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Effect of Student Emotion-Associations on Architectural Color Design of Educational Spaces in 3D Virtual Learning Environments

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***Abstract* — Research has been previously dedicated to investigating effects of traditional classroom colors on students' enjoyment, interactions and learning experiences. Students' emotional reactions towards different colors were also depicted and analyzed. However sparse research has been conducted representing analogous studies of students' color-emotional associations towards e-learning spaces in 3D virtual learning environments. This study investigates positive and negative emotional associations experienced by students due to immersion in e-learning spaces with a variety of selected interior colors. This should enable initiating guidelines for best and worst perceived color usage for design of 3D virtual learning spaces, for enhancement of students' e-learning experiences.**

***Index Terms* — 3D educational building, 3D virtual learning environment, architectural design, color of e-learning spaces, color associative memories.**

I. Introduction

The authors are presently conducting an ongoing study to determine the impact of architectural design of 3D virtual educational facilities on students' e-learning, to identify best practices for design. Integral with this study is the feasibility of investigating students' emotion associations with color design as an architectural element during immersion in their online sessions. This is due to the fact that brain-based learning occurs via the senses. What a student sees, hears, feels and smells has a significant impact on his or her learning. Color is one of the key elements in a stimulus–rich learning environment [1]. This entails initially defining the emotion associations of students with color in the physical world and thus exploring the existence of analogous associations virtually.

It should be noted at this early stage in the paper that the authors have been investigating, further to the role of color, how other architectural elements may affect the user experience in 3D virtual worlds used in an educational context. However color is the architectural design element of focus within this paper.

Color can elucidate and define space, form and structure. The function of color in design can augment and detail other visual line elements of space [2]. There is abundant indication, through research and controlled experiments on human biological and psychological reactions in different color environments [3], to support both the beneficial and hindering effects that adjustment of interior space colors of a physical space can have on a learning experience, thus highlighting the importance of color in the architectural design of educational facilities and the need for universal rules for interior space color design to stimulate users' learning [4]. Furthermore, there is extended research on emotions and psychological reactions experienced by students whilst being in different colored physical environments, supporting the same hypothesis of positive and negative effects of color on students [5].

Such work has evolved in three stages starting with: the use of color from a usability perspective, to computer supported cooperative work and Groupware applications in the 90s, to effects of color in virtual learning environments. The authors regard the 3D virtual worlds as a new application and research domain for the effective use of color which can present analogous or different results from those found in the physical world.

II. Background

Early research on color conducted by Humphrey [6] previously affirmed that to uncover the significance of colors to humans, specific studies must be conducted depicting their preferred sentiments and what colors induce them e.g. excitement, comfort. Early findings also demonstrated that red causes emotional arousal, changes in heart rate, skin resistance and the electrical activity of the brain. Intriguingly humans find red both an impressive color but also at times a disturbing one [7]. A latter experiment capturing emotional associations of school students with 9 different colors showed positive reactions for bright colors (e.g., pink, blue, red) and negative reactions for dark colors (e.g., brown, black, gray) [8]. This provided evidence for previously accepted findings by Failey et al. [9] recording an association between color choices of the learning space and the achievement of students. Optical stimulation for example was evidenced

to be caused by the use of warm colors and intensity of lighting invoking muscular tensions, respiration rate, heart action, blood pressure and brain activity. Cool colors and dim lighting brought about reverse effects such as muscle relaxation and drowsiness. Psychology of color usage for websites revealed the following sentiments in connection with different colors [10]:

- Warm colors: red – excitement and activity, pink - creativity, confidence, orange - distress
- Cool colors: green – peacefulness and harmony, blue - quiet, calmness, purple - beauty, inspiration.
- Yellow-greens are the least preferred colors, and while yellow can increase concentration and cheerfulness, it can be irritating
- Neutral: White - purity, Black – elegance, gloom

Further studies revealed an impact of specific colors on some body systems e.g. Motor Skill Activity – Red, Circulatory System – Orange, Cardiopulmonary – Yellow, Speech Skill Activity – Green, Eyes, Ears and Nose – Blue, Nonverbal Activity – Violet [11]. These effects manipulating a student's senses would hence affect the learning process and achievement.

