

ANALYSIS ON VIDEO GAMES DESIGN STYLES BASED
ON NEURO-AFFECTIVE COMPUTATIONAL MODEL

BY

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A thesis submitted in fulfillment of the requirement for the
degree of Doctor of Philosophy Computer Science.

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ABSTRACT

Visual elements in video games contribute to a huge factor in design decision of the production. This research explores the science behind the psychology of design styles in video games via quantitative analysis. Previous works studying design styles and their influence over the human mind lack quantitative analysis. Their approach of using subjective experiments do not accurately provide a clear picture of the design-psyche relationship. Current guidelines for designers to decide design style is vague, relying on traditional formula of using shapes as symbols for psychological influences. In particular, affective responses towards particular Design Styles were never understood. Thus, an analysis of Design Styles using Electroencephalogram (EEG) to study its effect on the human emotions is proposed. Classifying EEG data via machine learning allows accurate numerical analysis of Design Styles and their affectivity. The findings enable the understanding of the cause and effect between design and emotions. It can help designers exploit their design potential and the research framework will be a significant contribution in the field of computer science. Subjects play 2 video games of distinct design styles – abstract and realistic - following a strict research protocol for EEG experiments. EEG data sets collected include brain's cognitive functions, stimulated emotional responses, resting state, game playing sessions, and post-experiment state. These numerical measurements are classified using machine learning by applying a known computational model that was constructed from stimulated emotional responses. IAPS serves as the instrument for emotional stimulation. Computer models of valence and arousal are generated through PSD feature extraction while MLP algorithm is applied for the machine learning classification process. Tables and spreadsheets are then laid out for statistical analysis to correlate design and the human psyche. Results from these analysis show evidences of designs styles influences over the subjects' brain activity. Indeed, 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. While the emotional state never changed between the two different games, the intensity and mood certainly show some distinctions. It seems that arousal intensity are more responsive towards abstract than realistic design. Positive valency also showed its association with abstract design. On the other hand, realism seems to be associated with stable and sustained mood. 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.

ملخص البحث

تساهم العناصر المرئية في ألعاب الفيديو كعامل كبير في قرار تصميم الإنتاج. يستكشف هذا البحث علم نفس أساليب التصميم في ألعاب الفيديو من خلال التحليل الكمي. حيث تفتقر الأعمال السابقة التي تدرس أساليب التصميم وتأثيرها على العقل البشري إلى التحليل الكمي ويستخدمون نهج التجارب الذاتية الذي لا يوفر بدقة صورة واضحة للعلاقة بين التصميم والنفسية. الإرشادات الحالية للمصممين لتحديد أسلوب التصميم غامضة، وتعتمد على الصيغة التقليدية لاستخدام الأشكال كرموز للتأثيرات النفسية. ولم يتم فهم الاستجابات العاطفية تجاه أنماط تصميم معينة على وجه الخصوص. وبالتالي، يُقترح تحليل أنماط التصميم باستخدام مخطط كهربية الدماغ (EEG) لدراسة تأثيره على المشاعر البشرية. يسمح تصنيف بيانات EEG عبر التعلم الآلي بتحليل رقمي دقيق لأنماط التصميم وتأثيرها. حيث تمكن النتائج فهم السبب والنتيجة بين التصميم والعواطف. ويمكن أن يساعد المصممين على استغلال إمكاناتهم التصميمية وسيكون إطار البحث مساهمة كبيرة في مجال علوم الكمبيوتر. يلعب المشاركون لعبتي فيديو بأنماط تصميم مميزة -تجريدية وواقعية- ويتم اتباع بروتوكول بحث صارم لتجارب EEG. تتضمن مجموعات بيانات EEG التي تم جمعها الوظائف الإدراكية للدماغ، والاستجابات العاطفية المحفزة، وحالة الراحة، وجلسات اللعب، وحالة ما بعد التجربة. يتم تصنيف هذه القياسات العددية باستخدام التعلم الآلي من خلال تطبيق نموذج حسابي معروف تم إنشاؤه من الاستجابات العاطفية المحفزة. يعمل نظام الصور العاطفية الدولي IAPS كأداة لتحفيز العاطفي. ثم تم إنشاء نماذج الكمبيوتر للتكافؤ والإثارة من خلال استخراج ميزة الكثافة الطيفية للقدر PSD، بينما يتم تطبيق خوارزمية متعدد طبقات المستقبلات MLP لعملية تصنيف التعلم الآلي. ثم تم وضع الجداول وجداول البيانات للتحليل الإحصائي لربط التصميم والنفسية البشرية. تظهر نتائج هذا التحليل أدلة على تأثير أنماط التصميم على نشاط دماغ الأشخاص. في الواقع، توجد وظائف معرفية محددة مثل الذاكرة ومعرفه القراءة والكتابة والتفكير داخل جلسة اللعب، مما يشير إلى نشاط غير واع من اللعبة لم يتم تصميمه عن قصد لتحفيزهم. في حين أن الحالة العاطفية لم تتغير أبدًا بين اللعبتين المختلفتين، إلا أن الشدة والمزاج يظهران بالتأكيد بعض الفروق. ويبدو أن شدة الإثارة أكثر استجابة تجاه التصميم التجريدي من الواقعي. أظهر التكافؤ الإيجابي أيضًا ارتباطه بالتصميم المجرد. من ناحية أخرى، يبدو أن الواقعية مرتبطة بمزاج مستقر ومستدام. ويكشف انحراف استجابات الإثارة أن "جاذبية" أنماط التصميم تعتمد على الشخص، وليس التأثير الناتج عن أنماط التصميم. ويشير إلى أنه في النهاية، قد تؤثر أنماط التصميم على نشاط معرفي معين، لكنها ليست بدائل لقدرة المصمم الفنية على تصميم جيد.

