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

Agradecimentos.

Todos aqui.

Abstract

English Abstract goes here.

Keywords: one, two, three, keywords

Resumo

Resumo Português fica aqui.

Palavras-chave: uma, duas, três, keywords

Contents

List of Tables

List of Figures

Acronyms

IST Instituto Superior Técnico. 7

RNL Rede Novas Licenciaturas. 7

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

Research Design

3.1 Objectives

Remember the objectives.

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

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 qualque critério (referir ordem pela qual apareciam).

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.

Bridge to next chapter.

Chapter 4

Research 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.

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 emmiting a particular set of colors. The display was everytime fully calibrated, since the software manisfested an erratic bahaviour when using the other functions: the screen colors were presented in a very warmer/colder color profile tha 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 undeneath a fixed incadescent 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.

On the online environment, as easily predictable, cannot be completly 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 maniupulate 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 controled and calibrated window. Further investigation could focus in developing this system.

The users were asked to fill in a profiling questionnaire (as seeen 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

Referir problema que foi detectado entre Chrome e Safari, cores de calibração.

4.3 Data Processing

Como foram tratados os dados, no Matlab? Como foram preparados para a análise? Que processamento for feito aos dados?
Incluir a mesma tabela que em 3.2.4, com cores, mas com numero de respostas online, lab, e demo.

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 Comparation

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 codigo 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 caracteristica 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 comparámos 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 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 Deficiences 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

Exercises

Include Relevant Tables here.