A recent experiment was conducted with ninety eight college students depicting their emotional responses to being in a learning environment with different color hues: five principle hues (i.e., red, yellow, green, blue, purple), five intermediate hues (i.e., yellow-red, green-yellow, blue-green, purple-blue, and red-purple), and three achromatic neutral colors (white, gray, and black). The results demonstrated that the principle hues involved the highest number of positive emotional responses, followed by the intermediate hues and the achromatic colors. The color green evoked mainly positive emotions such as relaxation and comfort because it reminded most of the respondents of nature. The color green-yellow had lowest number of positive responses eliciting the feelings of sickness and disgust. For neutral colors, white attained a large number of positive responses giving peacefulness but sometimes boredom. Purple was not favored. Gray was associated with negative emotions; including feelings of sadness, depression, boredom, and tiredness [5].

Contrary to the previously declared evidence, scarce research exists that debates analogous effects for educational space colors (or design components in general) on students in online 3D Virtual Worlds [12], namely color effect on student attitude, conduct, retention, participation, enjoyment, psychological emotions, perception of room size, symbolism and augmenting space function as expressed earlier [13]. With the flourishing use of 3D Virtual Worlds such as Second Life as 3D Virtual Learning Environments (3D VLEs) for a multitude of advantageous e-learning applications [14], arose competitiveness among architects and designers to create different styles of 3D virtual buildings that range from realistic to imaginative defying all realms of reality and gravity which is absent in 3D Virtual Worlds [15]. These constructions include educational facilities and e-learning spaces to provide online campuses for many universities and educational institutions where education can be delivered within these virtual worlds. However, 3D virtual educational facilities are currently being created mainly in ad-hoc fashion, i) according to each designer's perceptions or taste, with no specific design guidelines for the different architectural components of the building including color design [16], ii) with no consideration for students' preferences, color-emotional associations or how the different design elements, including color, affect the student's e-learning experience [17]. For example, the innovative Real Life University building in Second Life, was designed as a spiral structure to enable it to re-configure its rooms' width and height based on number of users, but there was no consideration allocated to customizing design elements of the spaces, e.g. color, that would enhance the learning experience according to user demand or function of space [18].

The authors invested several months in planning and deploying pilot studies investigating effect of architectural elements in 3D virtual worlds in an educational context. One of these elements is color of virtual walls, floor and ceiling (effect of which on e-learning has not been researched before as evidenced above).

Hence this paper aims to investigate this gap by capturing extent of students' emotional associations with specific internal architectural design colors of educational spaces within 3D VLEs: by comparing i) the positive and negative emotional responses provided for being immersed in diverse colored environments, and ii) the difference between the emerging emotion reactions to virtual colors, and the previously researched emotion reactions to physical colors (according to which 3D virtual spaces are currently being designed). This gives the opportunity to issue recommendations for future color design enhancement of 3D virtual learning spaces, according to the positive reactions to virtual colors, which would subsequently encourage more engagement, participation, retention and enjoyment by students during e-sessions.

III. Research Rationale

To examine students' satisfaction and emotional associations with a diverse range of colors used in their e-learning spaces, several variables were initially taken into

consideration for their evidenced effect on student preferences for colors; e.g. culture, age, gender and even geographical region within the same country [19]. Furthermore the direction of daylight shadow thrown on the colored surfaces and time of day were found to change perception of the student for the colors of his surroundings [20]. These extraneous variables were controlled during the process of data collection as follows.

A series of controlled identical experiments were conducted using several student groups. The student sample consisted of 35 under graduates (2 groups) and 27 post graduates (2 groups). All students were from the School of Engineering and Information Sciences at Middlesex University. The 12 chosen colors represented primary hues: red, blue, yellow; secondary hues: green, purple, orange; neutral color: white; and light and dark hues (with white or black added to primary or secondary colors): light blue, light green, pink, grey, brown. These colors also corresponded to the main components of the Munsell Color System [21] and provided an even blend of warm (red, orange, yellow, brown), cool (blues, greens, purple) and neutral colors (grey and white).

Consenting participants took a complete e-learning session (according to course syllabus) within a predefined learning space inside Second Life as a representative of 3D VLEs. During the session, the colors of the walls, floor and ceiling were changed (all the same color) at regular intervals to immerse the students in 12 different color environments. At the end of the session, all participants were asked to answer four closed ended questions i) which color they remembered most from the 12 tested colors ii) what emotions were experienced during subjection to this color iii) which color they remembered least from the 12 tested colors ii) what emotions were experienced during subjection to this color.

The pilot study was structured in such a way that participants went through a series of stages familiarizing with the environment before acquiring the required skills. The aim was to ensure the learning environment became a comfortable setting for the students. It was critical to ensure that perception of architectural elements was not affected by lack of experience or novice users. The pilot studies did not alter the learning outcomes of the course students participated in and focused only on the transition of certain learning tasks in the university buildings in Second Life.

