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Exploring Emotional Responses of Design Styles using Electroencephalogram (EEG)

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ABSTRACT

Emotion is a huge factor in creating immersive experience when playing a video game. It can be stimulated by visual design elements. In particular, different levels of realism have an effect over the human feelings. Referred to as the Design Style, it is a spectrum of mimicking the real world ranging from Abstract to Realistic. Between them is known as Stylized Design. While there have been many studies to understand the relationship between Design Styles and emotions, their experimental observations lack quantitative analysis and prone to misinterpretation. Electroencephalogram (EEG) technologies have made the possibilities to explore emotional responses directly from the brain. This research aims to understand the relationship between Design Styles and the emotional responses of the player. To analyse design styles for correlation with emotions, a working framework for machine learning classification using EEG is used. Subjects played video games of similar gameplay but of two different Design Styles – each game represents each end of the Design Styles spectrum. Analysis of the EEG data revealed distinction of emotional activity between Abstract and Realistic games. Higher intensity, larger data distribution, and abruptness of change in emotions are all associated with Abstract Design. Realism, on the other hand, is associated with a more sustained emotional state and therefore a good choice for maintaining a steady mood.

Keywords:
Emotional valence and arousal; neuro-affective computational model; machine learning classification

1. Introduction

This document discusses a section of the research results conducted to analyse the effects of video games Design Styles using Electroencephalogram (EEG) based on neuro-affective computational model. As such, the topics on research methodology, data collection, and data analysis will not be discussed in detail. They are too big to be included within the scope of this document. In this paper, the final findings and the importance of the discoveries of the research is discussed.

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Design styles are one of many important decision factors faced by video games designers. It is a form of visual language to communicate the player what kind of video game he or she is playing. However, the psychological impact of design styles goes beyond what the eyes see. In animation production – a less interactive form of the same media – a phenomenon known as the 'uncanny valley' subconsciously caused the viewer to feel contempt towards realistic design styles [10]. On the other hand, exaggerated proportion of the stylized design styles may be attractive to younger audience such as cartoons for children [6]. Clearly, different design styles have different psychological effects to the audience. One particular psychological effect is emotion.

This research explores the emotional responses without the interpretation of the subjects' opinion, experimental surveys, or external observations. Human interpretation has the problem of mis-interpretation and inaccuracy of human feedback. So, the research did not rely on such method to gather data. Rather, the emotional responses are measured and recorded to allow numerical analysis via the advent of electroencephalogram (EEG) technologies.

Understanding how video games design affects the human emotions is essential in creating immersive experience when playing video games. In particular, Design Style is the main visual language that communicates with the players to stimulate the right emotions.

Although there have been many works in attempting to understand the emotional dynamics of Design Styles in video games, their results relied upon external and experimental observations [6,10]. While these methods provided invaluable insights to how emotions respond to a particular Design Style, they are prone to misinterpretations, inaccuracy, and lacked instantaneous emotional measurements.

The solution is to tap into the minds of the players while playing video games and measure their emotional responses directly from their brains. EEG technologies and machine learning computation allows this approach to be made possible. Emotional dynamics can be analysed without the need for the players to tell how they feel when playing the video games.

2. Literature Review

Emotions are key components in creating engaging and immersive video games [2,14]. Without the interplay of various degree of emotions, the video game lacks the interaction of excitement and game mechanics. An asset not to be taken lightly, understanding of emotional dynamics in respect of game design components is essential in producing a great video game [14].

The main visual elements in video games that can influence emotional changes is the Design Style. Design Style is defined by the level of realism or abstract that mimic the real world [9]. In between the two ends (Realistic and Abstract) of the Design Style spectrum is known as the Stylized design. Hypothetically, a particular Design Style influence emotional dynamics differently from other styles in the spectrum. It is thus an important insight to learn so that a video game design can be maximized to its full potential of its design objectives by using the right Design Styles.

Previous works such as by Carter [6] from Disney's Research Lab and Lee [10] both studied the effects of Design Styles. Each research is very similar in objectives with this research. However, like other researches that studied the effects of Design Styles, none of them actually tapped into the minds of the subjects to explore human emotions as they engage in activity with different designs interactively.

