



**TÉCNICO**  
LISBOA

## **Will It Blend?**

**Paulo Duarte Esperança Garcia**

Thesis to obtain the Master of Science Degree in  
**Information Systems and Computer Engineering**

Supervisors: Prof. Dr. Daniel Jorge Viegas Gonçalves  
Prof. Dra. Sandra Pereira Gama

### **Examination Committee**

Chairperson: Prof. Dr. Someone  
Supervisor: Prof. Dr. Daniel Jorge Viegas Gonçalves  
Member of the Committee: Prof. Dr. Someone

**October 2016**



# Acknowledgments

Agradecimientos.

Todos aqui.



## Abstract

English Abstract goes here.

**Keywords:** one, two, three, keywords



## Resumo

Resumo Português fica aqui.

**Palavras-chave:** uma, duas, três, keywords





# Contents

<b>List of Tables</b>	<b>ix</b>
<b>List of Figures</b>	<b>xi</b>
<b>Acronyms</b>	<b>xiii</b>
<b>1 Introduction</b>	<b>1</b>
1.1 Dissertation Outline . . . . .	1
<b>2 Background</b>	<b>3</b>
2.1 Theoretical Background . . . . .	3
2.1.1 Color Perception . . . . .	3
2.1.2 Color Models and Spaces . . . . .	3
2.2 Related Work . . . . .	3
2.2.1 Color Blending Research and Techniques . . . . .	3
2.2.2 User Color Studies Online . . . . .	3
2.3 Discussion . . . . .	3
<b>3 Color Mixing Perception: Designing the User Study</b>	<b>5</b>
3.1 Objectives . . . . .	5
3.2 Designing the Solution . . . . .	5
3.2.1 User Profiling Phase . . . . .	5
3.2.2 Testing Calibration Phase . . . . .	5
3.2.3 Testing Color Vision Deficiencies Phase . . . . .	6
3.2.4 Core Test Phase . . . . .	6
3.3 Evaluation Criteria . . . . .	6
3.4 Divulcation . . . . .	6
<b>4 Color Mixing Perception: Analyzing Results</b>	<b>7</b>
4.1 Protocol . . . . .	7
4.1.1 Laboratory Environment . . . . .	7
4.1.2 Online Environment . . . . .	8
4.2 Data Cleaning . . . . .	9
4.3 Data Processing . . . . .	11
4.3.1 Data Preparation . . . . .	12
4.3.2 Color Bins Comparison . . . . .	12
4.4 Results . . . . .	12
4.4.1 User Profile . . . . .	12
4.4.2 Color Mixtures . . . . .	12

4.4.3	Color Models . . . . .	12
4.4.4	Color Naming . . . . .	12
4.4.5	Demographic Groups . . . . .	13
4.5	Discussion . . . . .	13
4.5.1	Calibration Resiliency . . . . .	13
4.5.2	Creation of Color Scales . . . . .	13
4.5.3	Color Organization . . . . .	13
4.5.4	Consequences for InfoVis . . . . .	13
<b>5</b>	<b>Conclusion</b>	<b>15</b>
5.1	Limitations . . . . .	15
5.2	Future Work . . . . .	15
	<b>Bibliography</b>	<b>17</b>
<b>A</b>	<b>User Study Protocol</b>	<b>19</b>
A.1	Motivation . . . . .	19
A.2	User Profiling Phase . . . . .	19
A.3	Testing Calibration Phase . . . . .	19
A.4	Testing Color Vision Deficiencies Phase . . . . .	20
A.5	Core Test Phase . . . . .	20
<b>B</b>	<b>Chromaticity Diagrams</b>	<b>21</b>
<b>C</b>	<b>Tables</b>	<b>23</b>
C.1	Results Tables . . . . .	23

# List of Tables

4.1	Excerpt of Raw "Results"Table . . . . .	9
4.2	Excerpt of Clean "Results"Table . . . . .	11



# List of Figures



# Acronyms

**CSV** Comma Separate Values. 9, 10

**IST** Instituto Superior Técnico. 8

**RNL** Rede Novas Licenciaturas. 8





# Chapter 1

## Introduction

Introduction goes here.