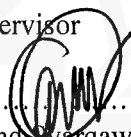
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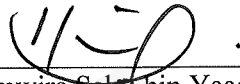
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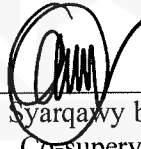
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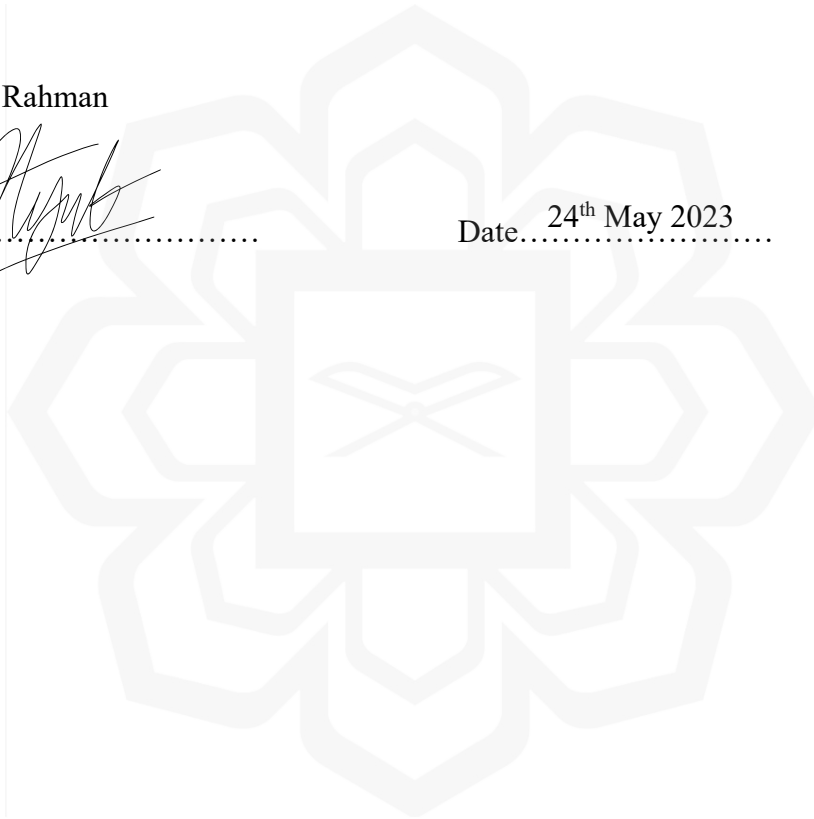
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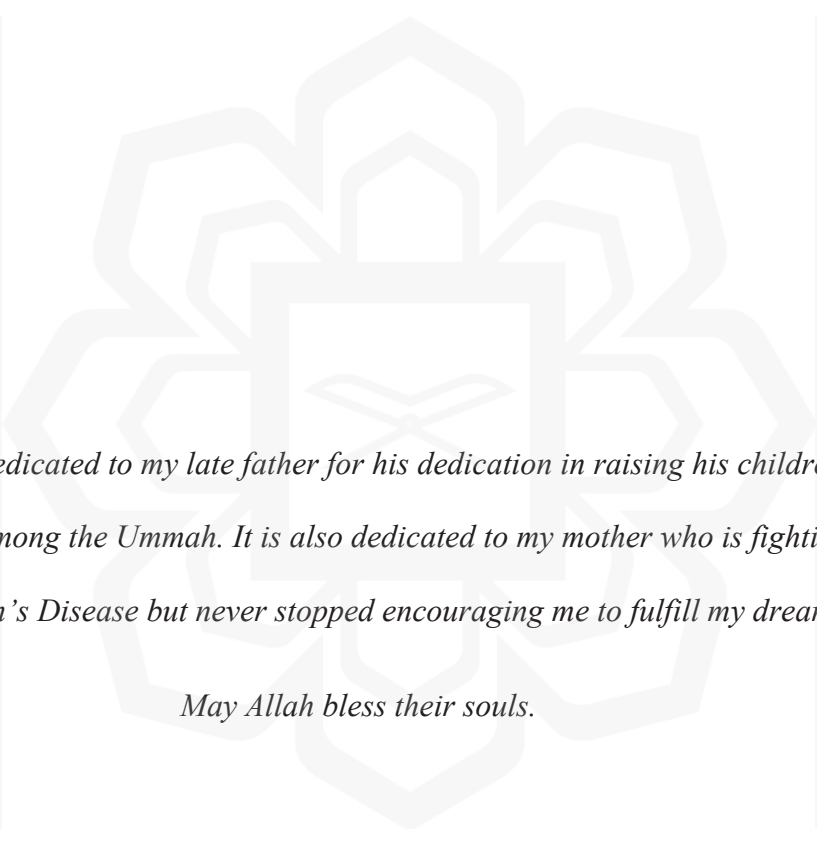
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This thesis is dedicated to my late father for his dedication in raising his children to be the best among the Ummah. It is also dedicated to my mother who is fighting Parkinson's Disease but never stopped encouraging me to fulfill my dream.

