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Virtual Museum in Chromesthesia Perspective as an Act of Education Sustainability

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ABSTRACT
This study aims to examine chromesthesia in a virtual museum as consideration for exhibition media design in terms of information accuracy. As one of the information resources, museums have several purposes; one of them is educational purposes. In this regard, museums need to provide holistic information to visitors. Furthermore, as an act of archiving and digitizing art, museums are also working on various digitizing processes and present virtual museums; however, this limits virtual museums to provide audio and visual approaches only. This condition makes virtual museums unable to accommodate several visitors' needs, such as those with chromesthesia. Chromesthesia is a neuropsychological phenomenon in which a person can perceive colors through the audio they hear. The case study uses Van Gogh Museum (VGM) virtual tour as a sample of a virtual museum that documents paintings on video with additional audio. The results obtained from this study are differences in color perception of the media and exhibition objects due to the audio elements provided, such as frequency, pitch, and tone. These findings consider providing audio that does not interfere with the color perception match of people with chromesthesia as an act of education sustainability.

Keywords: *Virtual museum, Display media, Chromesthesia, Audio-color association.*

1. INTRODUCTION

The COVID-19 pandemic has temporarily forced the educational system to close most institutions and change into a new system. Since 2020, this condition has impacted more than 91% of students around the world [1]. Regarding this, the United Nations is now leading SDG actions; one of the topics is Quality Education. UNESCO also adds that education for sustainable development means allowing every human being to acquire knowledge, skill, attitudes, and values for a sustainable future [2]. According to it, one of the goals is to build and upgrade education facilities that are child, disability, and gender-sensitive and provide safe, nonviolent, inclusive, and effective learning environments for all [1]. Adapting to this condition, the UN suggests including media and IT partners in the educational system [1]. As one of the educational resources, museums should follow this situation, such as virtual museums. In terms of this, museums should be inclusive and obtain the sustainability of education. As designers, this understanding could be used as a foundation for designing inclusive museums.

The experience in a museum is multi-layered, containing proprioceptive, sensory, intellectual, aesthetic, and social experiences [3]. Therefore, museums could provide multisensory experiences, and also offer holistic information for their visitors. In addition to multisensory experiences, museums are expected to provide information virtually. However, most virtual museums only provide visuals and audio information that have undergone a digitalization process.

The phenomenon of chromesthesia, which is also a multisensory phenomenon, allows the translation of information from audio into color. However, unlike people in general, a condition is owned by a small number of humans called chromesthesia. Chromesthesia is a neuropsychological phenomenon of perceiving color as an additional sensation from the heard audio [4]. By knowing this, we hope the chromesthesia mechanism can be considered in the design of a virtual museum to provide a multisensory experience and accurate information. Accordingly, having a further discussion due to chromesthesia in the context of a virtual museum is essential to enrich sustainability in

education, especially in presenting the right audio to help color information in the exhibition media.

2. THEORETICAL REVIEW

2.1. Virtual Museum and Education Sustainability

Quoted from Andre [5], museums' function is not only for storing and preserving historical values but also for learning purposes [6]. Today, integration between the pedagogical process in educational institutions and the culture is turning into a trend [5]. Moreover, based on research conducted by DCMS University of Leicester in 2004, museums complement formal education when pupils are off the curriculum, and 94% of teachers said museums were necessary for their teaching. Since the pandemic started in late 2019, most museums have changed their visiting approach into a virtual one; therefore, museums' function as educational institutions are still feasible [7].

Concerns about virtual museums as the most attainable and educational potential scheme of culture also demonstrate that virtual museums can be expressed as a pedagogical technology [5]. Furthermore, the latter is a communication medium for disseminating cultural heritage based on information and communication technologies. Referring to one of the SDG points, Quality Education, applying virtual media and technology in the museums, is an act for education sustainability.

Hence, using technology, virtual museums implement their assimilation through accelerated attractiveness and emotional recognition. The material appears to include informational text and also scientific and literary text [5]. Additionally, information brings in the features of representativeness, multilayer, interdisciplinarity. Accordingly, in response to this matter, virtual museums should acquire comprehensive materials which will lead to inclusivity.

2.2. The Process of Receiving Information at the Museum

Humans are creatures with visual dominance; therefore, it is easier to think and imagine visually [8]. In addition to visuals, they also use audio sensors (sight and hearing) as two modalities that dominate human imagination for design [8]. Therefore, how the space can direct the sound is also essential even though it is generally aimed to avoid noise.