The electroencephalogram (EEG) technology is capable of capturing the brain signals that correspond to emotional changes [1,13,16,17]. According to Yaacob [16,17], it is accurate enough to predict emotions of a subject to more than 90 percent. This opens up opportunities to investigate emotions in relation to game design [7,10]. For instance, it is possible to find out how Design Styles affect the emotional behaviour of the player while they are playing the video game.

The ability to capture instantaneous emotional changes while playing video games is also an important aspect of the EEG instrument [12]. Dynamic changes of the emotional valence and arousal can be observed at any instances during game play [16,17]. The real-time relationship between emotions and video game design can be visualized and analysed to conclude meaningful insights that can actually help designers design their video games.

As Lee [10] pointed out, the right game design can deliver effective educational performance for educational games. Ismail [20] also pointed out the effectiveness of proper visual design in educational courseware application. Besides educational games, other aspect of game play can also be delivered by understanding the effects of these Design Styles. It is hoped that this research can provide a powerful insight to game developers to exploit new ways in making a more effective game.

3. Methodology: Adapting a Working EEG Framework

EEG signals can be captured to provide raw data of the emotional stimulation of the brain. However, raw data straight from the EEG devices cannot reveal anything without a proper framework. In the case of Yaacob's research methodology, the signals have to be classified based on a computational model of stimulated emotions [16,17]. Henceforth, the requirements of two important pre-requisites of analysing emotional dynamics when playing video games.

First, the analysis requires a working framework that are reliable and accurate. Several existing frame works exist [16,17] but each varies based on their two main components of translating EEG data into emotions. The two components are the feature extraction process and the classifier. Combinations of different feature extractions and classifier algorithms yield different levels of accuracy [16,17]. Using Power Spectral Density (PSD) feature extraction and Multi-Layer Perceptron (MLP) classifier give the highest accuracy and is the most reliable [1,13,16,17]. Figure 1 shows the working framework [14] that were adapted in this research experiment.

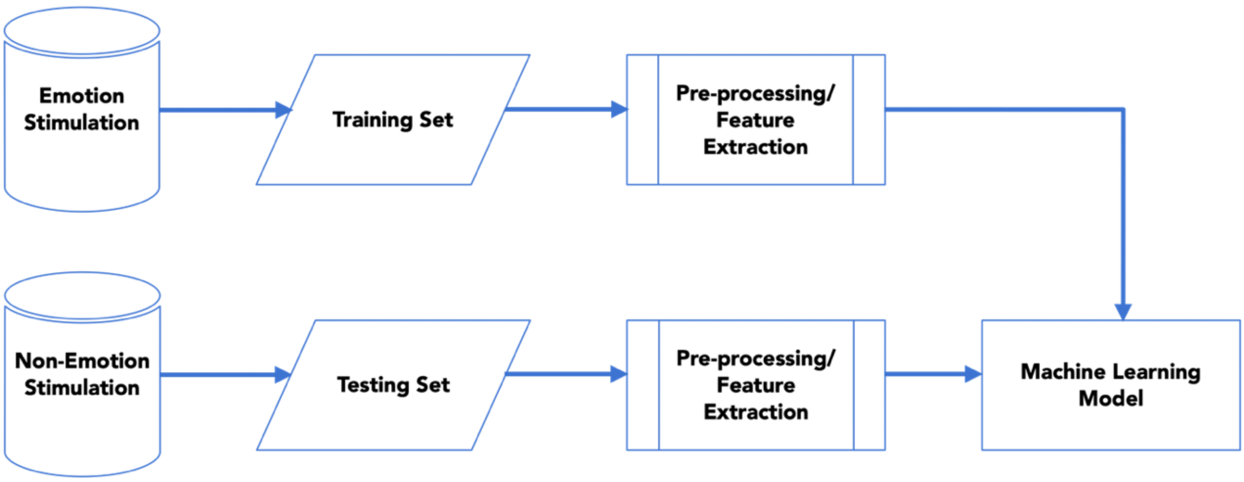

Fig. 1. A working framework to classify EEG data

Second, there must be a reference data in which it contains stimulated emotional responses to serve as the control variable [17]. The stimulated data allows recognition of actual emotional responses of the raw data and can therefore be translated as the computational model needed for the framework to work [16,17]. This can be acquired with the use of visual stimuli known as

International Affective Picture System (IAPS) [3-5]. It is an established and reliable stimulus for EEG experiments.

