UNIVERSIDADE FEDERAL DE SÃO CARLOS

CENTRO DE CIÊNCIAS EXATAS E DE TECNOLOGIA

PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIA DA COMPUTAÇÃO

A TOOL-SUPPORTED APPROACH TO ADAPT WEB USER INTERFACES CONSIDERING THE EMOTIONAL STATE OF THE USER

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São Carlos – SP

Março/2022

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Dissertação apresentada ao Programa de Pós-Graduação em Ciência da Computação da Universidade Federal de São Carlos, como parte dos requisitos para a obtenção do título de Mestre em Ciência da Computação, área de concentração: Interação Humano-Computador
Orientador: Profa. Dra. Vânia Paula de Almeida Neris

São Carlos – SP
Março/2022

UNIVERSIDADE FEDERAL DE SÃO CARLOS

Centro de Ciências Exatas e de Tecnologia
Programa de Pós-Graduação em Ciência da Computação

Folha de Aprovação

Defesa de Dissertação de Mestrado da candidata Patrícia Deud Guimarães, realizada em 10/03/2022.

Comissão Julgadora:

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O Relatório de Defesa assinado pelos membros da Comissão Julgadora encontra-se arquivado junto ao Programa de Pós-Graduação em Ciência da Computação.

A todos os que conseguiram seguir em frente com seus trabalhos de pesquisa em meio à pandemia de COVID-19.

Agradecimentos

Agradeço aos meus pais, que deram todos os tipos de apoio e suporte durante o desenvolvimento desse projeto. Também à minha orientadora, Professora Vânia Neris, pelos conselhos e direcionamentos que foram tão importantes para que esse trabalho fosse finalizado.

Aos professores das bancas de qualificação e defesa, professores Valter Camargo, Vinícius Gonçalves e Vivian Motti, obrigado pelas preciosas sugestões que fizeram com objetivo de melhorar a qualidade do que lhes foi apresentado.

A todos os colegas do LIFeS que contribuíram com a minha evolução como pesquisadora, obrigada por terem me ajudado – direta ou indiretamente – a fazer este projeto tomar forma.

Por fim, agradeço a todos os amigos e colegas de trabalho que estiveram ao meu lado em algum momento dessa jornada de pesquisa.

Don't you know I'm still standing better than I ever did. Looking like a true survivor, feeling like a little kid

Sir Elton John and Bernie Taupin

RESUMO

A área de Interação Humano-Computador tem como objetivo desenvolver sistemas computacionais colocando o usuário no centro do processo de desenvolvimento, de forma que ele possa ter a melhor experiência no contato com a solução final. Ao descobrir que as emoções afetam a relação do indivíduo com o que o cerca, estudiosos passaram a medi-las com base em instrumentos. Deve-se ressaltar que a emoção pode ser vista como uma composição de cinco componentes – reações fisiológicas, sentimento subjetivo, expressão motora, avaliação cognitiva e tendências comportamentais. Acredita-se, portanto, que avaliar mais do que um componente poderia trazer resultados com maior corretude. Embora alguns trabalhos já utilizem a mensuração do estado emocional do usuário para adaptar a interface de usuário e promover uma melhor experiência de interação, poucos se preocupam em levar o usuário a atingir um estado emocional desejado. Este trabalho apresenta uma nova versão do UIFlex, o UIFlex 2.0. A versão anterior é apresentada como um plugin do Google Chrome e é responsável por fornecer adaptações de interface para melhorar a acessibilidade das páginas web. Para isso, os autores criaram regras de adaptação no formato JSON (*JavaScript Object Notation*) que é "injetado" código nas páginas da Web. A nova versão proposta reúne duas grandes mudanças: (1) a arquitetura da solução, que agora é baseada no modelo MAPE-K (*Monitor-Analyse-Plan-Execute over a shared Knowledge*) (KEPHART et al., 2003); (2) novas regras de adaptação da interface de usuário com o intuito de prover alteração de cor. Ao final, um experimento duplo cego foi realizado com 44 usuários nos quais duas tarefas foram propostas – leitura e transcrição – em páginas com o plugin ativado. Os participantes do grupo controle tiveram acesso ao UIFlex 2.0, pois os participantes do grupo placebo utilizaram o UIFlex 3.0, que não fez nenhuma adaptação. Ambos os grupos tiveram a maior parte dos participantes atingindo o estado emocional desejado – como pode ser visto nos grafos de incidência gerados. Além disso, foi aplicado o teste estatístico Qui-Quadrado, que negou a hipótese alternativa. Assim, sugere-se que novas regras sejam desenvolvidas, de forma que haja um maior número de alterações de elementos de interface.

Keywords: Emoção, Adaptação, MAPE-K

ABSTRACT

The field of Human-Computer Interaction aims at developing computational systems that place the user at the center of the their development, so he/she can have the best experience when interact with the final solution. When it was acknowledged that emotions affect the relation of the individual with what surrounds him/her, scholars began to measure these emotions based on instruments that had been developed over the years. It should be emphasized that emotions can be seen as a composition of five components – physiological reactions, subjective feeling, motor expression, cognitive appraisals and behavioural tendencies. It is believed, therefore, that evaluating more than one component could bring results with greater correctness. Although some studies already measure the user's emotional state to promote the adaptation of user interfaces and promote a better interaction experience, few worry about leading the user to achieve a desired emotional state. This work presents a new version of UIFlex (PROENÇA; NERIS, 2017), UIFlex 2.0. The previous version is presented as a Google Chrome plugin and it is responsible for providing interface adaptations to improve the accessibility of web pages. To do so, authors created rules of adaptation in JSON (JavaScript Object Notation) format that "injected" code into the web pages. The new proposed version brings together two major changes: (1) the architecture of the solution, which is now based on the MAPE-K model (Monitor-Analyse-Plan-Execute over a shared Knowledge) (KEPHART et al., 2003); (2) new user interface adaptation rules in order to provide color change in it according to theoretical studies published previously. Finally, a double blind experiment was conducted with 44 users in which two tasks were proposed – reading and transcript – on pages with the plugin enabled. Participants of the control group had access to UIFlex 2.0 as participants of the placebo group used UIFlex 3.0, which did not perform any adaptation. Both groups had the majority of participants reaching the desired emotional state – as can be seen in the generated incidence graphs. In addition, the Chi-Square statistical test was applied, which denied the alternative hypothesis. Thus, it is suggested that new rules be developed so that there are a greater number of changes to interface elements.

Keywords: Emotion, Adaptation, MAPE-K

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GLOSSARY

API – *Application Programming Interface*

CAPES – *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior*

CSS – *Cascading Style Sheets*

DSR – *Design Science Research*

ECG – *Electrocardiogram*

EEG – *Electroencephalogram*

FACS – *Facial Action Coding System*

FAPESP – *Fundação de Amparo à Pesquisa do Estado de São Paulo*

GSR – *Galvanic Skin Response*

HCI – *Human-Computer Interaction*

HTML – *HyperText Markup Language*

IHC – *Interação Humano-Computador*

JSON – *JavaScript Object Notation*

LIFeS – *Laboratório de Interação Flexível e Sustentável*

MAPE-K – *Monitor-Analyse-Plan-Execute over a shared Knowledge*

MSIPE – *Mapping Self-report Instruments by Intensity and Polarity for Emotions*

SAM – *Self Assessment Manikin*

UI – *User Interface*

CONTENTS

Chapter 1

INTRODUCTION

1.1 Context, Research Motivation and Research Problem

One stimulus may result in different emotions in each person as emotions reflect one's personal experiences and memories, as well as associations made by their cognitive system (NORMAN, 2004). Therefore, the choice of a certain color, texture or size when conceiving an object aims to provoke physical senses that will awaken different emotional responses on its user (LIM et al., 2008).

Emotions are elicit from areas beyond the physical and arts environment. They are also present in the relationship users have with computer systems, for instance. When interacting with a user interface (UI), design elements such as color and graphic design can elicit sensations of enjoyment and satisfaction in case they are appealing for the user (CYR, 2013). By understanding that human emotions are influenced by the design of interactive products and that they are not aleatory, it becomes easier to understand the responses and behaviour that users have while interacting with them (LIM et al., 2008; CRISTESCU et al., 2008).

Many systems today are available on the web. A web page is the fundamental element of a website and is composed of colors, images and textual characters (JIANG et al., 2008; BIANCHI, 2016). When these elements relate harmoniously to the content of the site, they are able to deliver positive emotions (JIANG et al., 2008; CYR, 2013). This harmony, in addition to user satisfaction, varies from person to person (CYR, 2013) as well as the context of use (NORMAN, 2004).