### **... USAR ESTA PARTE DA INTRODUÇÃO DO RESEARCH PROPOSAL ...**

In this section, we introduce the majority of topics to be further studied, the different phases of our research, the metrics we are going to collect and how we are going to treat them. Since we aim to *study to what extent can a user distinguish different amounts of blended colors, when using color mixtures to convey information*, it is important learn from previous results, testing out not only the validity of them but also some missed opportunities.

There are several aspects to be considered when developing the broadest study possible: regarding color blending profiling tests, it exists - among others - some questions which remain unanswered; some of them were risen in the studies by Gama and Gonçalves [GG14b, GG14a]. These questions can be divided in four categories:

### **1.1 Dissertation Outline**

Describe the organization of the dissertation document, referring to other chapters.



## **Chapter 2**

# **Background**

### **2.1 Theoretical Background**

#### **2.1.1 Color Perception**

#### **2.1.2 Color Models and Spaces**

### **2.2 Related Work**

#### **2.2.1 Color Blending Research and Techniques**

Ver se houve desenvolvimentos na área em 2016.

#### **2.2.2 User Color Studies Online**

Ler artigos do David Flatla, investigar se existe trabalho feito na área nos últimos meses.

Procurar artigos do CHI.

### **2.3 Discussion**



## Chapter 3

# Color Mixing Perception: Designing the User Study

### 3.1 Objectives

Remember the objectives.

Referir HSL com hue variante, e SL com parametros maximos.

Estabelecer questões claras e perguntas que necessitam de resposta, para nos resultados serem mapeados com respostas.

Tipo: Q1: ...

### 3.2 Designing the Solution

Design the implementation, talk about the process ever since wireframing, through the mapping of concepts between what we want and how we implemented, in order to achieve what we want. Include screenshots from the implementation.

Important detail: color conversion between Excel and adapted colors with ICC profile, Spyder and all. ColorConverter.m.

Dividir secção em partes do estudo, introduzindo com Research Proposal para motivar decisões. Referir todos os detalhes de implementação. Justificar completamente todas as decisões que foram tomadas (número de placas, informações pedidas, métricas colhidas, tudo.) Falar de folha de calculo do excel com todas as cores, que depois for migrada para matlab e convertida de acordo com perfil de calibração.

#### 3.2.1 User Profiling Phase

#### 3.2.2 Testing Calibration Phase

Referir limitação descoberta entre Chrome Safari

### **3.2.3 Testing Color Vision Deficiencies Phase**

#### **3.2.4 Core Test Phase**

Incluir tabela com todas as cores, igual a folha de auxilio. Referir que Ciano, por erro, não esta a ser testado no formato objTwoColors.

Referir aqui que dados estão a ser guardados do utilizador, e como estão a ser guardados, (objTwoColors e twoColorsObj), etc. Referir aqui também que slider contemplava cores standard da folha de calculo para ambiente online, mas para ambiente laboratorio cores eram antes processadas no Matlab. Slider não tinha cores ordenadas para que utilizador não utilizasse algum modelo mental e aprendesse previamente a misturar. Cores foram misturadas sem qualquer critério (referir ordem pela qual apareciam). Referir aqui caminho do calibrador -> icc -> matlab -> converter cores -> slider

### **3.3 Evaluation Criteria**

Ishihara plates and more, whatever we consider relevant. Falar também de como a calibração era considerada válida ou não. Erros que poderiam ser gerados pelo field number html5, que com scrolls podia dar valores errados.

### **3.4 Divulgation**

MTurk problems, facebook, Reddit, FacebookAds, FNAC prize money.  
Como fizemos o controlo dos users (Analytics). Bridge to next chapter.