IAPS is critical in the success of this framework. Without it, there will be no way to establish the ground reference needed to computationally model each of the specific human emotions: Happy, Sad, Fear, and Calm. Fortunately, the development of the IAPS as established visual stimuli provide opportunity for this research to happen. Figure 2 is a diagram to show how the IAPS plays its role to help this research achieve its objectives.

The IAPS material contains four sets of pictures that are categorized with the four basic emotions: Happy (positive arousal and positive valence), Sad (negative arousal and negative valence), Calm (negative arousal and positive valence), and Fear (positive arousal and negative valence). Each category is exposed for one minute while the EEG device records the brain signals. These sets of EEG data contain signal features that correspond to the known emotions. Applying a feature extraction process on these data enable the computer model for valence and arousal to be constructed.

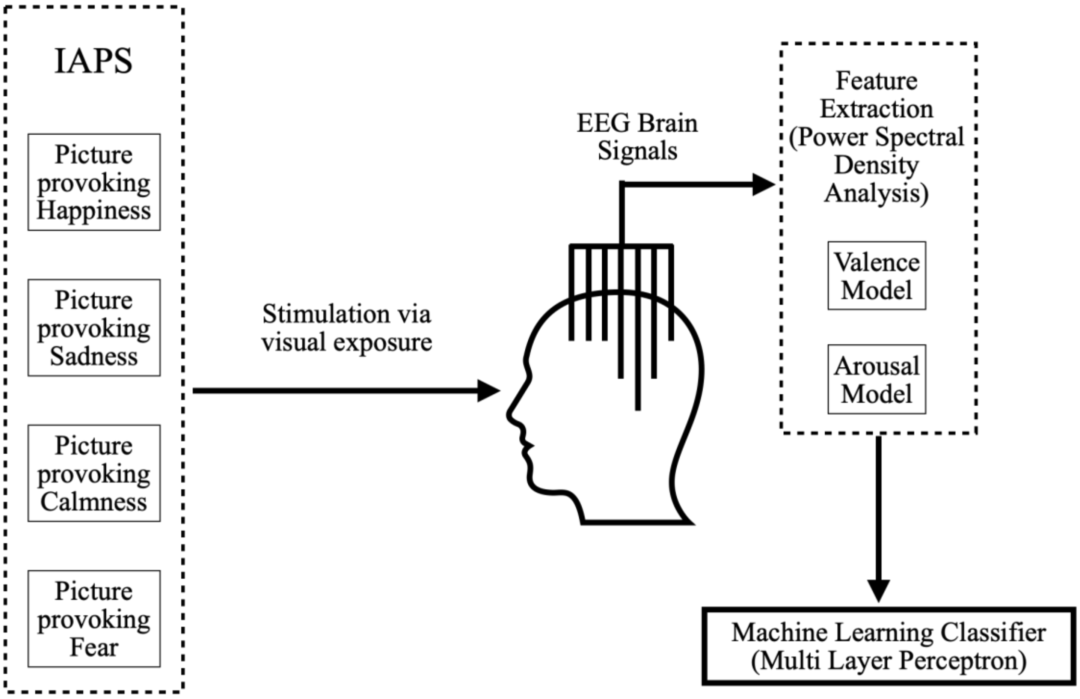

Fig. 2. Diagram showing how IAPS works to make the research possible

The resulting combination of adapting a machine learning framework using IAPS, PSD and MLP, provided systematic data collection process. The novel framework is based on these procedures:

i. Volunteers who participate in this research are the subjects providing EEG data from their brain signals.
ii. After attaching the EEG device on the subject's head, they are exposed to a stimulus to make them feel a particular emotion. The stimuli are a form of static pictures that when looked at, the viewer will respond with a specific emotional reaction.
iii. Following the emotion stimulation, the subject simply plays two different video games representing two different design styles.
iv. After the gameplay session is done, there will be two types of EEG data acquired:
    - Data with known emotional responses (known data)
    - Data with unknown emotional responses (unknown data)

v. To analyse the gameplay data – which is the unknown data – they will be classified with the known data before they can be scrutinized. By analysing the emotional responses within the gameplay (unknown) data, the relationship between them can be learned and understood.

The classification process is separated into two components: one is to measure emotional valence and the other is to measure the arousal. They are split for enabling the data to be plotted on horizontal and vertical axis. By doing this, statistical analysis and numerical vectoring is made possible. Figure 3 is the schematic of the new framework. At the end of the data collection, different numerical data of emotional responses while playing video games of two different Design Styles was obtained.

