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Abstract

An experimental setup for emotion regulation at home is introduced in this paper. The experimentation starts from the premise that changes in the ambience in terms of illumination and color are able to produce alterations in inhabitants' emotional state. The proposal uses RGB LED strips that are regulable in color and intensity to control the ambience. The full details of the assembly of a circuit that includes a micro-controller and a number of strips are provided. Afterwards, a novel approach for complex color emotion evaluation based on lexical semantic scales and self-evaluation is discussed. Then, the experimental results of a pilot test with 27 participants are discussed.

Keywords (separated by '-') LED strip - Color - Illumination - Emotion regulation - Experimental evaluation

LED Strips for Color- and Illumination-Based Emotion Regulation at Home

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Abstract. An experimental setup for emotion regulation at home is introduced in this paper. The experimentation starts from the premise that changes in the ambience in terms of illumination and color are able to produce alterations in inhabitants' emotional state. The proposal uses RGB LED strips that are regulable in color and intensity to control the ambience. The full details of the assembly of a circuit that includes a micro-controller and a number of strips are provided. Afterwards, a novel approach for complex color emotion evaluation based on lexical semantic scales and self-evaluation is discussed. Then, the experimental results of a pilot test with 27 participants are discussed.

Keywords: LED strip · Color · Illumination · Emotion regulation · Experimental evaluation

1 Introduction

Light is one of the principal environmental factors that influence on a user. Therefore, its affective impact has been widely researched and reported. Exposure to bright light and luminance distribution affect our mood. This is why, many researchers believe that light can be used to alter/improve emotional states. It is known that regulation of biochemical and hormonal rhythms is amongst the positive effects of light on humans. In this sense, a paper [1] investigates how changes in light exposure are related to the quality of life and social and emotional functioning. The authors find out some strong associations capable of improving these issues. Also, a seminal work has proved the time-course and durability of antidepressant effects of bright light in winter on depressive patients [2]. Exposure to light appears to cause higher clinician ratings of hypo-manic symptoms in patients. In addition, the findings of an experiment for light therapy combined with high-density negative air ionization for the patients with seasonal affective disorder show moderate efficacy of light therapy [3].

Color is another factor which is constantly present in any environment. Moreover, the evidences of the influence of color upon human emotions has been

discussed in a number of publications (e.g. [4–7]). Many authors highlight that certain colors are highly influencing for emotion elicitation and regulation. The four possible explanations to color and emotion association, which include references to metonymic and metaphoric thinking, formation of specific emotional reactions for color perception, and sharing connotative structure in the language for color and emotion terms, have been validated [8]. For instance, an experiment was aimed to discover possible relations between colors (and color groups) and emotional changes in participants [9]. The author offered some interesting outcomes, which allow to relate color with emotions. In another experiment, muscle strength reduces within 2.7 s for inmates in prisons which stay during limited time periods in specially painted in bubble-gum pink (Baker-Miller pink) cells [10]. It is important to mention that it has been demonstrated that color characteristics like chroma, hue or lightness also make an impact on emotions [11–13]. Indeed, the chromatic palette contains emotionally charged information as opposed to the achromatic one [13]. Lightness and chroma of color appear to dominate on most of the color emotion pairs in a report [11], although the degree of its influence is small in some cases.

This paper provides a description of the combination of color and light due to their double influence on emotion regulation. Thus, we introduce an experiment aimed to evaluate the influence of colored light on the emotional state of humans [14] by using LED strips in a room.

2 Light/Color and LED Strips

Lighting LED-based solutions have received recognition due to a series of qualities that place them as a leader technology in their area. Illumination based on LED enables obtaining a palette of colors from the basic RGB (red, green and blue) colors and white. Obviously, the quantity of white color determines the maximum intensity, which corresponds to a purely white light (and a maximum value of lumens). Thus, any other color than white has less lumen, but also consumes less energy. An advantage of LED strips is that they provide a way to organize a uniform colored lighting with the possibility to establish separate color zones on demand, and to control them.

With respect to the experiment, LED strips are used thanks to the following characteristics which make them optimal for their use at home: energy saving capabilities and environmental efficiency. Moreover, they are flexible, cuttable, and controllable. That is why they can be installed and easily removed along the perimeters of a room to fit the current needs. To sum up, they are an optimal tool to create the exactly needed lighting effect.

The proposed experimentation with LED strips supposes that each participant observes a colored light from a LED strip during a given exposure time. Afterwards, he/she evaluates the impression received. During the time a color is perceived, the brain links or associates it with a specific emotion or emotions [15]. This phenomenon is known as color emotion. Thus, an emotion can be described with semantic words, such as “stressful”, “warm”, “passive” or “bored”. The experiment has

Fig. 1. LED-based induced emotion recognition.

some common features with some previous research works (e.g. [11,12,15]), but provides the advantage to evaluate both direct (self-reported) and indirect information about the effect of color on emotions (as shown in Fig. 1).