The students were given the following list of emotions to choose from to answer the above questions. Positive emotions: comfortable, attentive, pleased, lively. Negative emotions: tired, bored, irritated, sleepy. These emotions were selected as category summarization of a list of comprehensive emotions identified by Kaya [5].

The following measures were taken into consideration to counteract for the extraneous variables mentioned earlier:

- The order of presenting the different colors was randomized for each group of students to prevent memory associations with order.
- All experiments were conducted using "midday" mode inside Second Life to unify amount of light and direction of shade falling on colored walls, floor and ceiling through artificial windows thus giving the same shades of color for all participants and replicating as close as possible the time of usual morning e-learning sessions.
- The pilots started after ensuring that all students had a harmonic experience of their displayed environment by ensuring consistency with respect to brightness and contrast monitor settings.
- Gender of each participant was recorded as well as age group (under graduate or post graduate) to be taken into account during data analysis.
- The cultural background of students was diversified. Also none of the participants had defective color vision as verified with the Ishihara Color Deficiency test (1993) taken online [22] prior to experimenting.
- The original background material of walls, floor and ceiling was set to "none" prior to administering color changes on them to eliminate effects of other material colors or textures on the resulting hues, thus obtaining pure shades of 3D virtual color. Also no mixtures of colors were used between walls, floor and ceiling to eliminate mixed effects of colors on participants.
- The dimensions and shape of the e-learning space was unified for all experiments to eliminate the effect of space size factor on the results. A medium seminar sized room was chosen with rectangular shape.
- During experiment, students were asked to view the space from different angles using their camera controls to get a comprehensive perspective of the colors used.

After answering the questions, and tabulating the number of positive and negative emotion votes given for each most and least remembered color and its emotion associations, the following equations were calculated:

I. The overall number of positive votes per color:

$$(\text{No. of positive emotion votes} - \text{no. of negative emotion votes}) \quad (1)$$

II. The overall percentage of positive emotion votes to the total number of positive and negative votes per color:

(No. of positive emotion votes –

no. of negative emotion votes) /
(No. of positive emotion votes +
no. of negative emotion votes) 100* (2)

III. The overall percentage of emotional satisfaction of students from a particular color:

(No. of positive emotion votes for a color –
no. of negative emotion vote for a colors) /
*total number of students * 100* (3)

Diagrams illustrating the different findings were created accordingly for all age groups combined differentiating and comparing only between results obtained from different genders, as demonstrated subsequently.

III. Discussion of Results

A. Student Overall Number of Positive Emotion Association Votes per Color

Figures 1, 2 and 3 illustrate the number of positive and negative emotion-association votes alongside each other (given by students for each of the most remembered colors). Initially it can be noticed that whereas light blue, white and light green are the colors mostly remembered by males, they seem to have no memory recollection – positive or negative – towards warmer colors like red, pink and yellow. This triangulates findings of previous research in progress by the authors depicting that blue, green and white colors provide most satisfaction and contentment for students in general when asked to rank their color preferences in order.

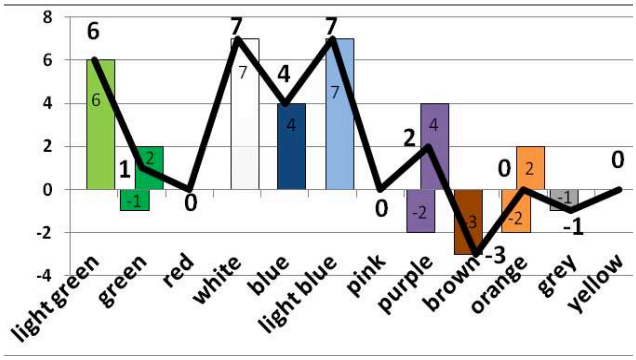

Fig1. Number of positive and negative emotion association votes, and their average provided by male students for each color

Female students share with males the same high positive emotions towards white and light blue only, whilst they seem to have an adverse inclination towards light green and dark blue compared to male students. They also have minor affinity towards all other colors in general. However females show least inclination towards cooler neutral colors like dark blue and grey, and surprisingly negative emotion associations towards pink and yellow.

Combined students opinions gave overall negative emotion associations and least memory recollection towards yellow, pink, brown and grey. Again this coincides with findings from prior research portraying lowest satisfaction for yellow.