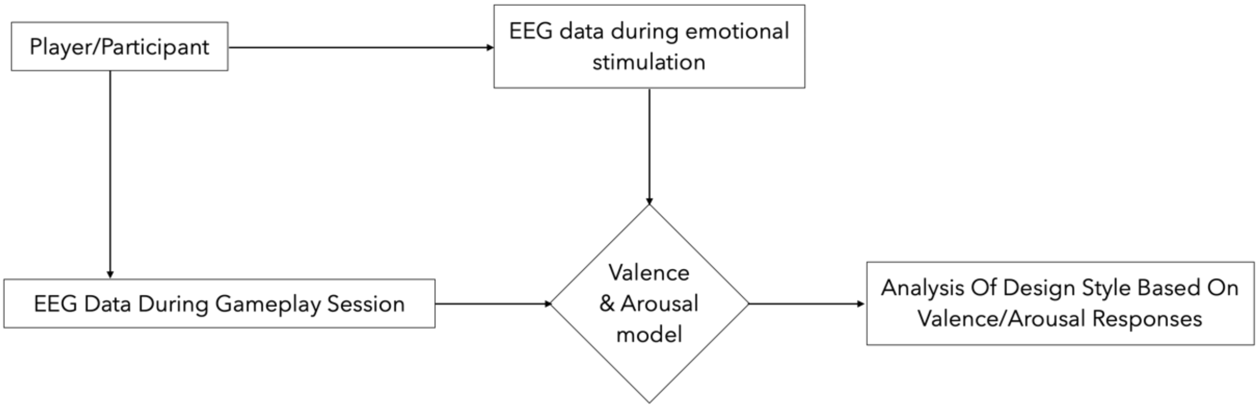

Fig. 3. Schematics of a novel framework

To turn this conceptual schematic into a useable framework, the existing working framework from Figure 1 was broken down into its core functions: feature extraction and machine learning classification. By modifying the structure of the framework to accommodate classification of gameplay data, a novel framework is conceived. The new framework can be seen in the Figure 4.

This new working framework, named Design Styles Neuro-Affective Classification (DSNAC) Framework, is to classify Abstract and Realistic gameplay data set and prepares the resulting emotional responses in a valence and arousal spreadsheet. The emotional responses can then be further analysed statistically for better understand the effects of Design Styles.

The DSNAC framework can be adapted to accommodate other parameters besides gameplay data as well. For instance, the gameplay activity used in this framework can be replaced with other activities such as an IQ or stress level tests. The process of classifying emotional responses from unstimulated activity remains the same. DSNAC is basically the core of this research, in which it is also the main contribution to the field of computer science and games design.