## Chapter 4

# Color Mixing Perception: Analyzing Results

In this section, we are going to dive into the results obtained from the user study described on chapter number 3. On the first section, we will clearly explain the test protocol which was followed by the users in the laboratory environment to correctly execute the study; this section will be followed, not only by the description of how the gathered data was treated and cleaned (Section 4.2), but also the transformation of this data using *Matlab* processing tools, in order to prepare it for the statistical scrutiny (Section 4.3). Hereafter, conclusions will be drawn from the study at section 4.4, when trying to find answers to the questions/objectives raised before.

The final section of this chapter will be dedicated to summarize the results and infer important conclusions, implications and guidelines which could be relevant for the InfoVis field of research.

### 4.1 Protocol

The existence of a test protocol, when performing a User Study is mandatory: without it, the test may not follow a strictly previously defined standard. As written before, this user study was conducted two-pronged: in a laboratory environment and *via* online dissemination channels.

#### 4.1.1 Laboratory Environment

The users were given always the same briefing when they arrived at the user study test site: it was explained the motivation behind the master thesis, the goals which were expected for this phase of the study and what was expected for them to execute. The most important information which was told was that "there was no pre-defined correct and wrong answers to each question, this test was designed to test the general color mixing capabilities of the majority of the users". Besides this information, the user study was self-contained, in the sense that every other relevant information and instruction was in the interface, adapted for each test phase, so it was not given any physical artifacts describing instructions. The instructions were available on two languages, depending on the choice of the user: Portuguese and English.

Before each session of the laboratory environment test-run, a Datacolor Spyder 5 Elite Color Calibrator was USB-connected to the computer and, using the software which is shipped along with it, the computer LCD display was fully calibrated (the software offers the option of recalibrating, the option of checking the calibration and also, the option of fully calibrating the display) by testing the pixel emission

when emitting a particular set of colors. The display was everytime fully calibrated, since the software manifested an erratic behaviour when using the other functions: the screen colors were presented in a very warmer/colder color profile than it was before.

The tests were conducted at, most of the repetitions, in Rede Novas Licenciaturas (RNL) at Instituto Superior Técnico (IST), and fewers times in other locations with similar conditions: this is due to constraints in finding users, so the test site needed to have a (limited) mobility feature. However, the conditions remained the same concerning the illumination, the position of the user and the computer used: a Macbook Air 13' (Mid-2013) was prepared underneath a fixed incandescent light-source (but slightly deviated from it, to minimize light reflections on screen), the user would sit in front of the laptop, in an almost silent environment. Ideal conditions of this test would be such that the user could be sitting alone in a completely silent room, his head would be always at the same distance from the screen, resting in a head-rest and the LCD display's inclination would be perfectly adjusted to the user's eyes.

#### 4.1.2 Online Environment

Performing the study online, as easily predictable, develops some characteristics which cannot be completely controlled. For the sake of calibration, it was asked the user to perform a set of six calibration easy steps before starting the test, so the online user's screen would be, somehow, in a standardized calibration fashion. The calibration steps which were asked are:

1. If possible, adjust your room lights for a comfortable usage of your device.
2. Avoid reflections on your screen, by diverting the screen from direct sources of light. This step is important, since light reflections can affect visualization of images.
3. To adjust the **Black Point** of your screen, define the Contrast and Brightness of your screen to their maximum.
4. After Step 3, gradually reduce **Brightness** value of your screen, in order to correctly distinguish the squares of each image below [calibration squares images].
5. If possible, define the **Color Temperature** of your screen to 6500 Kelvin Degrees.
6. You are now ready to answer the following questions!

The ideal conditions of this test would be such that we could control and manipulate the color calibration of online user's LCD display, using a software piece which would acquire important informations from the screen configuration, *e.g.* resolution, white-point, black-point, brightness, among others, digest the values and present the questions from the Core Phase in a completely controlled and calibrated window. Further investigation could focus in developing this system.

The users were asked to fill in a profiling questionnaire (as seen of section 3.2.1), as well as to respond to calibration form (Section 3.2.2). A validated simplified 6-plate Ishihara color blindness test [dAK92] is, then performed (Section 3.2.3), before proceeding onto the 32 questions test-phase, in which the user is asked to slide one(two) circular object(s) placed on top of a bar, to indicate a(the) color(s) which he thought were the correct mixture answers. In the end, the user could leave feedback, by sending a message which would be stored in a Relational Database.