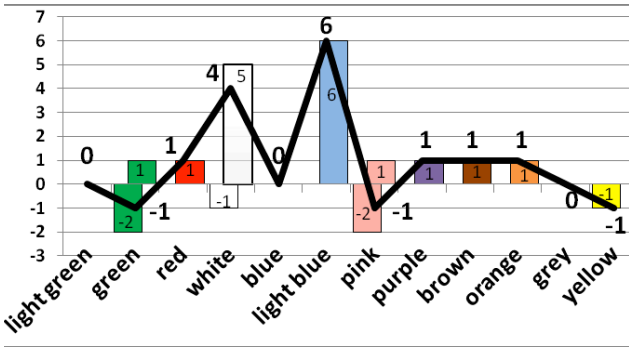

Fig2. Number of positive and negative emotion association votes, & their average provided by female students for each color

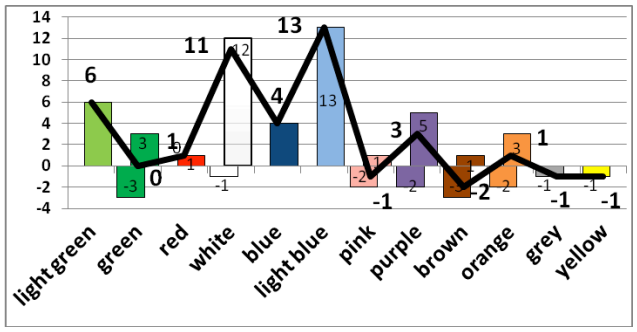

Fig3. Number of positive and negative emotion association votes, and their average provided by all students for each color

B. Student Overall Percentage of Positive Votes to the Total Number of Positive and Negative Votes per Color

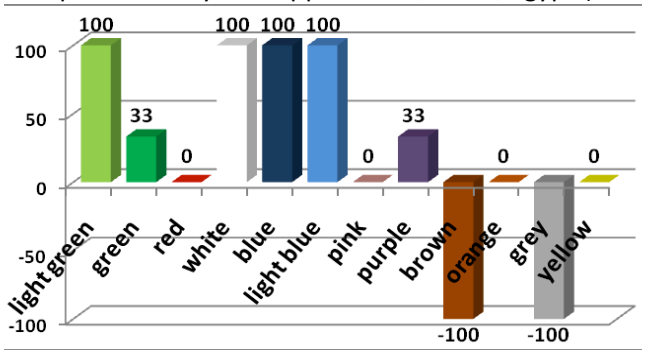

Fig4. Percentage of positive emotion votes to all votes provided by male students for each color

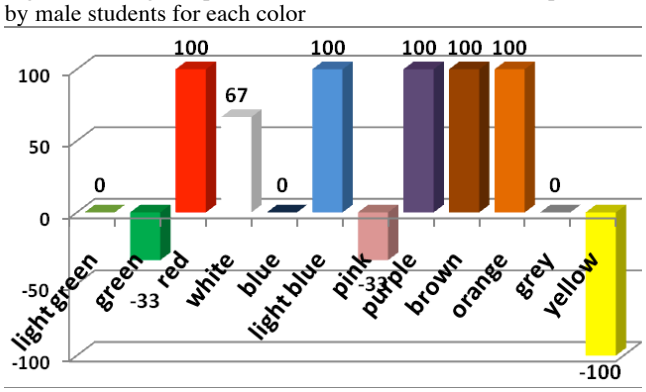

Fig5. Percentage of positive emotion votes to all votes provided by female students for each color

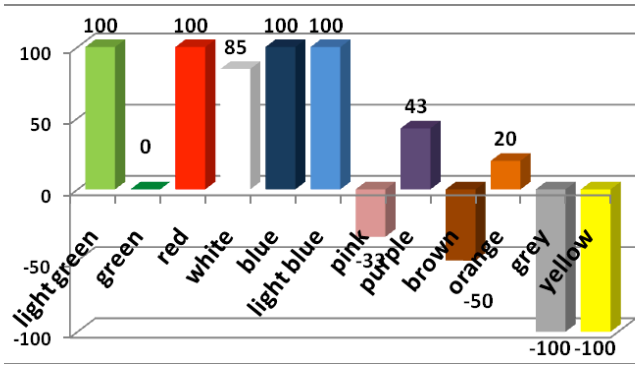

Fig6. Percentage of positive emotion votes to all votes provided by all students for each color

As evident from Figure 4, it can be seen that only positive emotions were expressed by male students towards cooler colors, namely green, white, dark and light blue (hence scoring 100%). On the other hand, brown and grey were remembered most by male students for having only negative impact. As for the warmer colors (red, pink, orange and yellow), male opinions were divided equally between feeling positive and negative emotions in association with them.

