Color Play: Gamification for Color Vision Study

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ABSTRACT

The study of color perception in humans is an important ongoing research which currently mainly relies on psychophysical studies. Most psychophysical studies are prune to limitations which can highly reduce the scalability and repeatability of their experiments, cause over-fitting, and fail to fully engage subjects in performing the given tasks. Gamification is becoming a popular approach in obtaining large amount of data, and making the tasks more interesting for subjects. We design a game called Color Play which consists of a series of simple color mixing and matching tasks. This game engages both the children and adults who visit a science center in experimenting with different colors and color spaces. Through this game, the players would learn about different color spaces while at the same time becoming subjects of our color perception study. By analyzing the players' performance we investigate the differences between the RGB and HSV color spaces, and compare the importance of luminance versus chroma.

1. INTRODUCTION

While the human visual system can be studied in biology using sophisticated techniques like MRI, research on human color perception as a rather cognitive process, relies mainly on the study of the human behavior given visual stimuli. These studies analize the results and performance of human subjects which take part and perform a set of tasks manually or semi-manually (e.g., segmenting objects in an image or rating images).

Performing such experiments is often time consuming, tedious, and can involve paid subjects. This all limit the number of subjects. Moreover, the tasks can be boring for the subjects and due to tiredness they might tend to pay less attention toward the end. Repeating the experiment (especially by other scientists) is not straightforward. Often these studies use participants from one location (e.g., their university), and mostly involve adults since collecting data from children requires much more effort. Lastly, the highly controlled set up and lab environment results in a less natural behavior from the users, especially when they feel that their behavior is being controlled (Heppner et al. 2007).

In the current work, we investigate "gamification" as a method to tackle all the above challenges in psychophysical studies. The main goal of our study is to investigate the intuitiveness and ease of color matching and color mixing tasks in different color spaces, namely for the widely used RGB and HSV, and for different colors. The main purpose of our gameplay framework is to take a typical color mixing/matching scenario out of the laboratory environment and bring it to the context of everyday life. We study how people interact with colors and color spaces in work and leisure. Such study would help us analyze people's relation with color spaces in practical scenarios like finding the desired color mixture for a room, a graphic design, website, advertisement, video game, and so on.

We briefly list our main contributions: showing the advantage of gamification in psychophysical studies to improve the subjects' experience as well as the performance and

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quality of the study; designing a portable and robust system to take advantage of science centers as a platform to reach wide variety of subjects (e.g., age, gender, nationality); using a game environment we help subjects to present more natural behavior compared to a controlled lab environment; and finally as a result we study the intuitiveness of the RGB and HSV color spaces as well as the importance and contribution of chroma and luminance for human observers in daily life. We provide quantitative data analysis.

2. RELATED WORK

Schwarz et al. (1987) designed a study on the effect of color spaces on color matching with a large number of naive subjects (96) in which 14 pages of instructions were handed out. Each subject matched five colors six times each for a total of 30 trials. They have concluded that in their study: first, subjects were faster in matching using RGB and opponent color space; second, having a lightness axis helped with matching lightness more than having a hue or chroma axis helped with matching hue or chroma; third, significant learning occurred with respect to matching time and closeness; fourth, inexperienced subjects using the RGB color model matched rapidly but inaccurately in comparison with other color models; and fifth, the opponent, LAB, YIQ, and HSV color models require learning to use effectively.

Douglas and Kirkpatrick (1996) studied the effectiveness of color models with respect to interface feedback level. The experiment was performed for four groups of naive subjects (12 in each group). Each group was tested for a combination of the color model (RGB or HSV) and one of the two interfaces with different feedback. The subjects were required to perform a color matching task (30 target colors with the time limit of maximum 3 minutes per color). They concluded that the color model does not play a role in time or accuracy of the matching task, while higher level of feedback results in more accuracy.

Lou et al. (2005) designed an experiment to study the sources of uncertainty in color matching experiments. They have presented quantitative results comparing each source and concluded that the observers play the main role in such uncertainty. Furthermore, they have provided solutions for various types of uncertainty.

Flatla et al. (2011) proposed a framework that simplifies the design of *calibration games* as a way to improve both the performance and the user experience while performing a tedious task like calibration. They conclude that the gamification does significantly improve the enjoyment, and that even though there are some differences in the recorded data it does not reduce the utility of the data for calibration.