The instructions which were presented in each page can be consulted in Appendix A.



## 4.2 Data Cleaning

Throughout the user study, we collected a **total amount of four-hundred and seventy-nine (479) users** which interacted with our study and fulfilled, at least, until the Color Vision Deficiencies Test Phase. However, only **two-hundred and sixty-one (261) users went on to the core phase of the study**, representing **54.48%** of the total amount, giving at least one answer on the set of 32 questions, losing the other two hundred and eighteen (218) users which did not leave any answer, defining the remaining percentage **45.52%**. This large drop of users could be due to errors reported by the users, apparently the inability to submit answers when using the "Submit" button after rating the question; there were also some complaints when users tried to perform the study in some mobile devices (namely, the *iPhone® 6*), whereon the color slider was not able to be dragged and change the color value at the user will.

Concerning the percentage of users which showed up at the **laboratory trials, there were twenty-nine (29) users who performed the entire study**. On the other hand, there were **two-hundred and thirty-two (232) users which carried out the study online**. There was also a small sample of color vision deficient users which we will analyze in a qualitative manner; this set of users contains only one (1) user from the Laboratory Environment - **3.44%** of the sample size - and two (2) online users - **less than 1%**. Lastly, we detected a small percentage of **six (6) users (2.59%) which did not presented a correct calibration of its LCD display**, evaluation based on the criteria referred before. The data presented and used in this dissertation document was gathered along roughly two months, from 15th of April until 8th of June. As said before, it was collected both with online and laboratory users, which was therefore stored in a Relational Database as previously explained in section 3.2.

In the end of the study, Comma Separate Values (CSV) files were exported from each table using a PostgreSQL for macOS called *Postico*<sup>1</sup>, which originated five files containing raw data to be cleaned and processed. The files were as follows:

- *raw\_data\_user\_profile.csv* - Data aggregated from "Profiling", "Calibration" and "Color Vision Deficiencies" Tables;
- *raw\_data\_first\_profiling.csv* - Data from "Profiling" Table;
- *raw\_data\_first\_calibration.csv* - Data from "Calibration" Table;
- *raw\_data\_first\_ishihara.csv* - Data from "Color Vision Deficiencies" Table;
- *raw\_data\_first\_results.csv* - Data from "Results" Table;

User ID	Type	First Color	Second Color	Third Color	Drags	Time	Rating	Resets	Question ID
5710cca334d60	objTwoColors	#0080FF	hsl(58.69565217391305,1,0.50)	hsl(98.15217391304348,1,0.50)	992	117	4	2	10
5745c1c07cc0c	objTwoColors	#8000FF	hsl(300,1,0.50)	hsl(324.13043478260875,1,0.50)	645	55	2	1	14
5745350dc1e22	objTwoColors	#0080FF	hsl(226.30434782608697,1,0.50)	NONE	115	11	5	1	10
57451c3b38192	objTwoColors	#00FF80	NONE	hsl(150,1,0.50)	462	39	5	1	15
574511e99b6d9	objTwoColors	#0080FF	hsl(15.652173913043478,1,0.50)	hsl(316.30434782608694,1,0.50)	442	40	1	1	10
57427cf6bad0c	twoColorsObj	#00FFFF	#####00	#46FF9C	6	14	3	1	32
5740bda9be3dc	objTwoColors	#FF7200	hsl(9.130434782608695,1,0.50)	hsl(50.21739130434783,1,0.50)	45	22	5	1	11
573c783748e8b	twoColorsObj	#00FFFF	#CBFF00	#00FF6B	44	25	3	1	32

Table 4.1: Excerpt of Results Table, with raw data.