Thus, presenting an unique UI for diverse individuals will probably not evoke the amount of satisfaction and pleasure expected when the page was designed. One way to address this issue is to allow user interfaces on web pages to adapt at interaction time to allow users to achieve a desired emotional state.

When adapting these UI, computer systems should be responsible for formatting the interface elements as well as provisions of them considering the emotions of users. This task is complex and, according to Galindo, Dupuy-Chessa and Céret (2017), requires three elements: the correct recognition of emotions; the effective adaptation of interface; and the existence of commands that allow the interface to be able to deal with the users' emotional changes.

Scherer (2004) suggested that we can better understand emotions if we consider a model based on components in a way that one stimulus elicit changes in several body components. These components relate to five reactions: physiological reactions, subjective feeling, cognitive evaluation, behavioral tendencies, and motor expression.

The current study presents UIFlex 2.0, a tool capable of collecting emotional data from different components: subjective feeling and motor expressions. The fusion of the collected data define the user's actual emotional state and a desired emotional one. This last information is necessary to allow a change on the web UI during interaction time based on previous design rules.

It is worth mentioning that the tool was also designed to collect physiological reactions. However, due to the COVID-19 pandemic and the social distancing – a measure determined by the Brazilian government to help contain the virus – during the development of this research, these had to be discarded. The measured has also affected the idea of running the experiments in the laboratory, leaving them to be performed by users while staying at home.

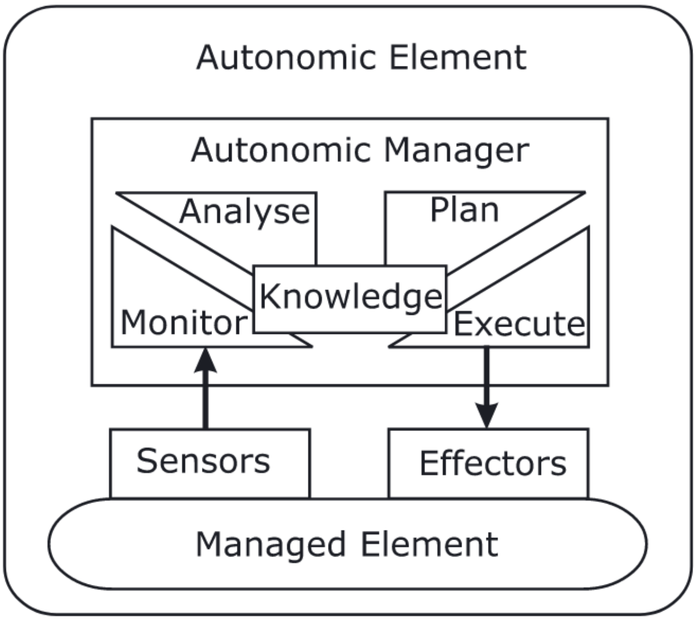
UIFlex 2.0 has an architecture that follows the MAPE-K model (KEPHART et al., 2003). It was designed by a memberof the International Business Machines (IBM) enterprise [1] and presented in an internal blueprint on the advances in Autonomic Computing architecture.

As Figure 3.4 shows, an Autonomic Element is composed by one or more Managed Element and an Autonomic Manager (SILVA; SASSI, 2019). The Managed Element is either software or hardware components of the architecture (KEPHART et al., 2003). On the other hand, the Autonomic Manager is responsible for a four-stage cicle: monitor, analyse, plan and execute whereas accessing a shared knowledge base. This cicle is known as feedback loop.

We opted for the MAPE-K architecture due to UIFlex's nature of adapting websites to improve users' experience. According to Kephart et al. (2003), SANTOS (2020), an autonomic computing system – also called as a self-adaptive system – can be classified in the following cat-

[1] https://www.ibm.com/

Figure 1.1: MAPE-K model.



Source: Huebscher and McCann (2008).

egories: self-configuring, self-healing, self-protecting and self-optimization. We can categorise UIFlex 2.0 in the last group.

It is expected that a self-optimization system, as well as all self-adaptive ones – need constantly revision of its rules. Therefore, we analyse the maintainability of a system when adopting MAPE-K and conclude this architecture provides benefits for our tool.

This characteristic also differs this study from the others as the work of the area focuses on adapting the UI or to the current emotional state of the user or to an emotional state chosen by the researcher. It is believed that, by allowing the user to choose the state he/she wishes to achieve, new possibilities for study on the subject are open.

1.2 State of Art

This work brings together two smaller HCI areas: the distinct approaches when collecting user's emotion and the formats of UI adaptation (GALINDO; DUPUY-CHESSA; CÉRET, 2017), specially on web pages. Therefore, it is possible to describe not only the advances of the intersection of the areas but also those related to each of them separately.

The choice to adopt one or more methods for collecting emotion is directly related to the concept of emotions. Because this work is based on Scherer's Component Model (SCHERER et al., 1984; SCHERER, 2004), we selected authors that addressed at least one of the components. Although there are a few studies (MAHLKE; MINGE; THÜRING, 2006; XAVIER; NERIS, 2012; GONÇALVES et al., 2017b) that have effectively measured the five components of emotion – physiological reactions, subjective feeling, cognitive evaluation, behavioral tendencies, and motor expression – most work published brings about a smaller number of components.

Some academics might opt for collecting only one of the components. The most commons are: physiological reactions (LISETTI; NASOZ, 2004; SOUZA, 2019; MARIMPIS; DIMITRIADIS; GOEBEL, 2020); motor expressions (BÄNZIGER; MORTILLARO; SCHERER, 2012; MANO et al., 2020); and subjective feelings (WATSON; CLARK; TELLEGEN, 1988; HASSENZAHL; BURMESTER; KOLLER, 2003; DESMET; VASTENBURG; ROMERO, 2016). This is possible once an external stimulus produces synchronized changes in most of the different subsystem of the organism (SCHERER et al., 1984; SCHERER, 2004, 2005). Therefore, all of the components should reflect the same emotional state.

However, the majority of studies present a multi-modal approach with two or three components as it allows more accurate analysis on the theme (MASUI et al., 2020). Huang et al. (2016) were pioneers on proposing combining facial expressions with EEG data. Then, other authors proposed this same arrange (CHAPARRO et al., 2018; CIMTAY; EKMEKCIOGLU; CAGLAR-OZHAN, 2020; RAYATDOOST; RUDRAUF; SOLEYMANI, 2020; ZHANG, 2020; TAN et al., 2021). However, some of the EEG limitations have already been described (MASUI et al., 2020; SUHAIMI et al., 2020).

On their work, Koelstra et al. (2011), Kim et al. (2012), Maia and Furtado (2019) selected physiological sensors along to subjective feeling instrument. Siddiqui and Javaid (2020) fusioned speech recognition with visible and infrared images to develop a highly accurate framework to detect emotions. Gonçalves et al. (2017a) brought together speech and facial emotion recognition and logical sensors for behavioural tendencies.

When searching the literature, the motivation for adapting user interfaces varies. It may relate to a change on the physical environment – from desktop to mobile or vice-versa (MANCA et al., 2013; BUENO; ZAINA, 2017; SONNENBERG, 2020; FINK; PAPISMEDOV, 2022); to increase a user cognitive workload on certain situations (LAVIE; MEYER, 2010; CARDOSO, 2019); help users feeling comfort and/or less stressed (LAVIE; MEYER, 2010; MAKRIS; EEKELEN, 2016) and offer better experiences, generally tailor-made ones (RATHNAYAKE et al., 2019; ZHANG et al., 2020; SCHÖLKOPF et al., 2021).

The idea of adapting UI based on user's emotion came after understanding existing relation between the usability and the aesthetics of user interfaces and users' emotions (SEO et al., 2015).

On their study, they related these two concepts with valence and arousal, two of Scherer's domains presented in his Semantic Emotional Space (SCHERER, 2005).

A second step on adapting interfaces based on human emotions is guaranteeing this process occurs at runtime once any stimulus can lead one to an emotional change. In this sense, the work presented by Galindo, Dupuy-Chessa and Céret (2017) is a pioneer, as it is one of the first studies to present a tool able to recognize the user emotion and provide changes on UI elements in a cyclical and constant process.