2. METHOD

In our gamification approach, the user is provided with a tangible environment consisting of four Philips Hue color light bulbs and the Playstation3 Move™ controller to interact with the game. The *feedback* element is provided by setting the bulbs to change color based on the user's action. We also provide scores to make the game more *competitive*.

2.1 Technical Specifications

We use a set of Philips Hue bulbs to represent the colors since they are capable of displaying a wide range of colors and their control interface is straight forward. Three bulbs are set to represent the three primaries in the color space to be studied and a fourth bulb displays the color produced by the subject. As the bulbs use colored LEDs, they are relatively robust and consistent over time. Furthermore they don't heat up much. On the other hand, as they are mainly targeted for commercial use to provide household ambient lighting, their gamut is rather limited to the common indoor and outdoor illuminant colors (e.g., dark green and cyan are outside the gamut).

To overcome this limitation, we created a look-up table for the colors using a Konica Minolta CS1000 tele-spectro-radiometer mapping the values in the sRGB color gamut to their corresponding values for the bulbs. This look up table helps us find a set of colors which can be displayed by these bulbs as well as the exact values to be provided to the bulb in order to display the desired colors. Since the color reproduction function of the bulb turned out to be nonlinear and complex, using a look-up table to convert the values between the game's sRGB system and the bulb is a reasonable choice.

Furthermore, we use the open source code of Perl (2012) for the tracking of the PS3 Move™ controller with the help of a webcam. The tracking is quite robust to occlusions.

2.2 Game Setup

Figure 1 presents a schematic view of the game setup. We divide the space to equal horizontal portions, each of which is assigned to one of the three bulbs who stand for each of the primaries of a color space (i.e., Red, Green, and Blue for RGB). When the subject places the controller in each of these areas, the corresponding bulb is activated. The vertical dimension is divided to three areas, namely, *up*, *middle*, and *down*. Therefore for example placing the controller in the area assigned to the first bulb in the up or down areas will result in an increase or decrease (respectively) in the contribution of that bulb in the color mixed by users. The *middle* area is design to introduce a null state which helps users get better control of the changing bulbs. The total number of steps in each color channel of each color space is kept constant to avoid giving more importance to chromatic and none chromatic characteristics of the color spaces.

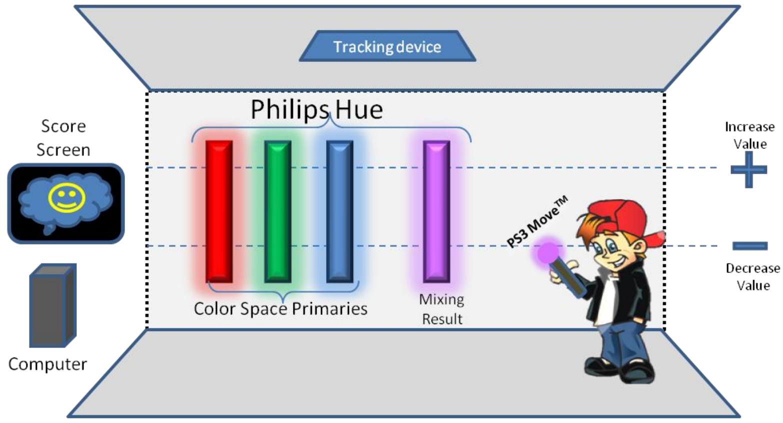

Figure 1: Schematic view of the game setup and its components.

The fourth bulb displays the color mixed by the player. The player needs to match this color to the color of the patch given on the screen. The screen also shows the player their score upon completing each round of the game.

At each instance of the game, one of the target colors is displayed in a large patch on the screen next to a few lines of instructions. The order of colors are random. The screen is placed in a way that the player can not see the target bulb and the patch on the monitor at the same time, so that they need to rely on their idea of that color. This way we can better study which characteristics of the color are more important for people. We setup the game inside a dark room to avoid the effect of ambient illumination and provide better contrast for the bulbs and the monitor.

Target Colors: We've chosen 6 colors, namely: Sand (RGB:206,188,96), Pimento (230,97,69), Sapphire (88,10,226), coral Pink (244,121,129), Lemon (225,238,24), pastel Purple (216,157,237).