The refined tables were then divided into new and more specific ones so that we could detail our results analysis according to the goals defined before; the "Results" table was refined into Laboratory Results, Online Results and demographic results: concerning the age, we divided it on Users aged below 20 Years Results, Users aged between 20 and 29 Years Results, Users aged between 30 and 39

<sup>1</sup>Postico - a modern PostgreSQL client for the Mac, Available at: [eggerapps.at/postico/](http://eggerapps.at/postico/). Last accessed on September 11th, 2016.

Years Results, Users aged between 40 and 49 Years Results, Users aged between 50 and 59 Years Results and Users aged above 60 Years Results. Respecting the division of genders, we created the categories Female Users Results, Male Users Results and Other Gender Users Results. An excerpt of raw data contained in "Results" table can be found in table 4.1; this allows us to support the explanation of the following steps of the cleaning phase.

Dividing the results among smaller CSV files was the first step of the cleaning phase: the next checklist represents the detailed path which was followed to fulfill the data cleaning.

- **Remove "hsl(..., 1, 0.50)"** - It was needed to remove the extra information stored in columns *First Color*, *Second Color* and *Third Color*, since this is redundant because it never varies from entry to entry of the table (remember Section 3.1). These values are the *Saturation* (S) and *Value* (V), primitives of the HSV Color Model used.
- **Format Values** - This step was performed just after the previous one. The value which remains to be formatted is simply the *Hue* (H), which is equal to a very precise position on the coded color slider on the interface; the value was composed of 14 decimal numbers, giving us much more precision than what is, in fact, needed considering that the hue is measured in terms of integer numbers. The number was rounded up to its closest integer number, then. Besides that, there was still one value to be adjusted which was the missing response: *NONE* needed to be replaced by 0, to simplify the processing of null answers.
- **Sort Entries** - In order to favour the iteration when processing the data, each line of the "Results" Table was sorted according, firstly to the *Question ID*, and after by *User ID*.
- **Normalize Laboratory Data** - As previously said, to perform the Laboratory Study we used a Spyder Color Calibrator to manage the color representation independently of the environmental conditions of light. Since the Color Profile file generated by the calibrator was used to adapt colors to be presented to the user, those same colors had to be trackbacked to the original color, for the sake of normalization of values. This is specially useful when comparing the results from this environment to the "Online" Results, helping in data processing later.
- **Verify Duplicated Entries** - This step was performed only to ensure that the entries would not have any matching copy. As expected, there were not found any copies.
- **Normalize Profiling Info** - Regarding the "Profiling" data, there was some which was written in Portuguese and other in English, depending on the language to perform the study chosen by the user. To avoid misleading profiling categories, all of the academic degrees were normalized to its corresponding name both in English and Portuguese. Also, the raw language values contained some specification of English dialects (e.g. en\_US, en\_UK) and other languages, which was more information than we actually needed; these values were normalized to correspond only to its native and original language (like English, solely).
- **Sanitizing Users** - The tables contained many entries from users that performed the study with incorrect calibration and from users which gave unexpected values on the color deficiencies test phase; the entries which corresponded to a user that failed all 6 values on the later phase, would be deleted, leaving no trace of its participation. Concerning the bad calibration values, it "opened a window" to investigate the resilience of results when the calibration was not what it was expected - this will be covered in sub-section 4.5.1. To end up the cleaning phase, it was decided to treat the color deficient users independently: we separated their values from the regular users to perform a qualitative evaluation.

An example of clean data can be found in table 4.2. The next step of data handling is processing it to prepare metrics, establish comparisons to pre-calculated answers and depict results in a CIE Chromaticity Diagram. More tables can be found in Appendix C, specifically Section C.1.