On their work, Donati, Mori and Paternò (2020) brought insights of the previous study on emotions and elements of interface (MORI; PATERNÒ; FURCI, 2015) to provide a study on how the best transition method to take the user from a negative to a positive emotion.

A recent study of Alipour, Dupuy-Chessa and Céret (2021) provides a literature review on the space problem related to UI adaptations specially regarding users' emotions. The review brings to light some "knowledge gaps", as mentioned by the authors, such as the right time to apply the UI adaptations. They also give name to interesting concepts related to both areas: UI plasticity – the ability of a UI to adapt; UI usability; emotions dimensions; temporal dimensions; among others.

One of the studies presented by Alipour, Dupuy-Chessa and Céret (2021) is Josifovska, Yigitbas and Engels (2019). The authors present a framework for UI adaptation based on the MAPE-K model (KEPHART et al., 2003). One of the reasons the author chose to adopt MAPE-K is because of the self-optimizing nature of the system they present.

This study advances the work of art as it presents a tool-supported approach to adapts UI based on the emotional state the user desires to achieve – and no longer the one the scholars believe they should feel. These states are based on Scherer's Semantic Emotional Space model (SCHERER, 2005) octants and are collected at runtime based on another study presented by the author: the Component Model (SCHERER, 2004). This approach is presented in a plugin format and allows future academics and developers to add both instruments for emotion collection and new rules of adaptation. This is possible due to the adoption of MAPE-K architecture (KEPHART et al., 2003) and the easily maintainability it offers.

1.3 Work Context

This work benefited from results of and also moves further a project entitled “Emoweb – an infrastructure to adapt the Internet user interfaces considering emotions”. Emoweb was funded by the São Paulo Research Foundation (FAPESP), grant number 2015/24523-8.

Emoweb aimed to propose and build a framework that would adapt the UI of different Internet applications in order to help users to achieve a desired emotional state. This process is done while the user interacts with the system. Students of the Flexible and Sustainable Interaction Laboratory (LIFeS) of the Federal University of São Carlos (UFSCar) have developed some of the modules that made up the final architecture of the framework proposed.

The first work of this project was in fact developed before the formalization of Emoweb. Xavier (2013) adopts Scherer’s Semantic Emotional Space (SCHERER, 2005) to demonstrate the user’s emotional state. The emotional data was collected through one instrument of all the five components of Scherer’s Component Model (SCHERER et al., 1984).

Then, Bianchi (2016) studied how the elements of interface – specially colour, text font and images – affect the user. She presented the Bianchi’s Colour Circle (BIANCHI, 2016), which connects the octants of Scherer’s Semantic Emotional Space (SCHERER, 2005) with a set of colours.

Alencar (2014) studied how to collect and model user preferences on ubiquitous computing. Finally, she proposed the architecture “Who am I”(ALENCAR; NERIS, 2014). Proença and Neris (2017) benefited from this solution when developing UIFlex, a plugin that adapts UI in running time to provide better accessibility for users with special needs.

On his work, Souza (2019) proposes a dataset that collects physiological data from low-cost sensors. The data is treated and classified according to Scherer’s Semantic Emotional Space (SCHERER, 2005).

Finally, this thesis presents a compilation of three studies as presented on Section 1.6. On Silva et al. (2020), the authors present a study on subjective feeling. The work of Guimarães et al. (2022) explains UIFlex 2.0, a tool based on the MAPE-K architecture and that adapts the user interface. And Guimarães, Souza and Neris (2022), that discusses an experiment with 44 participants to test UIFlex 2.0.

1.4 Objective

The main objective of this research project is to build a tool that alters web UI considering the user's initial and desired emotional state based on data from instruments of collection of different components of the emotion.

Others objectives were:

- A change of the tool architecture's to decrease maintenance effort;
- Design rules for changing the color of user interfaces considering user's initial and desired emotional state.

1.5 Research Method

Academics are known for not only answering open questions through science, but also proposing, testing and improving solutions adopted worldwide. There is, however, a common belief that many of these solutions, although theoretically ideal, are not feasible. It is with the intention of resolving this gap that Design Science Research (DSR) arises.

This research method supports the creation of a final artifact. In the case of Computer Science, it is common to create frameworks, algorithms, approaches, architectures, datasets, models, among others. This solution must be constructed in order to bring relevance to the external environment in which the researcher is inserted.

Hevner and Chatterjee (2010) developed a six-step DSR process: identification and motivation; definition of objectives; design and development; demonstration; evaluation and communication.

At this first step the researcher identifies the research problem as well as its context and the motivation for the study. The next step is when the researcher defines objectives that are possible and feasible to achieve. Besides the specialists' knowledge, it is suggested that the objectives are based on the previous published work. In order to understanding the state of art, a systematic literature review or systematic mapping studies may be done.

The third step is the design and development. At this step, the objectives evolve to the conception of the solution's structure and desired functionalities. Most times, this process is iterative and culminates in the final artifact. Then, scholars move on to the demonstration. At this step, the artifact must resolve one or more instances of the problem that was evidenced. A complementary method may be used at this step.

It is necessary to observe and compare the objectives previously defined with the results collected by the use of the solution. Consequently, the evaluation is the step when metrics are applied and later analysed. Examples of metrics may vary from system performance to user satisfaction surveys and feedback. If results are satisfying, scholars follow to the final step. Otherwise, they must return to step 3 and perform improvements.

Finally, the last step is related to disclosing the research. This includes not only the artifact developed but also its importance, utility and novelty.

Just as design is an iterative process, the Design Science Research is also. In this work, step 3, that is, stage of "Conception and development" had 7 cycles:

- Cycle 1: analysis of the previous architecture of the Emoweb project (UIFlex); documental analysis of infrastructures of other studies found; definition of the first necessary requirements to be developed; design of the first infrastructure of the Emoweb project; study on collection interfaces; testing of previously developed modules.
- Cycle 2: changes on the sensor module; inclusion of the first rules related to emotions on the rule bank (colour change); study of new infrastructure modules; redesign of infrastructure; creation of the fusion model; test with a virtually performed user.
- Cycle 3: adoption of the subjective feeling to measure the initial and desired emotional state of the user; adaptation of UIFlex to collect and measure this component; amendment of the rules to include such information; study on how to change UI fonts.
- Cycle 4: abandonment of the use of sensors due to the pandemic and need of social distancing; adoption of the motor expressions along with the subjective feeling of the user for composing the emotional data source; study on which tool to use to analyse motor expressions; change on the rules to also consider the fonts of the text.
- Cycle 5: adoption of Facial Action Coding System (FACS) model and MorphCast[2] analyser; decision to adopt the MAPE-K architecture model; change of architecture for the adoption of MAPE-K; internal testing.
- Cycle 6: analysis of maintainability metrics to understand whether the new architecture brought benefits to the framework; final changes on UIFlex to allow the case study to be conducted; renaming the framework to UIFlex 2.0.

[2]https://www.morphcast.com/

- Cycle 7: opting for running an experiment; adding a placebo version of UIFlex 2.0 – UIFlex 3.0; decision to running the experiment as double-blind.

Finally steps 4 and 5 of the DSR, which are the stages "Demonstration" and "Evaluation" had as result, respectively, an experiment and the evaluation of the data collected in it. On this research, a mixed factorial experiment was designed, which indicates an experiment with at least a within-subjects factor and at least one between-groups factor. The experiment was also designed to be double-blinded – neither the participant nor the experimenters know which group does a participant belongs to.

A number of 44 participants had to perform two tasks each, reading a scientific text and writing an email response on a neutral topic. The choice of both tasks aims to minimize any emotional bias that the participant may have. Finally, a hypothesis test was defined.

The data of both groups performing each task was collected and analysed in order to help answering the test. Also, they allowed us to understand the emotional path made by the participants. This information was grouped into four incident graphs.

The final step is the stage of "Communication", when the research finds are presented to the community. Three articles were written with the information gathered on this research. They are presented on Section 1.6.

1.6 Outline of the Thesis

This dissertation consists of five chapters. Chapter 2 presents an approved paper published on the HCI national conference. Chapters 3 and 4 present papers that are yet to be submitted to international conferences or journals. Finally, Chapter 5 concludes this work. The outline of the research contributions made by the studies that compose this work are:

[Chapter 2] SILVA, Letícia G. Zacano da; GUIMARÃES, Patrícia D.; GOMES, Luciana O. de Souza; NERIS, Vânia P. de Almeida. A comparative study of users' subjective feeling collection instruments. In: *Proceedings of the 19th Brazilian Symposium on Human Factors in Computing Systems*. 2020. p. 1-10.