3. EXPERIMENTS AND DISSCUSSION

In this section we provide details on our data analysis. First we define our metrics. Then we present the results for supervised and unsupervised experiments. Finally we compare the contribution of chroma versus luminance using the intra-observer data analysis.

2.1 Metrics

We use Median Observer Time (MOT) in seconds as a notion of how intuitive it is to mix and match colors in each space. The median is chosen since it is more robust to outliers. Luo et al. (2005) define *observer accuracy* as "the closeness of the agreement between the result of each individual observer and a true value of the measurement, i.e. the mean of all the observations for each color". Following Luo et al. (2005), we define Average Inter-Observer Inaccuracy $AIOI_{CS}$ for each color C and color space S in CIE ΔE^{*}_{ab} as:

$$AIOI_{cs} = (1/n) \sum_{i}^{n} \Delta E^{*}_{ab} (T_{CS}, P_{CS_i}),$$

where $T_{CS} = (1/n) \sum_{i}^{n} P_{CS_i}$, and P_{CS_i} is a player's result for each C and S. The number of observations is n. We have also calculated the difference between the T_{CS} and the actual match (from the look-up table explained before). We refer to this error as Average Observer Error (AOE) also in ΔE^{*}_{ab} units.

2.2 Supervised Experiment

For the first experiment, we asked 14 adult male and female subjects (8 expert and 6 naive subjects) with corrected to normal eye-sight to reproduce the six target colors in each of the two color spaces. They were also required to take a color deficiency test prior to the game to make sure they all have normal color vision. Two subjects repeated the experiment to provide data for the intra-observer study.

Questionnaires were provided to the participants to evaluate their experience. The subjects were asked to rate (on a scale of 1 to 5) the game based on how fun and how hard it is to play. On average the players rated the game as "fun" (4.1/5) and with "average difficulty" (2.98/5). On average, each color has been played about 35 times.

2.3 Unsupervised Experiment

In the second experiment we had the visitors voluntarily play as many colors as they like. These subjects were male and female between 22 and 27 years old and not included in the supervised experiment. The order of colors were random. On average, each color was played 5.2 times for RGB and 4.5 times for HSV.

2.3 Data Analysis

Figure 2 summarize the analysis of the supervised and unsupervised experiments respectively. According to the top row, HSV is a more intuitive color space as the naive subjects were faster in mixing colors compared to RGB. On the other hand, the subjects performed similarly in both color spaces based on their unanimity (AIOI). In average, coral pink and pastel purple were the most and least accurately mixed colors respectively (AOE). Even though, the naive group took longer time in RGB, both groups performed similarly in average regarding their AIOI and AOE.

The AOE is more than twice the AIOI and is quite high for a perceptual difference. This shows that the subjects' perception of the bulb color was quite far from its actual color value measured accurately using the tele-spectro-radiometer. There are several possible reasons for that, including the surround effect, and that the players did not have the screen and the bulb next to each other. This is a good indication of cognitive processes affecting our perception of colors.

Based on Figure 2 bottom row, when the player's task was to only play one color/space, they have performed faster but less accurately in HSV. Here the players were not able to obtain the learning experience which supervised subjects attained by playing six colors in two color spaces. This is a major reason for their high AIOI.