On the one hand, the indirect information is obtained from semantic words (“Tension”, “Temperature”, “Amusement” and “Attractiveness”), whereas direct information is gotten through emotional items (“Joy”, “Fear” and “Sadness”). Thus, it is possible to measure the relation between the direct and indirect evaluators with a “Fusion” module.

3 Experimental Setup

The idea of this experiment is to control the illumination of a standard room with dimensions of 5×5 m. Additionally, the LED strips have to vary their color and intensity with the aim of influencing on the emotions felt by the subjects under study. It is also required that the interval of color change is up to 255, and the intensity of light can change up to 4 levels.

The experiment is carried out in a white-painted room, which is equipped with two RGB LED flexible strips. Each LED strip is 5 m long and holds 60 LEDs per meter. Each strip has three access pins for colors in terms of RGB, and one pin for power supply. The strips are fixed along the perimeter of the ceiling and the floor of the room in order to obtain a uniform colored light (see Fig. 2).

Fig. 2. General view of the experimental placement (Color figure online).

Although LED strips are constructed to work in the RGB color model, it has been decided to transform it to the HSV (hue, saturation, value) model. Indeed, the HSV model facilitates the choice of the color characteristics. The color itself is codified with a hue component, the saturation describes the “whiteness” of the color, and, finally, value is related to the lightness of a given color, and can be changed without losing the chosen color or saturation.

It has been decided to control the LED strips with the *Arduino* micro-controller board due to its simplicity and versatility on the one hand, and its strong executive power and reliability, on the other hand. As the objective is to change the color and illumination by means of the micro-controller, the pulse-width modulation (PWM) outputs of *Arduino* are used in combination with three transistors. This combination enables power supply to each color channel, and it is the most flexible to perform pilot tests. *Arduino* receives the information about the color from a computer through the USB serial port. Moreover, the micro-controller determines a required color as a mixture of the three basic color components. At the same time, it is expandable and programmable to add proper functions.

The LED strips are connected to a central computer through a module as shown in Fig. 3. Here, LED strips are connected to the micro-controller *Arduino* and to the power supply device.

The program code that controls the *Arduino* board is given next:

```
//library RGB from: https://github.com/ratkins/RGBConverter
#include <RGBConverter.h>
```

Fig. 3. Schema of the electronic setup.

```
//Color pins
int pinR=3;
int pinG=5;
int pinB=6;
double dataHSB[]={50,1,10};
byte dataRGB \cite{bib3};

RGBConverter myRGBConverter;

void setup(){
  pinMode(pinR,OUTPUT);
  pinMode(pinG,OUTPUT);
  pinMode(pinB,OUTPUT);
  Serial.begin(9600);
}

void loop(){
  while (Serial.available() >=3) {
    for(int i = 0 ; i <= 2; i++){
      dataHSB[i] = Serial.read();
    }
    Serial.flush();
  }

  myRGBConverter.hsvToRgb(2*dataHSB[0]/360, dataHSB[1]/100,
dataHSB[2]/100, dataRGB);
  analogWrite(pinR,dataRGB[0]);
  analogWrite(pinG,dataRGB[1]);
  analogWrite(pinB,dataRGB[2]);
}
```

Firstly, as you can see in the program code, the library *RGBConverter.h* is included to convert between RGB and HSV. The pins which contain the colors and the object to convert are declared. The *setup()* method states that the pins are to be the output, and determines the speed of the output. *Arduino* and the computer are connected by means of the USB serial port. The *loop()* method continuously checks if the data is available. The information is read byte by byte, and the three values are set for hue, saturation and value. Actually, the hue (color) value is measured in degrees and varies from 0 to 360.

Finally, the values are converted into RGB using the *hsvToRgb()* method that displays each of the three values. Then, each of the three pins connects to the *Arduino* through the *analogWrite()* method. Once the program is loaded in the micro-controller's memory, the latter starts the execution.

4 Color and Light Emotion Test

With the aim to discover how the combination of color and intensity from LED strips influence on emotions, a pilot experiment is developed. The experiment consists in inviting subjects to carry out the visual assessments being placed into a room with the installed color and light intensity assembled system (described above). During the visual experiment, the participants are exposed to the following colored lights: red, orange, yellow, pink, green, blue, violet, and white. During the exposure to each color, the subject is offered to describe his/her feelings by answering some questions of a computer-based questionnaire.

There are two types of questions to be answered. Firstly, the test participants are asked to express their feeling about the colored light by selecting a semantic word from emotion-related word pairs, and by indicating its intensity. The semantic scales and word pairs are the following ones: "Tension: relaxed/tense", "Temperature: warm/cold", "Amusement: boring/stimulating", and "Attractiveness: pleasant/unpleasant". In order to ease the interface, each scale is divided into five intervals, and a given participant can only pick one of them, which corresponds to the intensity of the emotion. The second semantic scales and word pairs serve to evaluate what a participant feels while being exposed to the light [16], and these scales are the following ones: "Joy", "Fear", and "Sadness".

