea Advanced Institute of Science and Technology (KAIST) developed the Online Electric Vehicles (OLEV) platform; an electric bus which ply a 15-mile route up to 10 times a day. The South Koreans made buses that can charge while moving or when stationed without physical contact with the power supply. At the heart of the bus is power transfer technology that can shape electromagnetic fields in a specific direction (Keith Berry, 2013).

In Malaysia, Nissan becomes the second company after Mitsubishi to introduce the fully electrical car so called Nissan Leaf to the local market (Ben, 2012). Even so, there is still an endless discourse about the full potential of these electrical cars to suit the local needs. Some may realize the benefits brought by this new technology but still some people never heard of it. This happens due to lack of awareness about the green technology among local citizen. People are less aware on the importance of electric vehicles as a long term solution to reduce the dependency on the usage of petroleum and diesel for their vehicles. Thus, GreenVec Biofeedback Games (GVBG) using GSR sensor is one of the alternatives to increase awareness and educate these people about the existence of electric vehicles through a virtual game concept. Promoting the green technology through a virtual game concept is a

starting point for local native to accept the new idea of electrical vehicles in their daily life. Plus, with an increased use of green vehicles, more opportunities for renewable sources of electricity such as solar, biomass, and wind will open up.

#### **2.2.4 The Concept of Biofeedback Game**

Biofeedback game implements a cross concept of both biofeedback therapy and a virtual game concept. Although various definitions of biofeedback games have been proposed, the most common definitions for biofeedback game is that a game which is controlled through input from biofeedback devices. The patient controls the game with his or her body, with the game responding to things like changes in heart rate, skin conductance, skin temperature and blood pressure. (“What is a Biofeedback Game”, 2010). These physiological changes which affect the gameplay directly is known as an affective gaming. Affective gaming focuses on the integration of emotion into game design and development, and includes the following areas: recognition of player’s emotions, adaptations of the gameplay to the player’s affective states, and modeling and expression of emotions by non-playing characters (H. Eva, 2011).

Biofeedback game is a proven method of treatment that brought the elements of motivation and entertainment values into the biofeedback training. Compared to other forms of treatment, there is no concern about the side effects, and the skill you learn can be used to prevent symptoms rather than simply treat them (B. Robin, 2010). Biofeedback games are applicable in many fields of study. They can be used in psychotherapy, to help patients work through stressful situations, and they may also be used in imaging studies of the brain with the patient controlling the game while the brain is scanned to gather information about brain activity (Smith, 2010). Another study in 2011 from East Carolina University’s Psychophysiology Lab and Biofeedback Clinic showed casual games can reduce depression and anxiety, while some additional studies have shown that fast-paced video games can be helpful to children with attention deficit hyperactivity disorder (ADHD) by increasing their ability to concentrate (“Biofeedback Video Game Helps Kids Control Anger”, 2012).

In biofeedback game, there is often a combination of hardware (for monitoring physiology) and software (for connecting to the computer) (“Why Biofeedback Games”, 2005). There are various devices that the player may wear depending on what type of

games the player is involved in. Player may wear gloves, heart rate (HR) monitors, GSR sensor and so forth (S.E. Smith, 2008). Different devices have unique way to patterned user's physiological response towards the game. Usually, biofeedback game is designed with various concepts to suit player's needs and often designed along a reward model, with the game rewarding the player when she or he achieves a desired change. For example, a game which is designed to help people relax and promote stress management would reward players for reduction in blood pressure, sweating, and heart rate ("What is a Biofeedback Game", 2010). Another series of game may also implement puzzle concepts or shooting concepts to examine the physiological response and focus level of the player.

### **2.2.5 The Concept of Skin Conductance**

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).

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"). 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 Conductivity 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).

## **2.3 Technology**

Technology is the practical applications of knowledge especially in industry. For this project, we only use sensor technology for the whole project development.

### **2.3.1 Sensors Technology**

Sensor refers to a device that detects and responds to some type of input from the physical environment. The specific input could be light, heat, motion, moisture, pressure, or any one of a great of other environmental phenomena. The output is generally a signal that is converted to human-readable display at the sensor location or transmitted electronically over a network for reading or further processing (W. Ivy, 2012). If in the prior days, sensor only available in specific field of study, but today, sensor technology is widely used in scientific researches, educational experiments, medical fields and daily life activities. In this project, only few common sensors which closely related to biofeedback study will be discussed comprising from galvanic skin response (GSR) sensor, blood volume pressure (BVP) sensor, body temperature sensor and muscle tension sensor.

### 2.3.1.1 Galvanic Skin Response (GSR) Sensor

Galvanic Skin Response is another name for skin conductivity. It associates with the activity of sweat glands, which are connected to the sympathetic nervous system. Sympathetic nervous system is one of the two divisions for autonomic nervous system which operates mainly under the control of hypothalamus and the medulla oblongata. Autonomic nervous system controls cardiac muscle, smooth muscles in organ and the secretory action of glands for them to function smoothly. Sympathetic division works with one's emotions and stress that comes with them (B.Laura, 2011). But even when in extreme stress condition, only a subset of sympathetic division will be involved (G.Ians, B. Bill, 2008). For example, when a person is nervous, only the sympathetic activity in selected pathways, such as those to the cardiovascular system is affected, producing increased heart rate, skin blanching and perhaps high blood pressure, as well as an increased sympathetic output to the sweat glands, of the face, armpits and hands. Sympathetic division also might get someone into the "fight or flight" mode; would be able to get away from danger or react quickly to something or with reflex (G.Ians, B. Bill, 2008).