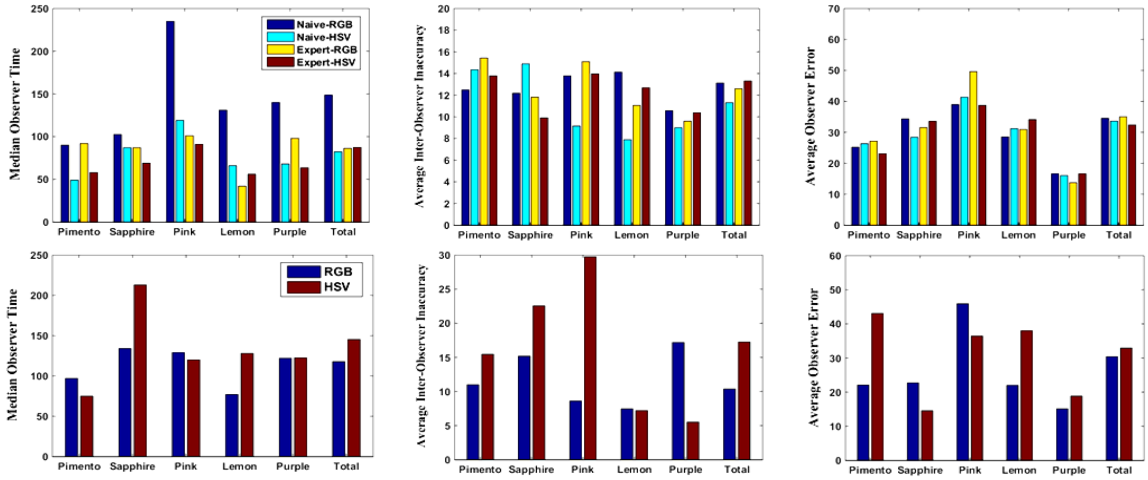

Figure 2: Top and bottom rows present supervised and unsupervised experiments respectively. From left to right: the MOT in seconds, AIOA and AOE in ΔE^*_{ab}.

To compare the contribution of chroma versus luminance we use the intra-observer data gathered from two expert subjects. Table 1 compares the Average Intra-Observer inaccuracy (AAO), as a measure of repeatability, and Average Matching Error (AE), absolute error, between the two color spaces in Chroma and Luminance. Based on the obtained values, subjects performed better in matching luminance than chroma in both color spaces.

Table 1. Intra-observer study:subjects matched better in Luminance than croma.

	Time	Number	AAO-Chroma	AAO-Luminance	AE-Chroma	AE-Luminance
RGB	73.5	32	8.6	5.5	41.8	21.3
HSV	75.1	33	7.0	5.3	41.5	24.8

2.3 Challenges

An inevitable challenge in a serious game is the *meta-gaming* (McCallum 2012). For example, a player might try to intentionally play bad. But it's difficult to ensure that there are no loopholes in the game rules, and restricting the game could limit the players' natural behaviour and bias the results. Having many subjects, reduces the effect of such outliers.

4. CONCLUSIONS

In this paper we have used gamification for designing a tool for color vision studies. The designed game was used to gather information about the intuitiveness of mixing and matching colors in different color spaces, in our experiments for RGB and HSV. The results of a supervised and controlled experiment indicate that HSV is a more intuitive colorspace as the subjects were faster in mixing colors compared to RGB. Results also indicate that subjects better matched in luminance compared to chroma. In an unsupervised experiment subjects were faster in the HSV color space, but less accurate.

Future work includes gathering data with more subjects. It can also include studies of the effect of gender, nationality, and age. The game can also be adapted for the observers to mix their favorite color, or for color memory experiments. It could also be interesting to see if one can detect color deficient users through the game.

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REFERENCES

Douglas, S. and T. Kirkpatrick. Do color models really make a difference? *In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 399–ff. ACM, 1996.

Flatla, D.R, C. Gutwin, L.E. Nacke, S. Bateman, and R.L Mandryk. Calibration games: Making calibration tasks enjoyable by adding motivating game elements. *In Proceedings of the 24th Annual ACM Symposium on User Interface Software and Technology*, pages 403–412, New York, NY, USA, 2011. ACM.

Heppner,P., B. Wampold, and D. Kivlighan. *Research Design in Counseling*. Research, Statistics, and Program Evaluation Series. Cengage Learning, 2007.

Luo, W., MR. Luo, S. Westland, A. Tarrant, and A. Robertson. Measuring the uncertainty of colour matching. *AIC Colour 05 – 10th congress of the International Colour Association*. Pages 1087-1090. 2005

McCallum, S. Gamification and serious games for personalized health. *Studies in health technology and informatics*, 177:85–96, 2012

Perl T.. *Cross-platform tracking of a 6dof motion controller using computer vision and sensor fusion*. Master's thesis, Technischen Universität Wien, 2012.

Schwarz, M.W., W. B. Cowan, and J. C. Beatty. An experimental comparison of RGB, YIQ, LAB, HSV, and opponent color models. *ACM Transactions on Graphics*, 6(2):123–158, 1987.

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