May Allah bless their souls.

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DEFINITION OF TERMS

1. Design Style is defined by the level of realism in the rendering of the virtual world in video games. Sometimes it can also be termed as Graphical Style (Carter, 2016). Throughout this research, the context of Design Style is video games visual design. This is to contrast the term Design Style used by architects and interior designers.
2. Machine Learning is an automated process of complex tasks in analyzing data. It can also be referred to as Artificial Intelligence (AI). However, the term AI may mislead to the idea of computational awareness that is usually associated with robotic design. This is not the case for this research. The Machine Learning process used in this experiment is a classification process of interpreting and predicting data.
3. Valence is an emotional dimension that refers to the positive and negative acceptance.
4. Arousal is an emotional dimension that refers to the intensity of the emotions.
5. Neuro-Affective is the emotional valence and arousal responses emitted by the brain through pulses of small electrical signals. This is a natural phenomenon. The signals can be detected and recorded, thus providing data for numerical analysis
6. Electroencephalogram (EEG) is a technology that allows brain signals to be recorded, measured, and analyzed.
7. Computational Model is the numerical and algorithmic references of a known data that serves as the baseline to predict unknown data. It is important to have a computational model to translate raw data into something meaningful for analysis. Computational Model can be obtained through the process of Feature Extraction.
8. Feature Extraction is an algorithm to acquire computational model of stimulated data. It is one of the key components to allow classification process to work.
9. Cognitive Functions are the many aspects of the human brain functions to perform cognition tasks.