5 The Pilot Test

A preliminary pilot test for 27 persons has been carried out. The participants are aged from 18 until 55 years, both males and females, and include people with full secondary and high education. The experiment is carried out in a dark room (no light) with white-colored walls. Each participant is placed in front of the testing computer. The relation between the colored light and emotion is performed with help of a software application.

Each participant is asked to judge about each one of the eight colored lights (see Table 1).

Look on the word pairs given below. For each word pair choose the one that describes best you feelings about the color of the lights

Tension

Relaxed ☐ ☐ ☐ ☐ ☐ Tense

Temperature

Cold ☐ ☐ ☐ ☐ ☐ Warm

Joy

Boring ☐ ☐ ☐ ☐ ☐ Stimulating

Attractiveness

Pleasant ☐ ☐ ☐ ☐ ☐ Unpleasant

Does the light make you feel one of these emotions? Please, mark the intensity of your feeling for each of the emotions below

Joy

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Extremely

Contempt

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Extremely

Sadness

Not at all ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Extremely

Fig. 4. Questionnaire.

Table 1. Colored lights used in the test

Color	Hue
Red	0
Orange	20
Yellow	60
Green	120
Light blue	180
Blue	240
Purple	270
Pink	330

Each colored light is switched on both LED strips placed above and below the working surface where the participant is sitting. After an exposition time to a given colored light, which is equal to 10 seconds, the participant evaluates the impression that he/she has received. Figure 4 shows a screen shot with the questionnaire to be filled after each exposition. The first part contains semantic concepts for the indirect evaluation, and the lower part contains three emotional scales for the self-reported emotion evaluation.

Table 2 shows the outcomes of the paired (samples) t-test obtained with the software package SPSS Statistics 15. This test is used to find out if there exists a significant difference in how participants evaluate their emotions towards the warm (red, orange, yellow, and pink) and the cold (green, blue, light blue, and purple) colors.

Table 2. Paired samples test.

Pair “Warm/Cold”	Paired differences					t	fd	Sig. (2-tailed)
	Mean	Std. deviation	Std. error mean	95 % Confidence interval of the difference				
				Lower	Upper			
“Tension”	0.759	0.921	0.177	0.395	1.124	4.283	26	0.000
“Temperature”	1.843	0.640	0.123	1.589	2.096	14.964	26	0.000
“Amusement”	-0.185	0.498	0.096	-0.382	0.012	-1.932	26	0.064
“Attractiveness”	0.315	0.755	0.145	0.016	0.614	2.166	26	0.040
“Joy”	0.093	1.017	0.195	-0.309	0.495	0.473	26	0.640
“Fear”	-0.092	1.282	0.247	-0.599	0.415	-0.375	26	0.711
“Sadness”	-0.454	1.125	0.216	-0.898	-0.009	-2.096		0.046

Fig. 5. Bar charts for the semantics concepts significant at a level of 0.05. The “C. Attractiveness” shows less attractiveness (Color figure online).

In more detail, the scales that are found significant at a level of 0.05 are:

- “Tension” with a mean of 2.176 for warm and 1.417 for cold colors.
- “Temperature” with a mean of 3.00 for warm and 1.154 for cold colors.
- “Attractiveness” with a mean of 1.852 for warm and 1.537 for cold colors.
- “Sadness” with a mean of 1.639 for warm and 2.093 for cold colors.

Figure 5 shows bar charts for these semantic concepts. Given the normal distribution of the experimental data for each “Warm” and “Cold” color group, the difference between these groups is evident. Thus, “warm” colors are perceived as more *tensed*, *warmer*, but *less pleasant* than the ones from the “cold” group. Indeed, this last conclusion can be due to the fact that LEDs offer a strong lighting, which results to be too intense with red, orange, yellow, and pink colors. The experimental outcomes show similarities in colored light perception on the emotional state both for males and females.

6 Discussion and Conclusions

An experimental setup for emotion regulation at home, based on the use of RGB LED strips, has been described in this paper. The selection of the components and materials for assembly, as well as the description of the experimental setup, has been provided in detail. The following statistical evaluation of the experimental results have proved the relation between colored light and emotional responses. In this sense, warm colors are rated as more tensed, hot, and less preferable for lighting. Meanwhile, cold colors are rated as more pleasant. With respect to the “Joy” concept, both color groups receive similar evaluations, which can be explained as a particular characteristic of the colors offered by LED strips.

The future steps to complete this experiment would include an additional set of experiments for more complex evaluations of colored light emotion detection and regulation.

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