User ID	Type	First Color	Second Color	Third Color	Drags	Time	Rating	Resets	Question ID
5713a02a13044	objTwoColors	#00FF00	0	137	459	56	2	0	17
573e4d0eb795b	objTwoColors	#00FF00	235	59	121	28	4	0	17
573edae85268b	objTwoColors	#00FF00	242	57	224	20	5	0	17
5740ad339507d	objTwoColors	#00FF00	228	67	205	14	3	0	17
573c70dabcfe0	objTwoColors	#00FF00	55	221	192	14	2	0	17
57582b17cd76a	twoColorsObj	#FF0000	#00FF00	#AF0049	724	65	2	0	18
573c783748e8b	twoColorsObj	#FF0000	#00FF00	#BFBE00	656	47	3	0	18
573e4022949b1	twoColorsObj	#FF0000	#00FF00	#B000FF	334	23	2	0	18
571151812791a	twoColorsObj	#FF0000	#00FF00	#C9B2A2	110	39	2	0	18

Table 4.2: Excerpt of Results Table, with clean data.

## 4.3 Data Processing

Processing the data was an important part of the process, since it was important to prepare the raw data collected and compute additional metrics which could be further analyzed to answer the raised questions. To perform this processing, we decided to implement a set of scripts in *Matlab* which could gauge the dataset of each question, demographic group and subset of users (non-calibrated and color vision deficient).

```

figure ( 'NumberTitle' , 'off' );
cieplot ();
title ( 'Question_1:_Laboratory_Regular_Users' , 'FontSize' , 13);
%% — CHANGE HERE
xlabel ( 'X_Value' );
ylabel ( 'Y_Value' );
hold on;

scatter(x_pre_expectedColors(1), y_pre_expectedColors(1), 60, 'black', 'Filled');
% draw GIVEN COLOR
scatter(x_pre_expectedColors(2), y_pre_expectedColors(2), 60, 'black');
% draw EXPECTED COLOR
scatter(x_pre_expectedColors(3), y_pre_expectedColors(3), 60, 'black');
% draw EXPECTED COLOR

% Draw every pair of responses.
for i = 1 : height(laboratoryResults)
    %% Check if any Component is white or empty Answer
    sColor = str2num(cell2mat(laboratoryResults.second_color(i)));
    tColor = str2num(cell2mat(laboratoryResults.third_color(i)));

    if sColor == 0 || tColor == 0
        whiteAnswers = [whiteAnswers ; laboratoryResults(i,:)];
        rowsToEliminate = [rowsToEliminate i];
        continue
    end

```

---

Como foram tratados os dados, no Matlab? Como foram preparados para a análise? Que processamento foi feito aos dados?

Incluir a mesma tabela que em 3.2.4, com cores, mas com numero de respostas online, lab, e demo. Separação de csv's globais em partes demograficas.

### **4.3.1 Data Preparation**

Conversão de respostas com perfil icc novamente, mistura das respostas de acordo com modelos de cor, etc. Detalhar.

### **4.3.2 Color Bins Comparison**

De onde apareceram os Bins, como eles são em bruto, incluir esquema do XKCD. Que tratamento foi dado, os problemas com o desenho dos mesmos e a comparação contra os pontos (em vez da área, que seria o ideal). O que esperavamos (áreas bem definidas, poligonos bem delineados que daria para desenhar o convexhull), as colisões entre áreas (valores comuns entre alguns Color Bins) e falar do facto de como se podia, alternativamente, encontrar o nome das cores (diagrama que já existe desde 1974 - ver ref - mas que não existe um svg ou código de todos os pontos, pelo que ainda havia essa curva de implementação). Poder-se-ia atribuir um nome à cor pela temperatura da mesma, mas não existia uma tabela credível de valores a utilizar.

## **4.4 Results**

Interpretação de valores. Começar por valores de laboratório. Online serve para corroborar.

Incluir tantas tabelas quantas necessárias em cada secção, adaptadas a cada secção e não standardizadas.

### **4.4.1 User Profile**

### **4.4.2 Color Mixtures**

Fazer também mistura mais fácil, comparando os ratings das questões e ver qual a mistura que apresenta melhores resultados.

Comparar misturas que originam a mesma cor, com base em primárias diferentes e perceber se utilizadores conseguem detectar várias misturas para uma mesma cor.

### **4.4.3 Color Models**

### **4.4.4 Color Naming**

Cores mais comuns em algumas perguntas; existe alguma ordem característica quando utilizador especifica uma mistura?