Conversely, female students conveyed totally positive emotions for warm not cool colors i.e. red, purple, brown, orange. The only similarity between males and females was favoritism of white and light blue. Pink and especially yellow were both negatively regarded by females, even more than by males. Light green, dark blue and gray were neutrally regarded.

As an overall combination of both genders, blue hues, white, green and red were the most acceptable colors whilst gray and yellow invoked most dissatisfaction and negativity.

C. Overall percentage of emotional satisfaction of students from each color

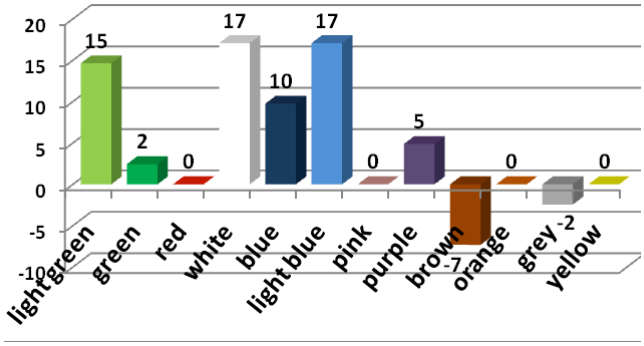

Fig7. Percentage of emotional satisfaction of male students from each color

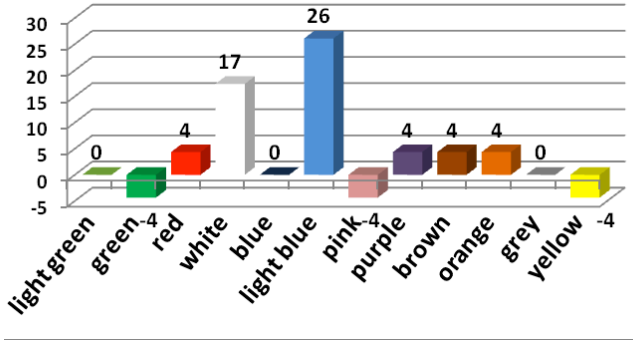

Fig8. Percentage of emotional satisfaction of female students from each color

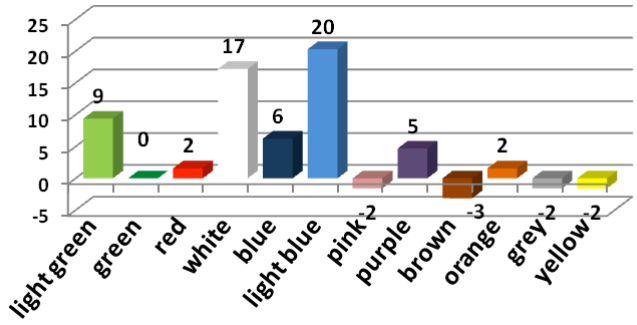

Fig9. Percentage of emotional satisfaction of all students from each color

On deriving percentage of emotional satisfaction of students from each color, as depicted by Figures 7, 8 and 9, light blue and white emerged to be the most remembered positively and agreeable among all of the student body. This was followed by light green. The rest of the tested colors showed negligible results in terms of user satisfaction.

IV. Conclusion and Future Work

The focus of this paper was to record different positive and negative emotions associated by students towards different design colors of a 3D virtual learning space. These emotions were experienced by students on immersion inside each tested colored environment. The positive emotions expressed were comfort, attentiveness, pleasure and liveliness. The negative emotions expressed were tiredness, boredom, irritation and sleepiness.

General findings demonstrated high evaluation for white and light blue by all students, followed by light green, which is similar to results in the physical world except that light green is most favored. However there was noticeable discrepancy between male and female students virtually. Favoritism of males was clearly towards cool colors (blue and green hues). However favoritism of female students shifted slightly more towards warmer hues (red, orange and brown). One unexpected result was the discontent of female students with pink as a color for the surrounding 3D e-learning space despite fondness for this color by females in other life activities. Males displayed disagreeability with orange and brown. As for yellow and gray, analogous to real-life findings, these were least remembered and regarded by students followed by brown.

Furthermore, the above findings contain considerable similarities with results from another complementary research by the authors, where students were asked to rank colors in order of preference. These results can be used as recommendations for initiation of architectural color design guidelines, for 3D virtual learning spaces in 3D VLEs, which are currently unresearched and non-existent.

Future work involves illustrating the effect of other architectural design elements outside the focus of this paper (such as shape, dimension ratios and lighting) on the e-learning experience of students in 3D Virtual Learning Environments for enhancement of 3D virtual educational buildings in 3D virtual reality worlds.

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