When studying about emotions, the subjective feeling is usually mentioned as a reliable source of data. Known as one of the five components of the emotion (SCHERER, 2004), numerous instruments have been developed to collect this type of data, using either verbal terms, different scales and pictorial drawings. However, there are few studies that compare these distinct approaches. This article compares four instruments to find out which one takes the users to inform a subjective feeling closer to an emotion already pre-classified by the literature for a given stimulus.

[Chapter 3] GUIMARÃES, Patrícia D.; SILVA, Fernando M.; CAMARGO, Valter, C.; NERIS, Vânia P. de A. An easy-to-maintain framework to adapt web user interfaces considering users' emotions. *Not yet submitted.*

There is a lack of studies focusing on how to help users to achieve a desired emotional state when interacting with user interfaces. To fill in this gap, we present UIFlex 2.0, a tool that alters interface elements according to users subjective feeling and motor expressions, components of the human emotion (SCHERER, 2001). This tool adopts the MAPE-K model (KEPHART et al., 2003), an architecture based on four steps – monitor, analyser, planner and executor – and a shared knowledge among them. Amongst other information, this knowledge stores the adaptation rules that should be applied based on the users initial and desired emotional state. UIFlex 2.0 is also designed to be a collaborative infrastructure. Finally, we evaluate the maintainability of the system after the MAPE-K model adoption.

[Chapter 4] GUIMARÃES, Patrícia D., SOUZA, Anderson L. A.; NERIS, Vânia P. de A. A mixed factorial experiment with colours and adaptive web user interfaces to change emotions. *Not yet submitted.*

The colour is one of the major elements of interface responsible for providing a change on the user's emotional state. UIFlex 2.0 was designed to help users to achieve a desired emotional state. An experiment with 44 participants divided into control and placebo group was carried out to assess whether UIFlex 2.0 fulfilled its goal. In the study, the majority of participants of both groups achieved the desired state. This, in addition to the application of a Chi-Squared test, concluded that the tool does not met its goal. Finally, graphs of incidence demonstrate the path followed by the users during the experiment.

Chapter 2

A COMPARATIVE STUDY OF USERS' SUBJECTIVE FEELING COLLECTION INSTRUMENTS

Although the interaction with computational systems influences human emotions, knowing what emotion emerges is a rather complex job. Researchers from the Human-Computer Interaction field have been using several different methods to measure altered emotions and collect users' subjective feeling is one of them. Nevertheless, there is a lack of studies that experimentally compare the different instruments to measure users' subjective feeling. This paper presents an investigation with four instruments – a set of emojis, the Self-Assessment Manikin, scroll sliders and the Semantic Emotional Space – to find out which one takes the users to inform a subjective feeling that is closer to an emotion already pre-classified by the literature for a given stimulus. The experiments had 29 volunteers that participated in four experimental rounds. In each round, each volunteer watched a movie or part of a video clip and later randomly interacted with either one of the instruments in a user interface. The results suggested that the Scroll Slider lead to greater proximity to the pre-classified emotions.

Keywords: user interface, emotion, subjective feeling, emoji, SAM, scroll slider, Semantic Emotional Space

2.1 Introduction

It is known today that emotion plays an extremely important role in the relation amidst computers and people especially in activities that are oriented towards an objective such as doing a search on the Web or sending an e-mail (BRAVE; NASS, 2007). Human-Computer Interaction (HCI) is the area of Computer Science that develops computer systems aimed at creating the best possible user experience. The study of emotions as well as their definition may be complex, leading researchers to adopt concepts that relate to their object of study. One of the best known definitions is that emotion causes changes in subsystems of the organism, one of which is the subjective feeling (SCHERER, 2001).

The literature has several methods and instruments capable of measuring an emotional state [15, 34]. Although they may be classified in different manners, scholars in general present at least one set of instruments to measure users subjective feeling. In [8], the authors presented two sets: one with verbal self-report instruments and the other with pictorial self-report. The elements of the first group have the advantages of being used to measure feelings that have little distinction between each other. However, they present limitations such as the difficulty of being applied to people that speak different languages or have different cultures. This is the main advantage of the second group as they do not need to be translated to be applied. On the other hand, if the instrument is not cross-culturally validated, it may also lead to misunderstandings.

Nevertheless, most of the published studies found present either the experimental application of only one method – such as [2, 14, 17, 32] – or a theoretical comparison among instruments developed to collect subjective feeling as in [15]. There are few studies that experimentally compare different instruments used to measure users' subjective feeling as did [12]. This last study, however, presented only instruments designed by the authors, which differs from our work.

Therefore, this study presents an experimental study with instruments found in the literature that collect subjective feeling. Our goal is to find out which one of them has the highest number of matches between pre-classified emotions and emotions informed by the user.

The four user interfaces (UI) were based on known instruments that measure emotion. Data from 29 users were collected in four experimental rounds each using a subjective feeling collection instrument. At each round the user watched a segment of a film or videoclip, which acted as a stimulus, and then described their emotional state through an UI. Between one round and the next, we invited the volunteer to express their opinions about the instrument used in order to neutralize the emotion previously generated by the video.

The results suggest that, among the four UIs used to collect subjective feeling, the scroll slider presents the greater proximity to the expected.

This work is divided into the following sections: Section 2 presents fundamental concepts for the understanding of this work, such as emotions, subjective feeling and instruments to collect subjective feeling; Section 3 briefly presents the works related to this article after an ad hoc search; Section 4 explains in detail the experiment carried out and separates it into three stages - planning, execution and consolidation of the results; Section 5 presents a general discussion of the founds of this research, including some limitations of this study; finally Section 6 summarizes what was presented in this article with the contributions made and ideas for future work.

2.2 Fundamental Concepts

To fully understanding this research, it is necessary to comprehend some of the concepts we have cited. Also,we present the instruments compared in this work and other that are similar or relate to them somehow.

2.2.1 Emotion

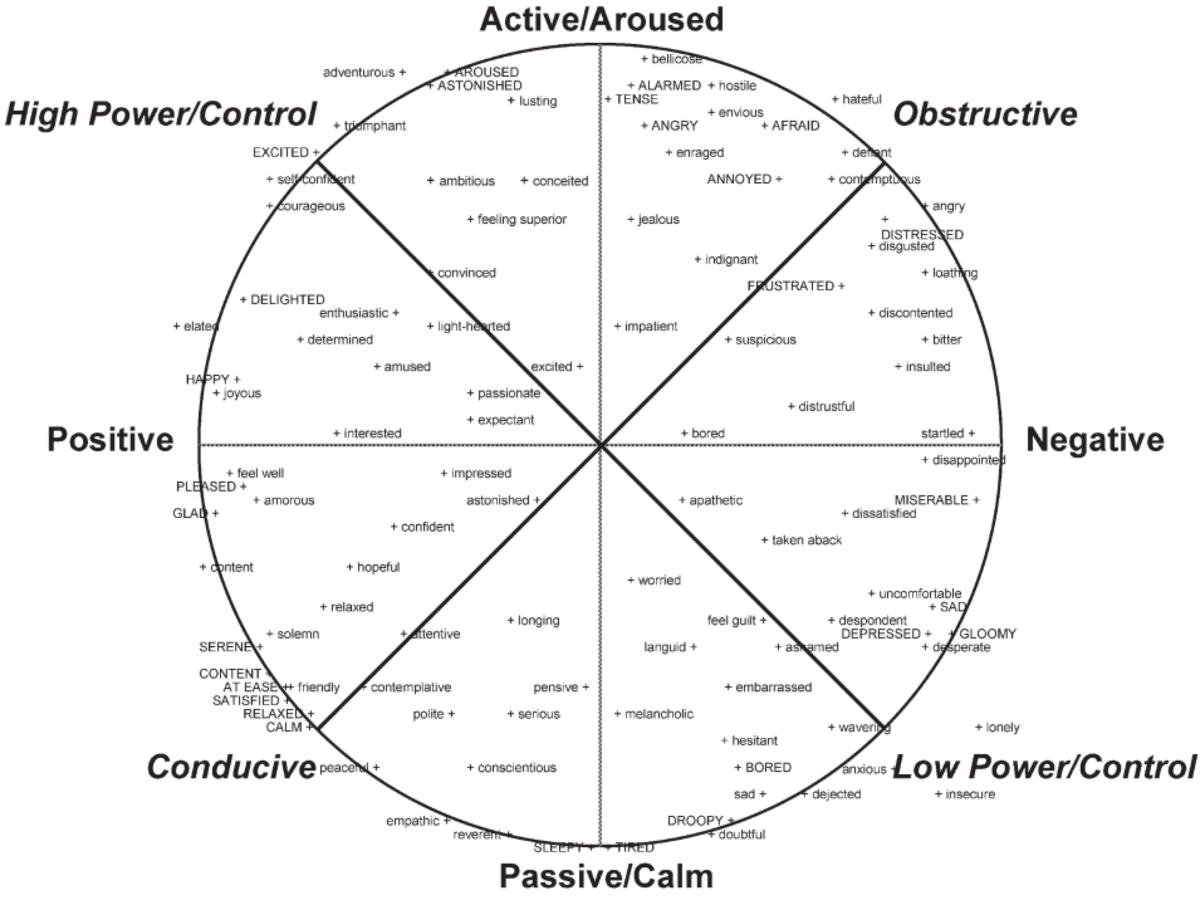
Although researchers have not yet been able to state since when does humans consciously feel emotions, they have made progress studying what are emotions and how they manifest.