CHAPTER 1

INTRODUCTION AND RESEARCH BACKGROUND

1.0 INTRODUCTION & BACKGROUND INFORMATION

In the age of the Fourth Industrial Revolution (IR4.0), video games have become one of the most popular and profitable business. According to the statistic portal, Statista (statista.com), in the Apple App Store alone, 12.68% of the most downloaded apps by 3rd Quarter of 2022 are games. This figure is significant, because the next most downloaded apps are in the business category, which is only 10.35% of total downloads. While parents may have concerns over the effects of games on their children's growth, they are so common that no one can ignore. It is thus important to understand the effects of video games design on the players.

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 (Mori, 2012). On the other hand, exaggerated proportion of the stylized design styles may be attractive to younger audience such as cartoons for children (Ben-Zvi et al., 2016). Clearly, different design styles has different psychological effects to the audience.

Since design styles can influence the mind and emotion (Khairuddin et al., 2014), learning acquisition skills are also affected. It is the effects on the learning aptitude that this research is focused on. While there exist video games designed to be 'educational' from the ground-up, the interest here is whether the 'non-educational' games has any effects on the learning aptitude at all. After all, around 95% of the games available in the market today are purely designed for entertainment rather than educational.

1.1 HISTORY AND DEVELOPMENT OF DESIGN STYLES.

The history of design styles started during the days of traditional animation. In the 1930s, animators (mostly by Disney) made animated films and cartoons by hand drawing. To achieve the effects of “persistence of vision” – thus creating the illusion that the drawings are moving and acting – animators had to draw a lot of drawings (Johnston & Thomas, 1981). A one second motion would take around 12 to 24 drawings (Williams, 2009). An hour feature film would take 86,400 drawings and that is just for one moving elements/character in the scene. A scene may contain more than one characters to be animated.

To simplify the drawing process, Disney animators designed their characters to be easy to replicate and hand drawn over and over again (Bancroft, 2006; Boot & Hommel, 2015). Their technique is part of the twelve principles of animation, known as ‘solid drawings’(Johnston & Thomas, 1981). This concept forces the animators to draw characters in volumes and consistent geometric structure underneath a detailed design. All of the iconic characters by Disney were designed like this: Mickey Mouse, Donald Duck, Goofy, etc. Thus, an abstract design was born. For years (and even now) animators adopted this technique including those by Warner Bros. who created Bugs Bunny and Daffy Duck.

However, cartoons characters with realistic proportions and forms made their appearance with the invention of a new technique called Rotoscoping. During these times, films were cheap enough to be made so that real life actors can be traced over and animation characters can take the form of realistic human shape.

Rotoscoping made animation production a little easier but it has major flaws. First, it cannot be made appealing due to the realistic movements in which it was traced over. Drawings, even when traced over a real sample, cannot be detailed enough to convey realistic motions. Cartoons with abstract design often has exaggerated movements to make it more interesting and attractive. This is the first sign of the ‘uncanny valley’ effect which will be discussed later in this thesis. Second, the rotoscoping technique cannot adapt the twelve principles of animation which creates the illusion of life (Johnston & Thomas, 1981). Principles such as exaggerated movements, squash and stretch, and staging are very hard to be adopted to rotoscoping technique. Finally, rotoscoping technique simply does not have the freedom of creativity that abstract design allows.

Over the years, technology and techniques evolve. They also merge, adapting Rotoscope with the animation principles as the main structure. Design also evolve, and a style between abstract and realistic was conceived. For instance, in Asia the most popular and appealing stylized character design is the Japanese anime. Somewhere between a simplified geometric shapes and realistic human proportions (particularly female characters), anime has fans all over the world.

Primarily, design styles evolve and developed side by side with techniques and technologies to make them. Abstract design has always been a starting point and the realistic design has always been the goal. Current technologies no longer pose any limits to character designs. Similar milestone also happened to other art medium such as puppeteering and 3D “virtual reality” video games. However, today, the technology to digitally ‘sculpt’ any 3D shapes in virtual space is so advanced and intuitive, designers are no longer constrained to limit their ideas. They instead use design styles based on conceptual needs. For instance, designers of the game *Team Fortress 2* adopted stylized characters so that their characters are instantly identifiable even in silhouette (McMahan et al., 2015). It is at this point that the awareness of design styles’ effect to the player’s mind, emotions, and other behaviors are not fully understood.