The sensors that humans perceive continuously influence each other, although most are unaware of these cross-sensory interactions. In this case, there is a rule called multisensory integration with dominance, super additivity, and subadditivity [8]. However, more than that, human perception is not only a combination of each modality (visual, audio, tactile) but perceived as a whole [9]. Moreover, we can add multilayered and multisensory experiences to achieve a holistic perception.

Humans receive information in the museum through the eyes as the sense of sight. It is the same with people who turn a blind eye to musical performances to enjoy music better. This occurred as the human brain works based on various modalities. This effect is called the cross-modal effect, which provides the quality of experience experienced by individuals. Therefore, a consideration of what types of artwork are displayed must accompany the design of the museum space. Art is inseparable from how we experience it, and a crucial part of that experience is the space where it is placed [10].

Human attitudes and habits in perceiving space are related to physical and psychological conditions [11]. Therefore, space design must also consider human character [11]. The change in space from physical to virtual also means a change in the perception of various existing manifestations, including objects placed in virtual space. The term 'virtual' means intangibility, non-existence, and loss from contemporary society [12]. Compared to physical space, some contrasting phenomena cannot occur [13]. This virtual space exists by itself, with or without association of physical space [12]. Stahre et al. [13] stated that producing accurate color perception is always a problem for two reasons: how to simulate the interaction between light and material and how to simulate the human perception of color.

Calculating the reflected light can help the translation process of colors change into digital entities to simulate the interaction between light and material [13]. Meanwhile, to simulate human perception in a virtual space, computations can be done on a physical model.

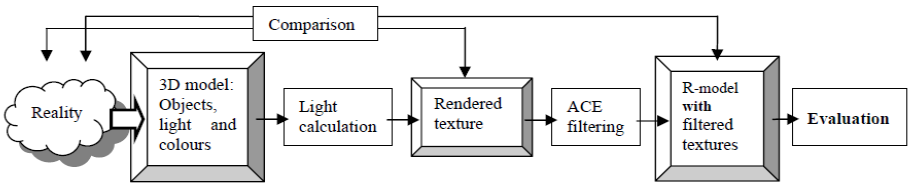

Figure 1 Physical object translation process to virtual objects [13].

In the process of displaying objects virtually from physical objects, it is not only necessary to translate the object's form but also the color. There needs to be an interaction between the light source, the reflected object, and the medium of processing color. The medium becomes the most crucial aspect in this translation process, considering the space where the object placed is very different. Objects perceived through the five senses are now limited to audio and visual presentations.

In addition, the quality of the tools used to capture this information also varies. According to Stahre et al. [13], three things become problems in presenting this virtual information: (1) Errors in the resulting reflection, (2) different lighting simulations may result in different information, (3) errors in the reproduction of contrast effects and too slight color variation; for example, a room that should be white is perceived as gray. Based on this, Stahre et al. [13] proposed a filter that can simulate human vision.

Additional information as support is needed considering the possibility of color information inaccuracy. As a multisensory phenomenon, chromesthesia can be set as one of the considerations in designing a virtual space by considering audio input that can support color information.

2.3. Chromesthesia's Perspective on Receiving Information in a Virtual Museum

Chromesthesia is a phenomenon of adding color sensation to the stimuli received [4]. In chromesthesia, the sensation that appears is the appearance of color perception from the heard audio. This phenomenon does not mean that chromesthesia, people with chromesthesia, lose their ability to receive audio stimuli. They perceive colors as different sensations instead. Perceived color also gives a certain feeling, as audio heard in different tones, pitches, and tempos will give specific color sensations and different feelings [14].

As one of the synesthesia phenomena, often referred to as colored-hearing synesthesia, chromesthesia generally has neurological conditions similar to other synesthetes. Therefore, the mechanism that can explain this phenomenon is cross-modal correspondence that occurs in the brain. This mechanism occurs because of the relationship between inducer (1) and concurrent (2) and multisensory plasticity. Cytowic [15] speculated that synesthesia occurs in the limbic lobe (the part of the brain that controls emotion, behavior, memory), the point where the connection between the inducer and the concurrent occurs.

Individually, chromesthesia experiences different sensations when exposed to the same trigger. However, when the chromesthesia are in a group, patterns identify the similarities in the sensations experienced [16]. This comparison may be formed as the chromesthesia is in the same environment and experiences "rules" that are formed unconsciously (unconscious "rules"). When a person with chromesthesia experiences an audio stimulus (indicated in yellow), reactions in the brain are not only perceived as they should be (indicated in blue) but also perceived in other sensory overlaps (indicated in red). In addition, the areas in the brain that are affected by stimuli also span different parts of the brain, which explains the possibility of why perception can arise from other modalities [17].