Emotion may be defined as a psychic and physical variation that arises in response to a stimulus received (DAMÁSIO, 2003). However, science is lacking on formal criteria to classify something as emotion or not (RUSSELL, 2003) leaving the researchers to adopt the definition that suits better their research.

In this work, we follow Scherer's definition of emotion: a response to an external or internal stimulus event that results in changes in at least most organismic subsystems (SCHERER, 2001). The choice of this definition is justified by the fact that, by studying the different subsystems related to emotions separately, it is possible to contribute to a broader view of the users' emotional experience (XAVIER; NERIS, 2014). These subsystems are responsible for five emotional components, which are cognitive assessments, behavioral trends, physiological reactions, motor expressions and subjective feelings.

Along with the definition, authors sometimes develop models that allow emotions to be classified. One of them is Russell's bidimensional model (RUSSELL, 1980). In this model, two axes are placed perpendicularly. Between these two axes, 28 emotional terms – such as tired, sad, pleased and excited – were plotted such as graph points on a coordinate plane. The final result looked like a circumference. Later, he presented a second model called Core Affect (RUSSELL, 2003). The axes then represent activation-deactivation (vertical axis) and displeasure-pleasure (horizontal axis). Also, this model has only 16 terms near the circumference edge. As closer as

Figure 2.1: Scherer's Semantic Emotional Space.



Source: (SCHERER, 2005)

the edge, the stronger the emotion. Similarly, as closer to the center, more neutral the emotion is.

The emotions located at the top of the circle have high levels of arousal while those below are low arousal. Likewise, those on the left have a low level of valence, whilst those on the right have high valence.

Intended to improve Russell's first model and based on items from the second one, Scherer (SCHERER, 2005) developed a model known as SSES (SCHERER, 2005). In it, he added two other domains: goal conduciveness and coping potential. The first one measures the ease one has on achieving objectives and the second assesses the feeling of control one has over an event. They were represented as two other lines that also pass by the center of the circle as can be seen in Figure 2.1. Finally, not only did the research place again the 28 emotional terms (RUSSELL, 1980) in his model, he also included 80 more.

The axes represent the four emotional domains – arousal, valence, coping potential and goal conduciveness – which have positive and negative poles as in the models (RUSSELL, 1980, 2003). The circle is divided into eight equal parts, called octants, where the emotional terms are located. These terms have their location represented for the plus sign (+).

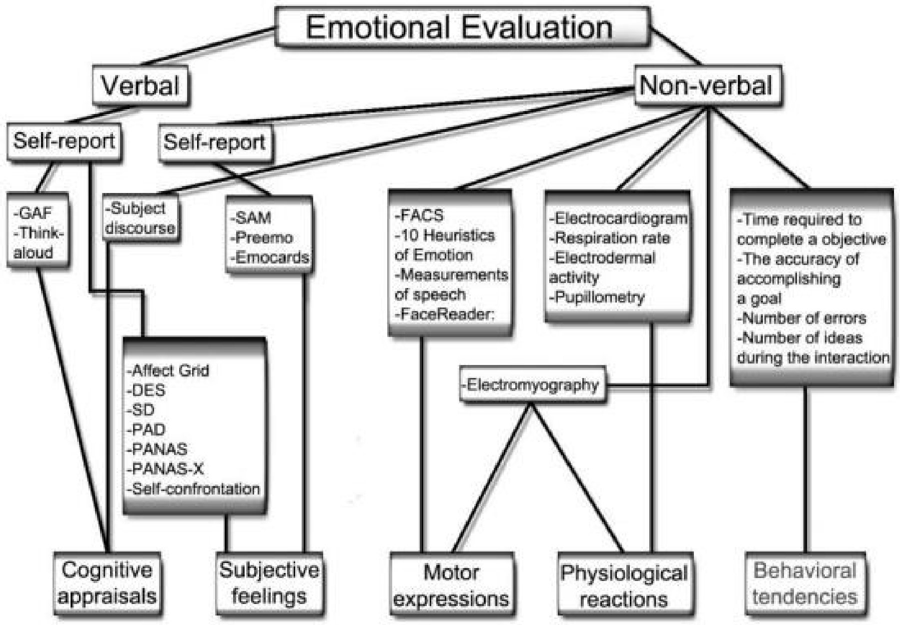
2.2.2 Subjective Feeling

According to Scherer (2005), the subjective feeling is related to the Central Nervous System. This system is responsible for monitoring not only the organism's internal state, but also its interaction with the environment.Scherer (2005) also comments on the lack of sufficiently objective methods that can analyse subjective feelings during an emotional episode. Considering the mental and behavioral changes that an object may affect the individual and therefore influencing his feelings, the only way to capture them is to ask the individual directly how he or she feels.

2.2.3 Instruments to Collect Subjective Feeling

Researchers around the world have developed and still develop instruments to collect and understand human emotions. Figure 2.2 shows some of the instruments found in the literature, relating them to the Component Model (SCHERER et al., 1984). Figure 2.2 illustrates the separation of instruments into verbal and nonverbal methods (DESMET, 2003). Specifically in the case of subjective feeling, nonverbal methods were then called pictorial by (DESMET; VASTENBURG; ROMERO, 2016).

Figure 2.2: Emotional evaluation methods .



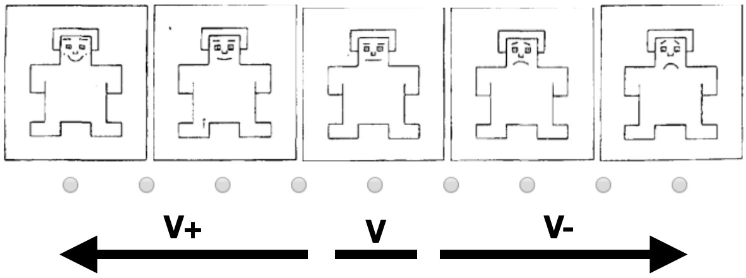
Source: (XAVIER, 2013).

As verbal methods, Figure 2.2 shows, among others, the Methods Affect Grid (RUSSELL; WEISS; MENDELSOHN, 1989) and Positive and Negative Affect Schedule (PANAS) (WATSON; CLARK; TELLEGEN, 1988). Affect Grid (RUSSELL; WEISS; MENDELSOHN, 1989) is based on a matrix with a scale from 1 to 9 developed to measure both user's pleasure and arousal. The participant is asked to mark an "X" in a single place in the grid, meaning his or her mood at the moment. Eight emotional terms are arranged around the grid to help guide the user. In a similar way, PANAS (WATSON; CLARK; TELLEGEN, 1988) presents 20 emotional terms – ten positive and ten negative – along with a 5-point scale to measure intensity.

Some instruments use a distinctive approach such as Atrack-Diff (HASSENZAHL; BURMESTER; KOLLER, 2003) and the instrument developed on SSES (SCHERER, 2005) presented on (ASSUNÇÃO; NERIS, 2019). Atrack-Diff (HASSENZAHL; BURMESTER; KOLLER, 2003) presents four dimensions, each composed by seven pairs of opposite words. To describe their emotion, the user uses a scroll slider positioned between each pair. Assunção and Neris (2019) also presents an instrument present as a virtual UI. After receiving a stimulus, the participant should mark on the space the point that best represents his actual emotional state on a colored version of SSES (SCHERER, 2005).