1.2 SIGNIFICANCE AND BENEFITS OF RESEARCH FOR GAME DEVELOPERS, DESIGNERS, AND THE INDUSTRY AS A WHOLE

In principle, when conceiving video games with specific target audience, design styles should function as one of the important visual elements that stimulate the player’s mood to tune-in to the proper mind set for the game’s intended concept. For instance, colorfully stylized characters suggests children related content. Alternatively, desaturated realism hints at horror themed genre. Design styles communicate to the consumer well before they play the game. Apart from visual communication, the pursuit of realism to attract as many audience as possible is also major factor in the video games industry. The technological advancement of these top rated games such as *Grand Theft Auto V*, *Metal Gear Solid V: Phantom Pain*, *Call of Duty: Modern Warfare*, and *Cyberpunk 2077* is so high that it is difficult for the untrained eye to distinguish between computer generated image (CGI) and image of reality.

However, these design styles can be mis-matched on purpose to create a new breed of content. Adult oriented content can also be made to look stylized and colorful, and children's content consists of realistic looking characters. There are also top tier games that did not recreate realism for attraction – games such as *Fortnite*, *Team Fortress*, and *Loadout*. Those games could have taken advantage of the powerful graphic technology to achieve realism. Instead, they had gone to the stylized route to create fun and enjoyable images of their products. In fact, in the case of *Team Fortress*, the designers purposely use stylized design to create highly memorable characters (Mitchel, 2007). They made it so that the players instantly recognize the characters in any angles, even in silhouette.

While design styles cue the consumer about the content of the video games, it can sometime be misleading (Carter, 2016). Parents may mistake games for children for games for adults. Games that are interesting at the few rounds of play may lose replay value and therefore its shelf life. Some games simply look outdated and dull. Not to mention the cost of creating realistic games may take a huge amount of money and designers' skills – only to find out that the pursuit of realism may not be worth it.

Realism in video games graphics also has a big problem. Historically, and studied by other researches (Mori, 2012; Geller, 2008; Schneider, 2007), realistic renderings of computer generated human (or human-like characters) has the tendency for giving a repulsive reaction to the audience. This reaction is known as the “uncanny valley phenomenon”. The uncanny valley refers to the valley-like curve of the likeness or pleasantness of the viewer when looking at a realistic looking artificial characters. It shows that as the character is closer to looking like a human, the interest and arousal increases until at a certain point where the curve suddenly drops. Having the game designed within the uncanny valley would be catastrophic, since no one wants to even look at the game. Let alone plays and buys it.

As a consequence, the full potential of the video game may not be exploited and benefited by the design styles they used. Contents may be misled by the wrong visual themes. Interesting and challenging games may lose their worth because they simply do not look promising. Those top tier games invested a lot to reach ultimate realism in graphics may not achieve the ultimate gaming experience as the design suggests – and lose money in making

them as well. Losing audience, high costs, and misunderstood contents are some of the issues that contribute to the failure of a production that, at concept stage, may have high potential.

The problem, then, stems from the lack of understanding of design styles and how it affects the players (Lee, 2018). In the context of video games, it is usually the correlation with emotion of playing the game that is important. Emotional responses helps make the game more enjoyable and motivates the player to grind and overcome the challenges. In particular, the emotional valence and arousal are the two quantitative constructs that can be measured for research. Thus far, there are no studies that relates design styles with emotional valence and arousal.

The biggest concern of this research is how it is going to contribute to the growth and development of the video game industry. It is also to be highlighted that the body of knowledge that this research discusses has a high significance in the design community. Most importantly, the contribution of this research can be a valuable asset for designers, developers, researchers, and the video games economy.

1. Significance

- a. Quantitative analysis and understanding via machine learning of the effects of design styles on video game players. This approach has the advantage of obtaining emotional information directly from the brain, eliminating misinterpretation from the subject's verbal feedback.
- b. Correlation of design and brain activity, specifically the cognitive functions. Since the data obtained is quantifiable data, correlation between Design Styles and brain activities extracted from EEG is possible.
- c. Emotional responses affected by different Design Styles, thus allowing the study of design-player relationship through neuro-affective model. By understanding this relationship, designers have the potential of being empowered to enhance the effectiveness and value of their design.

2. Benefits

- a. Adding factors to design decisions enabling developers to evaluate their projects effectively. The most gain can be obtained by channeling the right