The Influence on Environmental Adjustment Levels of Mind and Body Caused by Digital Games

Reika SATO, Tiejun MIAO, Tsuneo JOZEN, and Mayumi OYAMA, Member, IEEE

Abstract — It seems that playing digital games can have both positive and negative effects on the body and the mind. Therefore, recognition of the environmental adjustment levels of mind and body caused by playing digital games is important for scientific studies in physiology, psychology, sociology, and informatics, etc. If these effects are understood, there is a possibility of greatly influencing game development and play in a positive manner.

In this research, Pulse waves of the body were measured and analyzed in various environments. Some tendency of change in mental state to these different environments was noted. If we can learn more about the influence on environmental adjustment levels of the mind and body caused by playing digital games we may be able to use this learning in future games development.

I. INTRODUCTION

Digital games influence people in many ways. Recently, there has been considerable publicity regarding the possibility of digital games influencing people to commit crimes. Our research was conducted to pay attention to the effect digital games have and to isolate an individual influences of different aspects of games using a scientific approach, and to obtain findings concerning the best use of games for particular purposes. For instance we looked at how playing games can reduce fatigue and stress (changes the negative image), or cancellation and recreation of stress (effect of positive game).

II. EXPERIMENT AND ANALYSIS

Our research method analyzed the state of the mind and body’s using chaos analysis applied to pulse wave information gathered from individuals when a game was played.

A. Chaos Analysis

In the testing, we used the chaos analysis method to analyze the pulse data of the observers.

The principle of pulse testing involves determining pulse by capturing blood flow at peripheral capillary sequentially by near-infrared to measure hemoglobin reflection. The fingertip or the ear is often used for testing because blood vessels in these regions are very sensitive and easy to analysis.

Vital signs refer to information indicating the living state of the human body. These include body temperature, blood pressure, and pulse, among others. The human body is composed of chaotic characteristics that cannot be determined by a simple calculation. Vital signs detected from the ear (fingertip and forehead) are different from an electrocardiogram (ECG), as they reflect the state of the nervous systems as well. Therefore the Lyapunov exponent, calculated by complex non-linear analysis or chaos analysis following time sequence, was employed.

As general knowledge in the future, it may be considered that a healthy body consists of movements of regular order, under inconstant conditions at any given point but recurring periodically. It therefore can be considered as one kind of fluctuation type mechanics process. In other words, the living body resisting fluctuation is not avoiding changes outside but escaping cyclical chaotic fluctuation. It generates physiological and psychological compatibility and flexibility. Thus, chaos analysis with the Lyapunov exponent is effective to analyze such non-linear data. Moreover, the pattern of attractor, i.e. structure fluctuation (shape and pattern) and function may indicate the relaxation, concentration, brain activation, uncomfortable state, fatigue and other abnormal mental states as well as recovery, which are all signs of the activity of autonomic nervous system. The attractors of health, energetic state, concentration and sharp thinking are transformations of complex and dynamic total structures to complex partial ones by reversing them to spiral-shaped forms, which can be compositions of more a complex attractor.

Illness, abnormality and fatigue result in unstable psychiatric, psychological and physiological conditions. The attractor structure is converted into less complex, unstructured, linear configuration, leading to a mechanical periodic phenomenon, and consequently, as the composition of the attractor reduces the Lyapunov exponent decreases. In contrast, a person with healthy mental and physical condition maintains a dynamic balance with the environment, and his/her pulse attractor and Lyapunov
exponent display an optimal sensible state of body and mind, represented as a unique status for the specific environment.