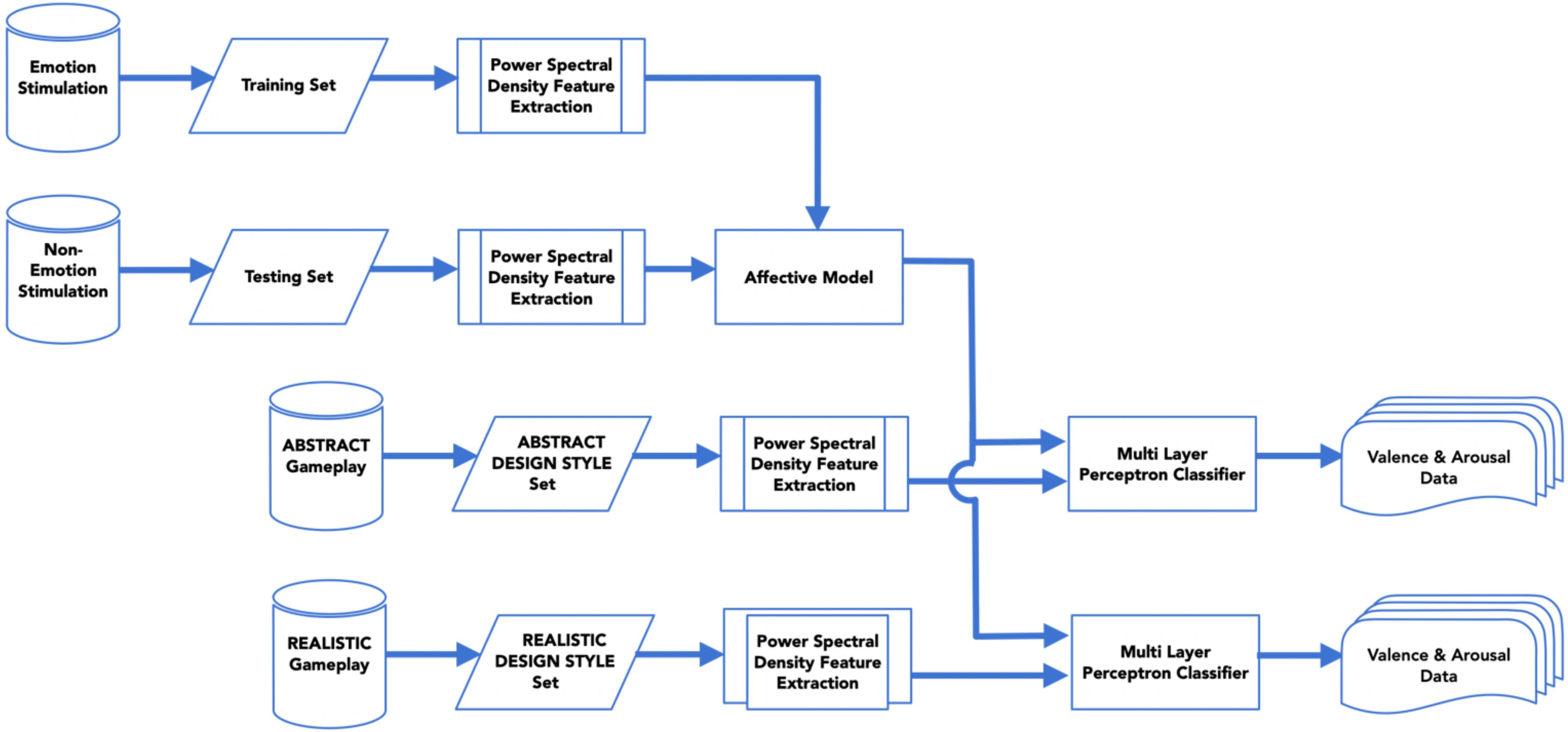

Fig. 4. The Design Styles Neuro-Affective Classification (DSNAC) Framework, based on the neuro-affective computational model

DSNAC is designed around a proven and tested working framework. The components that build up DSNAC consist of a combination of feature extraction and classifying algorithm that yields high accuracy results. It is expected that the prediction of emotional responses by this novel framework is higher than 90 percent. For high data sampling rate (250 samples per second) that will generate thousands of data count, 90 percent is more than adequate to reliably classify unknown data.

DSNAC is also modular in design. Much like a prefabricated component of a building, the framework has the flexibility to be used for a lot of other analysis constructs. If required, a third or more gameplay data from different levels of realism in the Design Styles spectrum can be added to the framework. Modular design also made debugging errors much easier and a more organized way. Since each module operates independently, errors will not affect other modules easily.

The modular design of DSNAC is contributed largely from the way the source code is written. Built using Python programming language, each component in the DSNAC framework is executable separately and individually. Parallel processes for multiple subjects are also possible, speeding up the classification process for analysis.

The only drawback to these features is that the framework has no user interface designed in it. To operate, the source code has to be executed via an IDE (Integrated Development Environment). The IDE used in this research is the Microsoft's Visual Studio Code. The Python packages were installed via Anaconda software, for better management of Python modules. The Spyder IDE was also used initially but only for testing.

4. Data Collection

After the data collection has been completed, 15 participants took part in the experiment. Following the strict steps and protocols of acquiring quantitative data for analysis, each participants contributed a set of 14 EEG data files. A total of 210 raw EEG data were acquired for analysis from all participants. These data are in numerical spreadsheet format (*.csv), and yielded 28 arousal and valence responses data sets after they have been processed with machine learning classification. Final output of machine learning classifications using Python programming yielded 420 emotional dynamics data files.

The objective of this data analysis is to classify EEG data collected from subjects into emotional valence and arousal responses. It is also to understand, once the classification process is successful, the effects on valence and arousal when playing two video games of distinct design styles. The final analysis results are hoped to be able to provide the understanding of what it takes to fully maximize the design potential of video games by choosing the right design styles.