Emocards (REIJNEVELD et al., 2003) and PrEmo (DESMET, 2003) are non verbal methods cited in Figure 2.2. They were both developed with the initial intention of identifying the emotions of participants to items considered physical office tools, such as chairs and cell phones.

Figure 2.3: One of SAM axes.



Source: Based on (XAVIER; NERIS, 2012).

The first presents four facial illustrations for each set of two emotions present in the work of Russel (RUSSELL, 1980), and it is up to the user to choose the one that best represents their emotion. The second presents 14 illustrations with facial and body expressions – seven of which are pleasant and seven unpleasant – and allows the user to select complementary figures to represent how they are feeling, but never figures of conflicting emotions.

The figure also mentions the Self-Assessment Manikin (SAM) (BRADLEY; LANG, 1994) a nine-scale-evaluation-method that measures three domains: pleasure, arousal, and dominance – a synonym for coping potential. Each domain has five images to help the user to better describe their emotions. Figure 2.3 adapted from (XAVIER; NERIS, 2012) demonstrates the scale in the pleasure dimension and what each space represent. In this case, a V+, V- and V were used to indicate the valence – or pleasure – felt after a stimulus. If a user marks one of the four first circles, it means they had a positive valence experience (V+). If they mark one one of four last circles, they had a negative valence experience (V-). The central circle means a neutral valence experience (V).

Another method is the Experience Sampling Method (ESM) (LARSON; CSIKSZENTMIHALYI, 2014). It is based on a form and used to collect user's daily information. The questions are usually accompanied by a Likert scale where the user must mark a number or symbol to represent their answer. On Júnior, Kronbauer and Campos (2019), the authors used emojis to represent the scale.

2.3 Related Works

As mentioned, there are significant studies that bring about new manners to collect the user's emotional state, specially the user's subjective feeling. However, only a few of them compare the instruments and methodologies found in the literature either theoretically or experimentally. The studies below have brought a comparison between different methodologies or instruments used to collect participants' subjective feeling.

Fuentes et al. (2017) presents a systematic review of 40 studies with 32 UIs in order to understand the new trends when the theme is self-report instruments. Of the 32, 40% use questionnaires as a tool to collect subjective feeling, which reinforce the need for innovations in self-reporting. Also about only 9% are web UIs, a percentage below the expected as people have been spending an increasingly amount of time on the Internet.

Both Novak et al. (2015) and Tigwell and Flatla (2016) analyse the use of the emoji. The first one analyzes its importance signs in expressing emotions in contemporary's communication and the second studies the variable emojis interpretation between different users and different platforms respectively. In Novak et al. (2015) study, most messages empirically classified as neutral did not contain emojis, evidencing the emotional charge inherently employed by emojis. On the other side, Tigwell and Flatla (2016) highlight many variables in the interpretation of the emotional information expressed by emojis. This last paper suggests an emoji interpreter that would adapt the emojis according to the receiver's profile once the meanings of an emoji may have different interpretation between people therefore causing some miscommunication.

In order to provide an intuitive tool to report feelings, Laurans, Desmet and Hekkert (2009) developed in his thesis the "emotion slider". He associates congruence movements with a single domain of classification of emotion, valence. After conducting experiments with 51 users, the author indicates that the movement of pushing to more positive valence and pulling to the most negative valence are more intuitive to the user compared to opposite movements.

With his work, Fritz (2015) seeks to raise awareness of individuals about their own emotional states through a computational mediation instrument in which the user must consider the emotional state of another person. The Dynamic Emotion Wheel (DEW) was based on Geneva Emotion Wheel (GEW) (SACHARIN; SCHLEGEL; SCHERER, 2012), an UI that presents the domains of valence and arousal, with 40 emotional terms related to 20 intensity scales, arranged in a circle. DEW, however, has two scroll sliders – one to each of the previously mentioned domains – and present three possible emotional states to the user based on the combination collected by the scroll slider. This instrument validates the association of scroll sliders with measuring valence and arousal for self-reporting tools and subsequent emotional classification.

Júnior, Kronbauer and Campos (2019) presents a platform that integrates seven self-report tools. Four of them are the most relevant to the experiment presented on Section 2.4: the ESM method represented with five emoji arranged on a linear scale already mentioned on Section

2.3; a blend of SAM [2] but using sliders; Emocards (REIJNEVELD et al., 2003) and AttrackDiff (HASSENZAHL; BURMESTER; KOLLER, 2003).

With regard to the recurring emotional transition in video games, Granato (2018) infers the excitement of 33 players. Data was obtained through sensors and a instrument they developed and named Emotion Self-Assessment Tool (ESAT). It was based on the works of Bradley and Lang (1994) and A (2016), bringing Manikins, emojis and sliders into a single subjective feeling UI instrument.

Pick-A-Mood (DESMET; VASTENBURG; ROMERO, 2016) new self-report method for measuring mood with a focus on design applications for mood. While emotions are specific and high-intensity feeling states that usually last for a short period of time, moods are diffuse and low-intensity feeling states that may last for days. In addition to the new instrument, Desmet, Vastenburg and Romero (2016) presents an extensive list with diverse methodologies that collect either emotion or mood. When relating to self-report tools, the authors point out their preference for pictorial scales as they are more accurate intuitive and universal – once they do not need to be translated.

Georgios Kouroupetroglou, Nikolaos Papatheodorou and Dimitrios Tsonos (2013) adapted SAM (BRADLEY; LANG, 1994) to a web UI that would allow the self-assessment of the emotional state. On their work, however, authors, reversed the polarity of the figures representing dominance in addition to changing the classification scale of the three domains (valence, arousal and dominance) to only five points.

In the analysis of the responses, these are converted to a variable percentage scale of -1 to 1 and later applied in the SSES (SCHERER, 2005) proportionally according to each domain – applying another methodology for a purpose similar to what we present in the mapping of UI-2, presented in the Section 2.4.

When analysing the participant's answers, the authors converted the marks to a value between -1 and 1. Later, they find the values in the SSES (SCHERER, 2005) in each domain. In the analysis of the responses, these are converted to a variable percentage scale of -1 to 1 and later applied in the SSES (SCHERER, 2005) proportionally according to each domain – applying another methodology for a purpose similar to what we present in the mapping of UI-2, presented in the Section 2.4.

The last study found presents three physical prototype used as self-report instruments (GOOCH et al., 2020). Two of them – Emotion Board and Emotion Clock – were based on Russell's Core Affect Model (RUSSELL, 2003) and the final one – Emotion Octagon – on Pick-A-Mood

(DESMET; VASTENBURG; ROMERO, 2016). The objective of this study was to find which instrument had a greater proximity to the participants emotions, the closest we found to our objective. They concluded that all three instruments are in the short term sufficient to support the well-being of older people – their target audience – but further research is necessary to find the instrument that best approaches to daily life. They also recommend that, in a next study, at least one of the instruments to be tested be a tool that allows greater granularity in emotional classification, allowing, for example, the participants to choose between fright and fear or calm and relaxed.

2.4 Experiment

This section presents the entire process of planning and executing an experimental study to investigate in which UI the emotions informed by the user are closer to those pre-classified, found in literature. Finally, it present the results of our experiment and the analysis of the collected data.

2.4.1 Planning

The first step of planning the experiment consisted on elaborating an experimental design, presented in the list of items below:

- **Null hypothesis (H_0):** At least one of the UIs that collects subjective feelings has one or more results that coincide with the pre-classified standard.
- **Alternative hypothesis (H_1):** None of the UIs that collects subjective feelings has one or more results that coincide with the pre-classified standard.
- **Dependent variables:** The resulting octants (set of emotions in SSES (SCHERER, 2005)).
- **Independent variables:** The four subjective feeling collection instruments.
- **Conditions:** The four subjective feeling collection UIs.