The chaos analysis of pulse data started with dynamics re-constitution. The parameters were set as follows: window length - 4,000 points, bury dimension - 4, delay time - 10 o'clock. The Lyapunov exponent was then calculated based on Sano-Sawada algorithm with the following mathematical formula.

$$\lambda_i = \lim_{t \to +\infty} \frac{1}{t} \log \frac{l_i(t)}{r(0)}$$

Here in the condition space, the attractor is approximated to 2 (the distance is $r(0)$) based on the unstable track (divergence). Embarking from here, a predication is made to estimate how far the two points will separate (information formation rate) along the two tracks (the distance is $l_i(t)$). Chaos theory indicates the greater the Lyapunov exponent, the more difficult the estimation. When the Lyapunov exponent is negative, the tracks tend to join together towards a periodic point. In reverse, a positive index value suggests that two extremely close points embark on the track to separation with increasing distance.

B. Relation between chaotic process of and state of mental: The mathematical principle model's simulation

The generation mechanism concerning kinetics of the pulse wave (finger pulse waves and earlobe pulse waves) was discussed, and the nonlinear mathematical principle analysis model was constructed. Moreover, it simulated by the change of various parameters. As a result, a chaos source of the pulse wave can be specified, and relations with the center are interpretable. Therefore, grounds for the presumption of the mental activity (mental concentration, attention power lack, cognitive ability, and mental calculation activity, etc.) by the pulse wave were established. It was shown to be able to separate information on the autonomic nerve system related to the generation of the pulse wave and information on a high-ranking center separately, and to presume those states more separately.

We have known that the central nerve activity can be shown with an EEG, and there was chaos dynamics. This research used the Duffing equation to describe the chaos activity of EEG. The Duffing equation influences centrifugal nerve activity at the heart and breath center (Cardio-center) and it relates to the pulse wave generation system. We simulated the model to influence the activity under the chaos of each central nerve. Consequently, it has been understood that uplift, the excitement, control, and the relaxation, etc. of the mental activity can presume quantitatively from maximum Lyapunov exponent of the pulse wave. We concluded verification of the model is correct by the EEG measurement and the experiment.

By information obtained from the pulse waves and analysis results, the mental activity (attention power, Distraction, cognitive activity, and mental calculation, etc.) and mere body activities are distinguished when the game is played, and the state can be distinguished separately. The mind and body activity was able to forecast further by the simulation method foreseeing.

Moreover, it has been understood that we can identify the body immanence parameter (phase etc. of the nerve ignition rate, the nerve transmission secretion, and the pacer) in physiology by the element concerning the acceptable observation pulse wave (wave height and rhythm, etc.) on the outside according to the model. It has been understood to be able to presume the element of Shitscatawaracac (PVN) of a hypothalamus assumed to be a part that takes part in a central adjustment of the circulatory system.

The cardiovascular system is effective in circulation control as a circulatory system receiving adjustment from the autonomic nervous system. The autonomic nervous system consists of the sympathetic nerve and parasympathetic nerve. The two nerves have acted each other and rivaling The sympathetic nerves work promoting, and parasympathetic nerves work controlling the circulation adjustment. Basically, the blood vessel is chiefly under the rule of the sympathetic nerve while the heart is under rule of both the sympathetic nerves and the parasympathetic. The activity of the autonomic nerve system is adjusted by instruction from the high-ranking center including the hypothalamus and centripetal reflection input from tip receipt receptors like the pressure receptor. It considers as a driven model that the compulsion vibration paragraph of the nonlinear system for the self-excited oscillation of a changing breathed rhythm by
the action of the sympathetic nerve that get from the pressure receptor reflection and parasympathetic of the feedback. The input of the influence paragraph by breath was a vibration.

C. Cardiovascular nonlinear model who relates to pulse wave generation- Figure of continuous model [reference the SH model]

The validity of the model was verified by the comparison between the result of the model and the result of the experiment.

Finger point pulse wave (left hand forefinger) and continuous blood pressure

Comparison of U:

It is understood it has almost same Dynamics from finger point pulse wave (Fig.6) and continuous blood pressures (Fig.7).

And, the shape of waves, the attractor, and FFT of the model were shown in the following figures.