Chromesthesia generally gets a color sensation and feels certain emotions emotionally when hearing certain sounds [14]. When humans hear a sound, the brain releases neurotransmitters, which will give them certain emotions or feelings. For example, feelings of happiness arise because of the hormone dopamine, which is released in the brain when listening to certain music [14].

3. METHODOLOGY

The research takes data in a virtual tour of the Van Gogh Museum in Amsterdam, the Netherlands, as a case study. We chose the museum because it is a fine art museum that primarily exhibits objects in the form of paintings and has a virtual tour in the form of video documentation accompanied by music in each part. We expect this museum to be a suitable case study for this topic as it prioritizes audio-color elements. The data taken included general information, background music used in each exhibited section, objects on display, and the exhibition media in a virtual tour of the Van Gogh Museum, which is visited online through the official website https://www.vangoghmuseum.nl/. The Van Gogh Museum is a physical museum in the Netherlands that now provides virtual access via virtual video tours. The objects on display are paintings by Vincent Van Gogh and several other artists, which are documented in videos and music is added to each part. Van Gogh Museum divides the virtual tour into seven sections according to the sections in the physical museum accompanied by supporting audio in the form of background music.

The museum is accessed online, considering we conducted this study during the COVID-19 pandemic. We took audio data used in the virtual museum and colors in objects and exhibition rooms compared to the audio-color association process from a chromesthesia perspective. The data is then processed using three stages of analysis: the audio-color association based on the theoretical approach, an interview analysis of a chromesthesia as a resource person, and a comparison of the two results. The first stage uses the Sonic Visualizer application to visualize and measure the audio in each part. The second stage uses interviews with one chromesthesia resource person to determine the comparison between the perceived color and the applied

color. The color comparison uses the average color percentage value in RGB format. As for the third stage, we compared the two results to determine which parts are intersected to see the effect of audio placement on color.

4. RESULTS

Based on the Strategic Plan of the Van Gogh Museum 2021-2024, the Van Gogh Museum (VGM) has 205 paintings, 500 drawings or sketches, and almost all letters written by Vincent van Gogh himself. In addition, VGM also collects paintings, drawings, and sculptures from 1840 to 1920 of the associates or artists whom Vincent van Gogh inspired during his lifetime. The museum also tells about Vincent van Gogh contextually, including the time, place, and inspiration in producing the works. Around 30% of the VGM collection in the gallery was also exhibited in a virtual tour. Other works are archived because they are color-sensitive. VGM has the vision to be a museum that is inclusive and accessible to the broadest possible international visitors. The form of a virtual museum is documentation in photos, interactive sites, and virtual tours in videos. VGM enters the museum with the second approach, which uses digital media to present the services in the physical museum [12].

Displayed objects are primarily paintings, accompanied by several three-dimensional objects such as painting tools and sculptures. Most of the paintings on display are the works of Vincent Van Gogh and several other artists' works that have influenced the development process of his work from time to time. The virtual tour is directed according to the directions at the physical museum so that the virtual state exhibits objects and exhibition media as they are in their original state. In this virtual tour, different music is added to each part.

Based on the first analysis, namely sound analysis of the seven parts, the audio presented allows linear translation of several color-audio elements, including frequencies with light levels, frequencies with color choices (hue), and certain types of tones and chords. The higher the frequency, the higher the level of light associated [18]. The frequency difference determines which color choices can be associated [19]. Furthermore, the chord harmonizes various tones associated with specific colors [19-21].

Figure 2 Comparison of perceived colors and given colors in VGM virtual tour (Source: Personal illustration).

Subsequently, through a second analysis in the form of interviews, the interviewees responded that additional colors could be perceived while watching the video. This analysis was carried out to compare the colors that emerged from the virtual tour with additional colors perceived by the informants and then compare the results in percent. This comparison used RGB format for each pixel obtained from the average color for each part of the object and display media. As control variables, the color codes '000000' (black) and 'ffffff '(white) have a match rate of 0%.

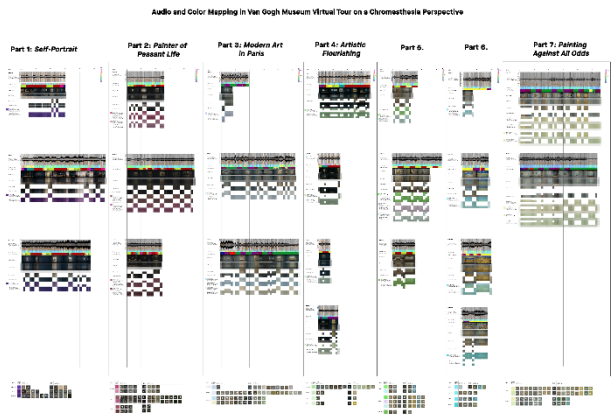

Figure 3 Audio and color mapping in Van Gogh museum virtual tour on a chromesthesia perspective (Source: Personal illustration).