When psychological stress is put upon an individual, this stimulus will trigger the hypothalamus in the Central Nervous System (CNS) to discharge flood of nerves via the spinal cord to reach the selected sympathetic division to activate the sweat glands activity. The arousal of the sweat glands activity will lower the skin resistance plus increasing the skin conductivity level of an individual. In simpler term, when an individual has a disrupted emotion, he or she will have higher tendency to get sweaty. Imbalance emotion state may increase the sweat gland activity and skin conductivity level but at the same time lowering the skin resistance which results in more sweat to be produced. The sympathetic nervous system and emotional arousal is closely related to each other, although one still cannot identify which specific emotion is being elicited (F.D. George, 1977).). The skin surface is naturally highly electrically resistant, and many studies have shown that being able to measure skin conductivity is directly affected by sweat gland activity, which offers a conductive path for the currents to take in and on the skin ("What is Galvanic Skin Response"). Due to these properties, skin conductance is used as an indication of psychological or physiological arousal (Wikipedia).

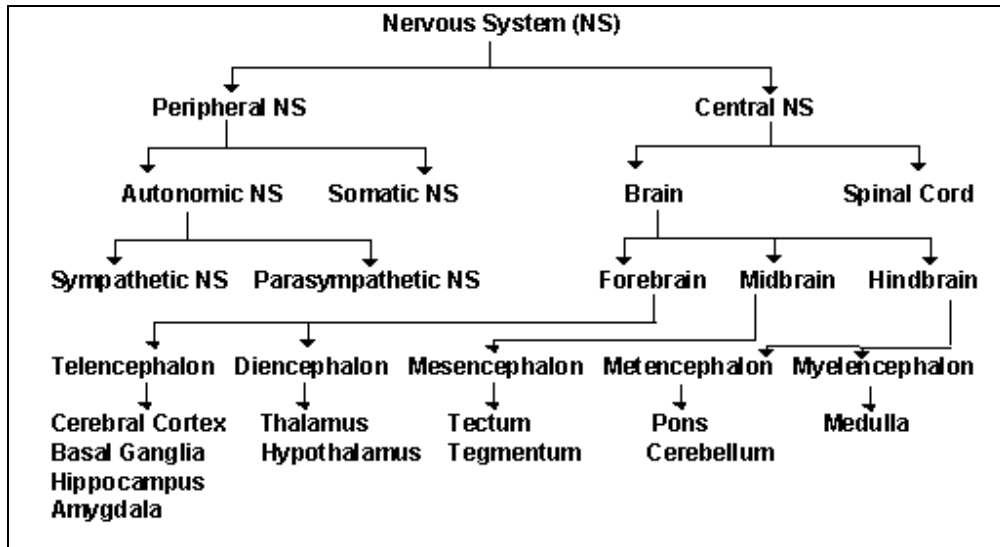


Figure 2.0. General hierarchy of human's body nervous system ("What is Nervous System", 2012)

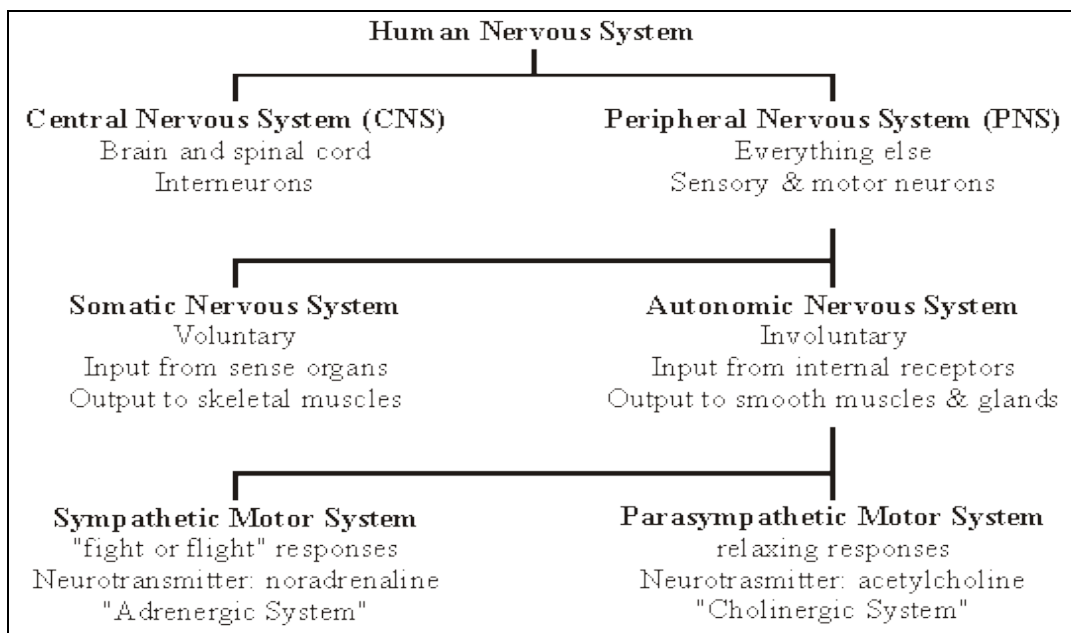


Figure 2.1. Smaller scope hierarchy of human's body nervous system ("The Human Nervous System", 2004)