(A)  

(B)  

Fig.6: A finger point pulse wave

Fig.7: Continuous blood pressures

Fig.8: the shape of waves, the attractor, and FFT of the model
III. MEASUREMENT RESULT WHEN GAME IS PLAYED

Because there is a problem that is easily buried in the noise in the measurement of the pulse wave, the power value of the pulse wave (we call incline), the situation of the time change, and the time change in maximum the Lyapunov exponent was used. Then the time series response analysis and chaos were analyzed.

The measuring object used was twenty healthy adults. The state of the rest for five minutes before the game is played, and the state during game play were measured using capacity pulse wave. The inclination of the power value and the inclination of the maximum Lyapunov exponent were analyzed in the chaos time series diagramed. As the detection method, of state the pulse wave at rest and the physiological change when playing a game, the utility was examined.

The measuring instrument is composed of the infrared-emitting diode and the phototransistor. The change in the capacity of blood was measured for five minutes before the game was played, and for ten minutes while playing the game.

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>KIND OF GAMES AND PLAY TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kind of games</td>
<td>PLAY TIME (minutes)</td>
</tr>
<tr>
<td>Music (classics)</td>
<td>5</td>
</tr>
<tr>
<td>Music (rhythmical)</td>
<td>5</td>
</tr>
<tr>
<td>Horror game</td>
<td>5</td>
</tr>
<tr>
<td>Sports game</td>
<td>5</td>
</tr>
<tr>
<td>Quiz</td>
<td>5</td>
</tr>
<tr>
<td>Action game</td>
<td>5</td>
</tr>
</tbody>
</table>

IV. RESULT OF MEASUREMENT

The change in each chart index is seen in the state of play before it plays and as each game is played.

A. Musics

Normal circumstances:

When listening to the classical music:

Fig. 9 Pulse wave and attractor chart1

Fig. 10 Pulse wave and attractor chart2

When listening to rhythmical music:

Fig. 11 Pulse wave and attractor chart3

You can see that the attractor showing classical music let the man relax more and that rhythmical music stimulated the man to more rhythmical pulse waves.

B. Horror game

Normal circumstances and during at playing:

Fig. 12 Pulse wave and attractor chart4

The tension from which the game is played is clearly seen in the attractor.

C. Sports game

Normal circumstances and during at playing:

Fig. 13 Pulse wave and attractor chart5

When the sports game is playing, the attractors are showing that both the left and right ear charts are active.
D. Quiz

Normal circumstances and during thinking taking a quiz.

During thinking games, you can see that some people’s charts change more in the left brain. It may showed that a lot of left brains might be used. It is scheduled to examine it in addition in the next step.

E. Action game

Normal circumstances and during game playing

Change in the action game was smaller than expected. Players were perhaps not so tired in this short term. We are planning to run more tests in this area to get clearer results.

V. RESULT AND RESEARCH TOPIC IN THE FUTURE

As for living body information through pulse wave, some element of uncertainty is included when seeing the result of the analysis. However, a part of this tendency can be confirmed through the chaos analysis in the person’s state of excitement or the normal living body reaction. We believe that a elements influencing the persons living body information can be taken out through a further examination analyses. Especially if a good correlation for the chaos of the EEG and chaos of the pulse wave is obtained. As a result, we think that the nonlinear activity of the central nervous system by the chaos analysis of a finger point pulse wave can be guessed. For instance, when a game is played, the effect of psychology can be checked by chaos analysis. It can be used to propose game development based on the verification of a positive influence on the person.

This time, the pulse wave of both ears was measured. The state of the pulse wave measured from both ears was different. This might indicate that the state of excitement during operation of the person’s right and left brain might be different. To examine the state that influences the right and left brain further we will collect and analyze more data using the right and left hand.

This research got the results we expected; we can see the change of the pulse wave through the sympathetic nerve and the mental status of the person playing a game. The changing pulse wave can be analyzed, and the Lyapunov exponent calculated. It may be possible to calculate a new psychological index using a system with elements in the autonomic system other than ventricular rate using chaos as shown.

REFERENCES