Accuracy analysis was the gateway for the rest of the quantitative analysis in this research. Without validating that the computational model works, other aspects of this research analysis would have been questionable. While figures of more than 90 percent on prediction success of the emotional model may sound like a high accuracy, pure numbers are meaningless if it is not put into context. When the results were visualized through scatter plots, clear separation between different emotions are evident. This is proof that the classification method works.

5. Data Analysis Results and Findings

Results from these analysis show evidences of designs styles influences over the subjects' brain activity. Although there are no changes in emotional categories – happy, calm, fear, and sad, the intensity and agitation showed some distinction. Much of the characteristics of the emotional behaviour are in line with other researches [6-8].

One of the first thing to notice in the data samples for both Design Styles is the difference in overall positive valence data count. It is apparent that for Abstract design, subjects showed a more frequent positive emotional valence than they would when playing Realistic games. The high sampling rate in this research means the data count statistics is significant. An average of 19 percent higher data count is observed to be inclined to stimulate positive valence when playing Abstract designed video game. The highest statistic is as high as 113 percent while the lowest is 1 percent higher count in positive valence associated with Abstract Style.

The next thing to notice is the foot print size of the data spread in a scatter plot of valence vs arousal. Abstract Design Style consistently shows larger area of data distribution compared to Realistic Design Style. Further investigation requires a box-and-whiskers plot analysis. Consequently, the fluctuation behaviour can be studied along the timeline when the games were being played.

The level of fluctuation of each Design Styles influences the emotional responses. Abstract style seems to provoke higher agitation and more erratic rate of change than Realistic game. In Figure 5, a typical graph of data streams for both Abstract and Realistic Games is shown alongside its corresponding box-and-whiskers plot. All other subjects exhibit similar emotional dynamics.

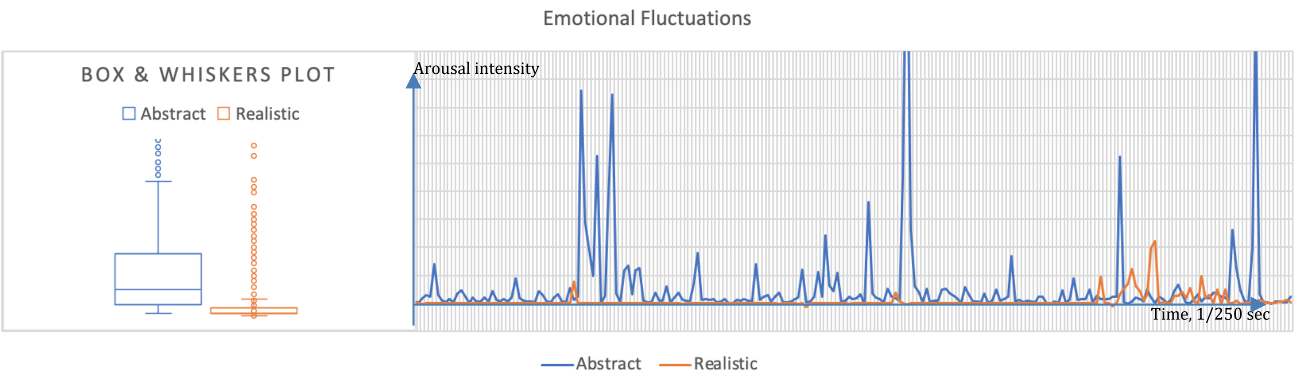

Fig. 5. Emotional fluctuations between Abstract and Realistic Gameplay

It is apparent that the fluctuation of Abstract game play is higher than Realistic game. The box-and-whiskers plot indicates that the higher agitation translates to larger data spread. This means faster rate of change, lower density, more erratic behaviour. In contrast, the smaller data spread means a steadier and more stable fluctuation of emotional levels.

The box-and-whiskers analysis further exposes even more behavioural patterns of the valence-arousal responses when the data set is scrutinized in one-minute intervals. Additionally, cumulative of every one-minute average responses were also studied. These analyses exhibit erratic fluctuations for Abstract Design and a smoother fluctuation for Realistic Design Styles. Figure 6 and Figure 7 both demonstrate the difference in emotional responses between Abstract and Realistic in one-minute intervals and cumulative per minute analyses respectively.