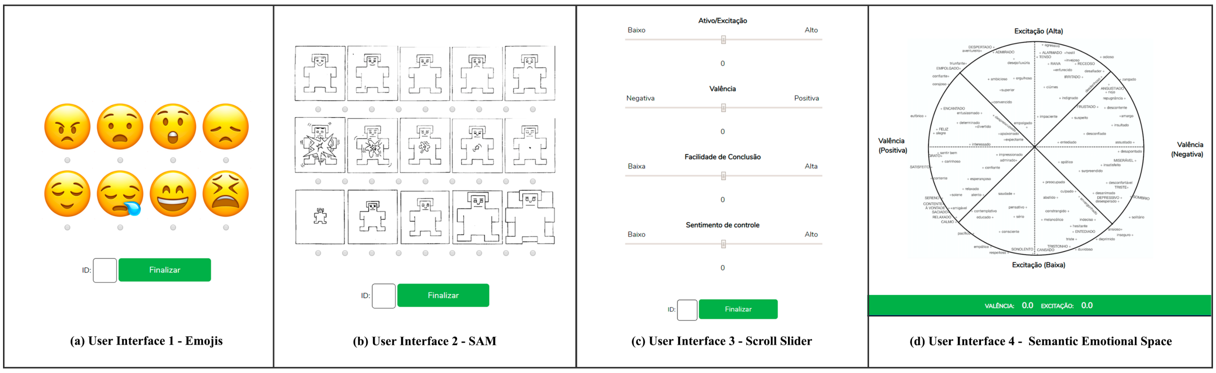
The second step was decide how we were going to stimulate our participants. We chose to use the visual and sound stimuli, presenting extracts from movies and video clips. The extracts chosen were already pre-classified in the literature according to the emotions they probably provoke by Koelstra et al. (2011), Schaefer et al. (2010) and Soleymani, Pantic and Pun (2011).

Table 2.1: Stimulus in videos

ID	Source	Videos	Emotion	Oct.	Duration
1	*Corporate Cannibal*	Koelstra et al. (2011)	Scary/ Fear	1	03min00
2	*E.T.*	Schaefer et al. (2010)	Sad	4	04min46
3	*Her Morning Elegance*	Koelstra et al. (2011)	Relaxed	6	03min36
4	*Love Actually*	Soleymani, Pantic and Pun (2011)	Happy	7	01min38

Source: The authors.

Figure 2.4: UI prototypes. In c, the domains shown in Portuguese refer to arousal, valence, coping potential and goal conduciveness in English respectively and the options refer to low/high, negative/positive, low/high and low/high. In d, the domains shown in Portuguese refer to high arousal/low arousal on the vertical axis and positive valence and negative valence on the horizontal axis, respectively. The terms that appear are the emotional terms translated in (SCHERER, 2005) from English to Portuguese.



(a) User Interface 1 - Emojis (b) User Interface 2 - SAM (c) User Interface 3 - Scroll Slider (d) User Interface 4 - Semantic Emotional Space

Source: The authors.

In his study, Souza (2019) selected some pre-classified extracts present on the literature and added a new classification according to the octants on SSES (SCHERER, 2005). He did it by searching the emotions terms on the SSES (SCHERER, 2005) and then linking the extract with the octant. For our experiment, we grouped the octants two by two, forming quadrants, and chose a well-known emotional term in each quadrant. Then, we chose one extract of Souza (2019) list according to the emotion they would stimulate and the octant of the extract. In Table 2.1 the selected videos are presented with their respective emotional terms and octants.

The next step was defining which UIs would be presented to the participants. Four instruments that had been already proposed and validated were chosen: emoji, SAM (BRADLEY; LANG, 1994), scroll slider and SSES (SCHERER, 2005). Four prototypes were developed, each one based on one of these instruments. Their final versions are represented in Figure 2.4.

For UI-1, Figure 2.4-a, we searched for articles that related emojis to the emotions cited in Table 2.1. We chose (MILLER et al., 2016) where the authors bring about one of the most completed sources that relate emoji to emotions, the Emojipedia[1]. To avoid any bias by only presenting emojis related to the chosen emotions to be stimulate, we selected one emotion – and, consequently, one emoji – from each octant of the SSES (SCHERER, 2005).

We searched in Emojipedia for emojis whose descriptions contained the same emotional terms as the videos that represented octants 1, 4, 6 and 7. If the term was not found – or in the case of octants 2, 3, 5 and 8 that did not have a video to be shown, we look for emojis whose description contained any of the emotional terms present in the respective octant. They chosen emojis were: anger (octant 1); disgusted (octant 2); disappointed (octant 3); tired (octant 4); sleepy (octant 5); relief (octant 6); happy (octant 7); and astonished (octant 8). During the execution, the volunteers had to choose which emoji best represented how they were feeling.

UI-2, Figure 2.4-b, was an adaptation of SAM (BRADLEY; LANG, 1994) to an online form format. To indicate their feeling in this UI, the volunteers had to mark one point out of the 9 present in each line.

In UI-3, see Figure 2.4-c, we added 4 scroll sliders one to each domain of SSES (SCHERER, 2005). In every one, volunteers had to slide the bar located at the center of the slider. The more they slide to the left, the lower or the more negative they were feeling in that domain. Contrarily, the more to the right, the higher or more positive they were feeling. As they slided, numbers between -1 (left) to 1 (right) appeared to represent the exact point they were at. If the button kept on the center, the number 0 would appear indicating a neutral feeling.

UI-4, Figure 2.4-c, is an Portuguese adaptation of the SSES (SCHERER, 2005). In this UI, the volunteers were asked to click on the space that would best represent how they were feeling.

The next step was defining the profile of the volunteers who would participate in the experiment. To avoid regulation problems, the minimum age to participate in the experiment was 18 years old. Because the experiment was held inside a university, most of the participants were undergraduate or graduate students. Therefore, all of them had at least completed high school. The other participants were either students at another university or academics. As we developed the UIs, the participants would not have any knowledge on how to use them. To avoid any kind of embarrassment, we also excluded participants who did not have experience in browsing web sites. Finally, as the test should be in person, we searched for people who lived in the city of omitted for blind review or spent much of their days in the city. Table 2.2 shows the profile of the experiment volunteers. To find them, we sent emails to both internal and external com-

[1]https://emojipedia.org

Table 2.2: Users' profiles.

Age	Between 18 and 50 years
Education	Had from complete high school to finished doctorate/pos-doc
Computer experience	Ease of browsing web sites
Location	People who lived or studied in the city of São Carlos

Figure 2.5: Experimental setup.

munity, did a local campus outreach and posted information about the experiment on a social media.

The last step was deciding how would the experiment be executed. It was decided that users would go through four rounds. In each one, they would watch one of the four selected videos and then, at the end of the exhibition, they would mark in one of the four UIs how they were feeling. However, if all volunteers performed the tasks in the same order, the results could be biased, as they might learn about the measuring from one UI to the other even if unintentionally. Therefore, the experiment was randomized[2] so that each volunteer could watch the 4 videos and interact with the 4 UIs randomly and with a minimum of repetitions between them.

A pilot test was then carried out. In Figure 5 the configuration of the experiment station is shown as well as the position of volunteers and evaluators during the experiment.

In view of the ethical and scientific rigor, the research project was sent and approved by the Ethics Committee for Research in Human Beings (CEP).

[2]To randomize the order of presentation of the videos and UIs of the experiment to the volunteers, the website was used: https://www.randomizer.org/

2.4.2 Execution

30 volunteers were recruited to participate in the experiment. However, due to a university power failure problem, user data 29 was incomplete and had to be removed from the analysis.

At the beginning of each session of the experiment, all volunteers read, signed and received a copy of the consent form and image and sound capture authorization. They also responded to a pre-session questionnaire in order to collect information about their profile. Soon after, the volunteers performed the tasks defined previously in Section 2.4.1. In the interval between one task and another, the evaluators of the experiment asked the volunteers how they felt, in relation to the stimulus and interaction with the UI presented. At the end of the session, a final questionnaire was delivered to collect general information about the execution of the entire experiment.

2.4.3 Consolidation of the Results

As the methods of collecting subjective feelings chosen for this work have different forms of measurement, it was necessary to ensure that they would have the same pattern to allow data comparison. Thus, we chose the SSES (SCHERER, 2005) classification as our measure pattern. As the movie extracts were already classified using this work, we believed maintaining the pattern would be the greatest choice for also evaluating UI-1 and UI-4. Also, the instrument present all domains that are found in UI-2 and UI-3.

In terms of mapping the volunteers answers into octants the UI-1 was one of the simplest to perform. Because each emoji already had a pre-classified emotion, after the volunteer selected one of them to represent their feeling, we already knew what was the emotion chosen and the octant it was located in SSES (SCHERER, 2005).

As expected, no mapping was necessary for UI-4. When the volunteer scored a point in the space, we already knew the final octant.

For the analysis of the data collected by the UIs UI-2 and UI-3, we created the Mapping Self-report Instruments by Intensity and Polarity for Emotions (MSIPE) Method, or (MAIPE) for acronym in Brazilian Portuguese (pt-br). This method allows mapping discrete or continuous scales present in self-report instruments to SSES (SCHERER, 2005) octants. To do so, it is of paramount importance to understand the polarity (positive or negative) and the intensity (high or low) of the four domains – valence, excitation, dominance and conduciveness – present on (SCHERER, 2005) work. This aspects are presented in Figure 2.7.