#### **4.4.5 Demographic Groups**

### **4.5 Discussion**

#### **4.5.1 Calibration Resiliency**

Como verificamos ainda alguns users com calibração imprópria para teste, considerámos que poderia ser uma fonte de resultados interessantes. Como tal, criámos um dataset para os mesmos e comparamos com os resultados dos utilizadores calibrados. Os resultados são os que se seguem...

#### **4.5.2 Creation of Color Scales**

#### **4.5.3 Color Organization**

#### **4.5.4 Consequences for InfoVis**

Resumo dos resultados todos e regras que se podem levar deste trabalho para a área de InfoVis em geral.



## **Chapter 5**

# **Conclusion**

### **5.1 Limitiations**

Most of the data cleaning would be avoided if the collected were saved in a different fashion (NONES, HSL)...

### **5.2 Future Work**

Software de calibração remota.





# Bibliography

- [dAK92] Dilogen de Alwis and Chee Kon. A new way to use the ishihara test. *Journal of Neurology*, 239(8):451–454, 1992.
- [GG14a] Sandra Gama and Daniel Gonçalves. Studying the perception of color components' relative amounts in blended colors. In *Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational*, NordiCHI '14, pages 1015–1018, New York, NY, USA, 2014. ACM.
- [GG14b] Sandra Gama and Daniel Gonçalves. Studying Color Blending Perception for Data Visualization. In N. Elmqvist, M. Hlawitschka, and J. Kennedy, editors, *EuroVis - Short Papers*. The Eurographics Association, 2014.



# Appendix A

## User Study Protocol

### A.1 Motivation

By conducting this first study, we intend to:

- Conclude if there is any chance that cultural behaviours influence the user's color perception.
- Realize which color mixtures are more easily perceived by humans.
- Understand if, by using color, it is possible to clearly and easily convey information. This can be particularly interesting and useful when visualizing graphs or maps.
- Conclude if a person is capable of, not only building a mental color mixture model, but also deconstructing mixtures into their basic components.

### A.2 User Profiling Phase

This study is anonymous and should take you up to 15 minutes. Please, answer the following answers accordingly.

### A.3 Testing Calibration Phase

In this step, it's going to be presented to you a set of images. You should tune you screen definitions, in order to answer the questions, keeping them until the end of this study.

Please, follow the steps below indicated and answer the questions.

1. If possible, adjust your room lights for a comfortable usage of your device.
2. Avoid reflections on your screen, by diverting the screen from direct sources of light. This step is important, since light reflections can affect visualization of images.
3. To adjust the **Black Point** of your screen, define the Contrast and Brightness of your screen to their maximum.
4. After Step 3, gradually reduce **Brightness** value of your screen, in order to correctly distinguish the squares of each image below [calibration squares images].
5. If possible, define the **Color Temperature** of your screen to 6500 Kelvin Degrees.

6. You are now ready to answer the following questions!

NOTE: These 6 steps are only available to the Online Users, since the Laboratory Users do not need to perform these steps as the LCD display is already calibrated.

## **A.4 Testing Color Vision Deficiencies Phase**

This is the Color Vision Deficiencies Test.

In this step, it is going to be presented six plates with a colored pattern. Your job is to identify the number present in each plate, typing it down in the text box below. According to your answer, this test will inform us if you have any type of color vision deficiency which may undermine the job of color detection.

## **A.5 Core Test Phase**

Choose the Resulting color which you believe it is the result of mixing the First and Second color, by adjusting the slider below the Resulting color.

Choose two colors with which you can achieve the Resulting color, by adjusting the sliders below each color.

NOTE: These instructions appear alternately, depending on the type of question which is shown.

## **Appendix B**

# **Chromaticity Diagrams**

Include Diagrams generated of CIE Horseshoe.



# Appendix C

## Tables

### C.1 Results Tables

Users

Um exemplo de uma tabela de resultados raw

Um exemplo de uma tabela de resultados clean

Um exemplo de uma tabela de calibração