In Figure 6, the box-and-whiskers A1 to A5 are form Abstract gameplay dataset. While R1 to R5 are the Realistic data set. Each box represents data distribution within one minute. As the Figure 5 shows, the Abstract gameplay has a much more dynamic changes of data distribution per minute than Realistic gameplay. For Realistic design, the box size is homogenous, indicating stable and sustained emotional condition.

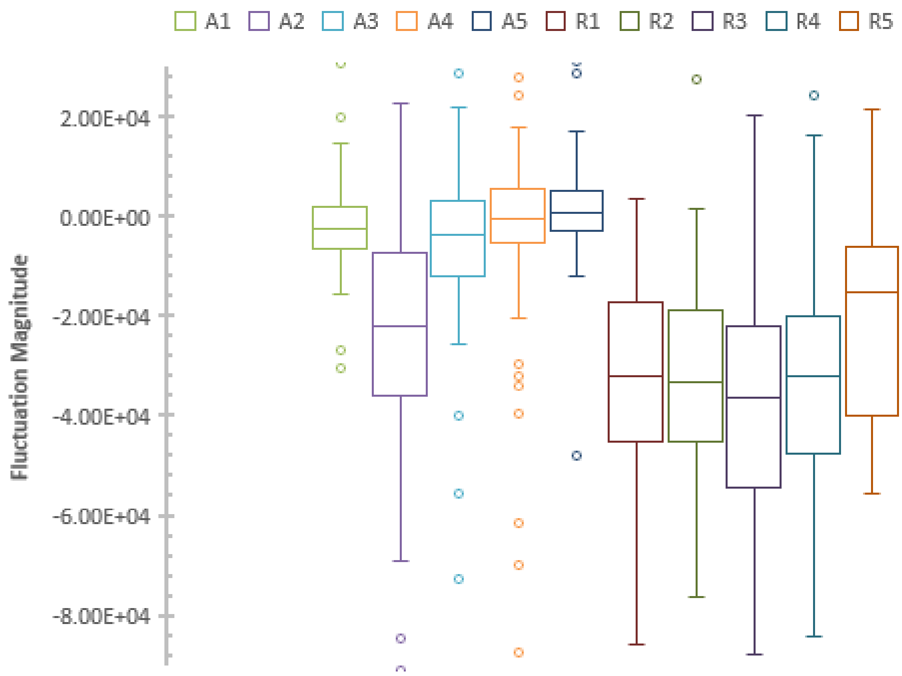

Fig. 6. Emotional fluctuations observed in one minute interval

In Figure 7, each successive box-and-whiskers plot is a cumulation of every one minute of gameplay. The Abstract dataset A1 to A5 show gradual but relatively large changes in emotional fluctuation. On the other hand, Realistic data set R1 to R5 show constant data distribution, therefore implying that Realistic Design Style sustains more stable emotions, reluctancy to changes, and stimulate a constant state of emotional responses.