The third analysis is a comparison between two former analyses. Several parts have a high degree of match between the perceived color and the color shown in the seven parts analyzed. This finding indicates that from the perspective of a chromesthesia, a mismatch between the perceived additional color and the color that should be visible can occur because the applied audio attracts their attention in the first place. In addition, the feelings that were felt explicitly by the interviewees stated that audio could be associated with certain feelings [14,22].

The association of audio and color based on the theory states that additional colors can be associated through the applied audio elements. Based on the results of association with theory, Section 3 and Section 5 have the most relevant results among the seven sections. However, compared with the interview results, the colors perceived by the informants in Section 3 have a low degree of compatibility with the exhibited object (27-82%) and are decreased (to 24-56%). Whereas in Section 5, the perceived color of the object is at a higher match level than in Section 3 (36-88%) and is still within the same range (to 42-84%) when the interviewee sees the object through a virtual tour.

5. DISCUSSION

Designing an exhibition space based on the chromesthesia phenomenon in the case study requires several considerations. Chromesthete perceives audio inducers and color as concurrent [15,23]. In audio, the uniform structure applied to each audio element becomes the primary consideration, mainly the audio frequency. Frequency relates to tone choice and how it is perceived into color by a chromesthesia [19,24]. Therefore, tone choice becomes vital in determining color perception either through association theory or from the perspective of a chromesthesia. In addition, the selection of chords, which is a collection of notes, also plays an important role. Chords aim to provide harmonization of various tones so that although individual tone choices vary, chords can unite these tones into a single particular color [21,25].

In addition, frequency, pitch, and tone can also affect the lightness of the perceived color. High frequencies tend to be associated with high lightness or value [18]. From the results of the analyses, the amplitude or volume of the sound does not affect the additional colors that the chromesthesia can perceive. In addition to the additional perceived color, audio can also be associated with certain feelings [14,22]. In this case, the resource person associates color with experiences or feelings that they have experienced so that the appearance of color is subjective and influenced by events that have been triggered intensely since childhood [16].

The level of color match between objects and display media, in this case, is different when the object is applied to the virtual exhibition space and scanned in digital form. This mismatch is probably due to the translation process in digital virtual tours causing different perceptions, apart from the audio, making the speakers feel additional colors [13]. In addition, the transfer between existing media influences the mental perception process. The chromesthesia who can also associate certain feelings when watching the video will experience a slight difference in emotional perception [26]. Therefore, this difference should consider object placement and display media with commensurate and unobtrusive audio [8,27].

6. CONCLUSION

The phenomenon of chromesthesia as a neuropsychological phenomenon related to the translation of audio into color can provide additional different perceptions for individuals who have the condition. As two elements related to the absorption of information on space, this condition makes the chromesthete's perception of space different from ordinary people. A chromesthesia will experience the added color he perceives when he hears audio, especially music.

Placing music as one of the elements to complete the virtual exhibition space in the perspective of a chromesthesia has its challenges as the music applied can give a different perception of color than its original purpose. In presenting an inclusive exhibition space, the virtual exhibition space design needs to consider this condition. Chromesthesia, a high-level ability to associate music with color specifically, can be studied through various approaches to the association of sound and color. These approaches involve structural associations of sound and color elements. Points to note include; sound frequency, pitch, and tone can be associated with the type of color and the level of color

brightness, and the configuration of the tone or structure of the music to the whole or part of the exhibition space.

Chromesthesia is not a physical visual impairment because the chromesthesia (if not indicated by any visual impairment) can see colors. However, their perception of the colors they see becomes increased or disturbed when they hear particular music or audio stimulus. In addition to color, chromesthesia is also able to associate music with certain feelings. The colors that one chromesthesia can associate with are not the same as those of another chromesthesia. Therefore, audio and color associations are carried out not to determine what colors to apply to the space but rather to compare how well the perceived colors match the colors designed. There must be equal or equivalent comparators in the associations. In this case, the association of audio and color is done in a virtual exhibition space, so the format suitable for both elements is a digital format (MIDI for sound and RGB for color). It aims to facilitate measurements according to linear parameters.

All the information analyzed shows that considering chromesthesia as a fundamental design foundation could enrich the virtual museum design. This finding allows a possibility for the museums to give holistic information, especially for chromesthesia. Therefore, the importance of this study regarding education sustainability is due to inclusivity. If the information is accessible to everyone, it could achieve a museum objective as an educational institution. A holistic approach to information distribution will lead to sustainable education.

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