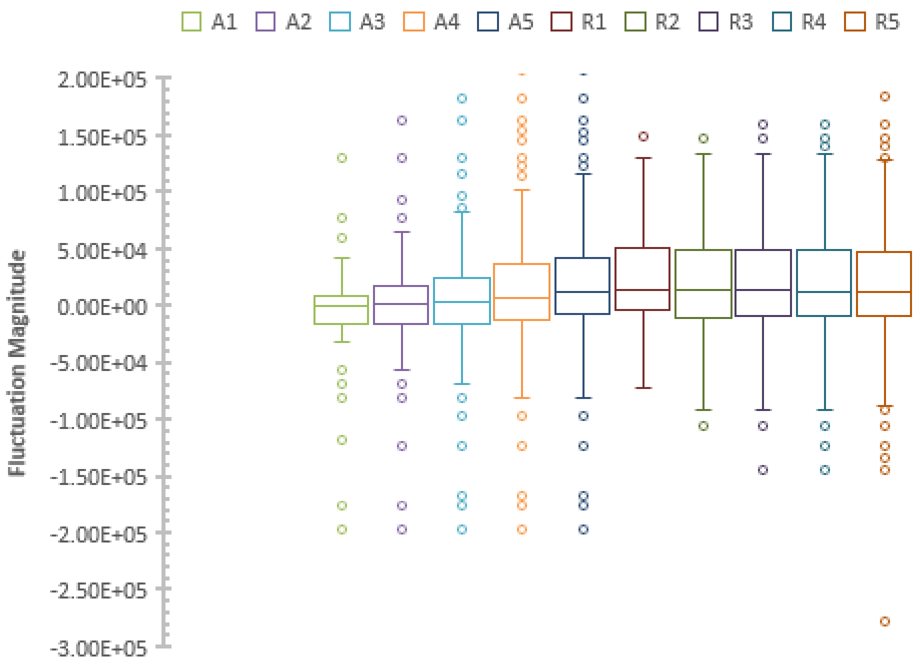

Fig. 7. Emotional fluctuations in a cumulative per 1-minute

In a nutshell, Abstract design is prone to high agitation, erratic changes, and higher average intensity. Realistic game, on the other hand, is more consistent in sustaining a particular emotions level, has smoother transitions when changing levels, and has lower agitation than Abstract Games. Figure 8 visualizes the emotional behaviour within the Design Styles spectrum at a glance.

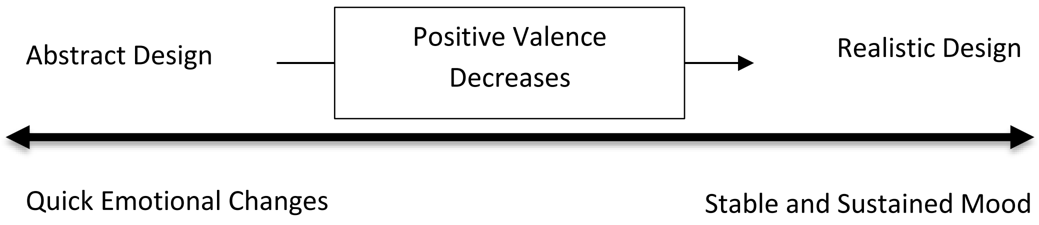

Fig. 8. Relationship between Design Styles and emotional dynamics

Indeed, different Design Styles stimulate emotions to behave differently. Conveniently, the findings exhibit emotional dynamics which can be estimated or approximated in the Design Style spectrum. Apart from the visualization of the findings, the Table 1 summarizes the research findings.

Table 1
Research Findings Summary

	Abstract	Realistic
Emotional state	Mostly emotional state does not change. But to the few bandwidths that does change, it only changes on one of the AV axis and not both. No correlation with specific emotions. Each subjects varies emotionally.	
Arousal and Valence	Higher positive valence count.	Lower positive valence count.
Emotional Fluctuation	High fluctuations	Relatively lower than Abstract
Fluctuation changes in every minute	Erratic and abrupt changes	Stable and progressive changes

Specific cognitive functions such as memory, literacy, and reasoning are present within the game playing session, indicating a sub-conscious activity from the game that was not purposely designed to stimulate them.

Deviation of arousal responses reveals that ‘appeal’ of the design styles depend on the person, not an influence resulted from the design styles. It points out that in the end, design styles may influence certain specific cognitive activity, but they are not substitutes for the designer’s artistic ability to make good design.

6. Conclusion

In conclusion, EEG based research experiment provided the opportunity to delve in deep into the human mind to explore new insights on how video games affect emotions. Although current video games production workflow does not include the understanding of emotional behaviour, the insights that it provides can significantly improve the way games are developed. Particular dynamics profile of the valence and arousal responses correlates to particular level of realism in the game’s renderings.

The novel framework is undoubtedly the biggest contribution of this research. Using the combination of IAPS stimuli, Power Spectral Density feature extraction, and Multi-Layer Perceptron machine learning classification process, the effectiveness of the framework is above 90 percent. It can successfully classify unknown emotional data set and is modular enough to be adapted for future research.

Abstract Design Style is keen on agitating emotional response much more rapidly. Such graphical approach to visual communication is suitable for short storytelling, high engagement, intense action, and relatively short gameplay. On the other hand, Realistic will be much more suited for enduring suspense, serious narrative, and longer gameplay scenario.

Future recommendations include adapting the same framework for other aspect of video game designs. Among other things, audio design, colour schemes, and frame rate can be the context of research instead of Design Styles. This research can also be repeated to potentially investigate specific subject group involving autistic conditions or colour blindness issues. With the advent of A.I. technologies, this framework can further be developed to work in real time [18]. With real-time capability, it can be used to enhance Virtual Reality (VR) application design since VR effectiveness is influenced by the degree of realism in its content [19].

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