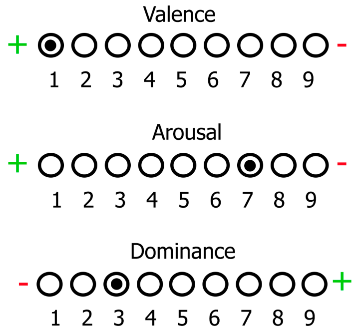


Figure 2.6: Representation of SAM points.

The mapping of the responses obtained in the UI-2 for octants was more complicated in relation to the accuracy of the results as SAM (BRADLEY; LANG, 1994) does not seek to describe the emotion felt by the user, but rather to measure the intensity of the emotion. To do so, it uses discrete scales to measure arousal, valence and coping potential (dominance) levels. Unlike the SSES (SCHERER, 2005), which has a continuous scale and four domains that, as mentioned, divide the space into eight pieces.

In the first stage of mapping for octants, polarities and intensities were defined for the domains understood by both SAM (BRADLEY; LANG, 1994) and SSES (SCHERER, 2005). In SAM valence and arousal domains were classified as follows: points 1 and 2 as high intensity positive responses, low intensity positive points 3 and 4, low intensity negative points 6 and 7, and points 8 and 9 were considered high intensity negative responses. Figure 6 graphically represents this mapping.

For the dominance domain, we classified points 1 and 2 as representatives of high intensity negative responses and low intensity negative numbers 2 and 3. Points 6 and 7 represented positive responses of low intensity and points 8 and 9 positive high intensity. In all domains point 5 represented neutral for polarity and intensity. Since SSES (SCHERER, 2005) does not understand any octant as a representative of a neutral emotion, any marks on point 5 of SAM's (BRADLEY; LANG, 1994) domains were disregarded during the mapping.

In the second stage of the MSIPE Method, we used the definitions of polarity and intensity in SSES (SCHERER, 2005) as exemplified in Figure 2.7.

The set of octants representing each domain were divided into positive and negative with high and low intensity. For example, the arousal domain had octants 1, 2, 7 and 8 defined as positive (painted in dark blue in Figure 2.7) and octants 3, 4, 5 and 6 as negatives (painted in light blue in Figure 2.7). For the set of octants referring to positive arousal, octants 1 and 8 were considered high intensity and octants 2 and 7 of low intensity. In the set of negative arousal

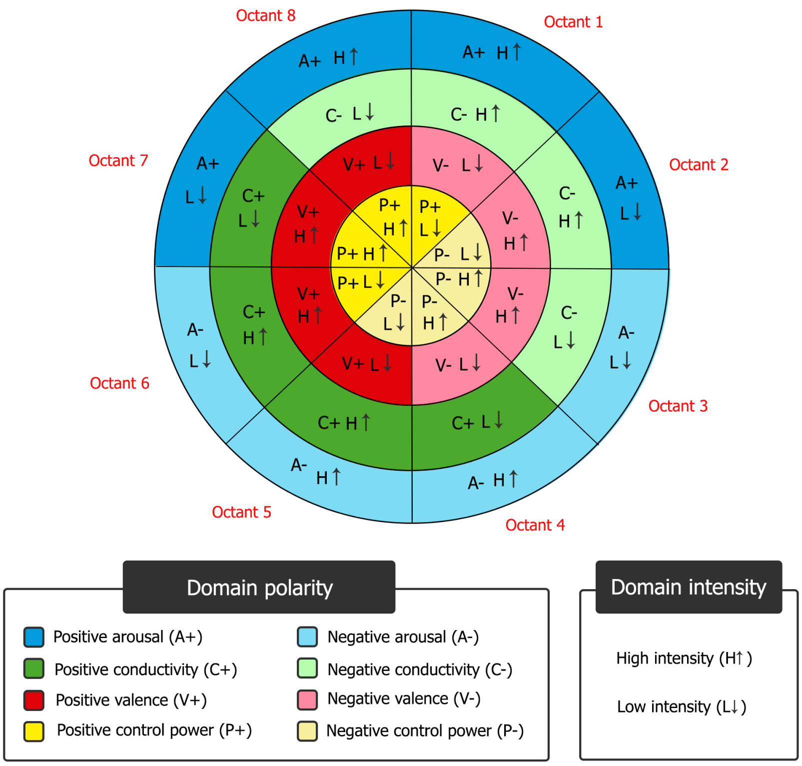


Figure 2.7: Adaptation of the Semantic Emotional Space: relationship between the polarity and intensity of the domains.

octants, octants 4 and 5 were high intensity and octants 3 and 6 of low intensity. An equivalent classification was performed for all four domains, following the polarity already indicated by Scherer (2005).

Figure 2.6 presents an example of user 03 response. The participant marked point 1 for valence, which is classified as high-intensity positive valence; point 7 for arousal, which is considered as low intensity negative arousal; and point 3 for dominance, which refers to low intensity negative dominance. Thus, in the next step of the MSIPE Method, we mapped SAM (BRADLEY; LANG, 1994) domains to SSES (SCHERER, 2005) domains by combining the polarities and intensities of both and obtaining the following octants:

- Valence: 6 e 7;
- Arousal: 6 e 3;
- Dominance (Control power): 5 e 2.

To consolidate the final result, we deciced to do the octant's mode. Hence, the prevailing octant would be the one with the highest incidence – in this example, octant 6.

On UI-3, volunteers chose a value in each of the four domain sliders. To allow the mapping of UI-3 to SSES (SCHERER, 2005), each of the four domains represented by sliders were classified according to the intensity and polarity of their values. The final classification of the domain's intensity and polarity are declared above.

- Values between -1 and -0.5 are considered negative with hight intensity (closed range);
- Values between -0.5 and 0 are considered negative with low intensity (opened range);
- Values between 0 and 0.5 are considered positive with low intensity (opened range);
- Values between 0.5 and 1 are considered positive with high intensity (closed range);

The following mapping steps occurred in a similar manner than those explained in UI-2. However, because UI-3 also considerates the domain of conducivity, the MSIPE Method was applied to four domains instead of three. In addition, the mode and the analysis of higher incidence for the definition of the resulting octant(s) also took into account the new domain.

No mapping was necessary for UI-4. As the volunteer selected a point in SSES (SCHERER, 2005), we automatically new the final octant or octants (if marked in a division line).

In order to state which of the previously mentioned instruments had the chosen emotional closer to the pre-classified stimuli, comparisons were made between them. As presented in Table 2.3, we considered three criteria for comparisons: number of equal, neighboring and distinct octants.

Equal octants correspond to the octants marked by the user that are coincident to the stimulus' octants. Neighboring octants are those who were at a distance of 1 or -1 from the pre-classified octant – the predecessor and successor octants. For example, if a pre-classified octant was number 7 its neighbors octants were those of number 6 and 8. Distinct octants are all the other possible octants not mentioned here. Again, if the pre-classified octant was number 7, its distinct octants are octants 1, 2, 3, 4 and 5.

The results, presented in table 3, inform that UI-1, out of a total of 29 results, had only two equal octants, 12 neighbors and 27 distinct. The UI-2, out of a total of 29 results, had four equal octants, seven neighbors and 25 distinct. The UI with the most coincidences was UI-3, where six results were equal to pre-classifications, 15 neighbors and 23 distinct. Finally, the IU-4 had four equal results out of a total of 29, eight neighbors and 25 distinct.

Table 2.3: Comparison between the octants resulting from the UIs and the pre-classified stimuli.

Comparison criteria	Result of the UIs			
	UI-1	**UI-2**	**UI-3**	**UI-4**
Same octants	2	4	6	4
Neighboring octants	12	7	15	8
Distinct octants	27	25	23	25

These results suggest that at least one of the UIs of collecting subjective feelings had one or more results that coincide with the pre-classified pattern thus validating the null hypothesis presented in the Section 2.4.

2.5 Discussion

This section brings up discussions about the choice of each UI, the development of the MSIPE Method and evaluative perceptions from both the experimental phase and the analysis of the collected data.

Considering its target audience elderly people Gooch et al. (2020) chose to implement and compare tangible user interfaces (TUI) as they might be more accessible than user interfaces. Similarly, considering our younger audience, we considered the approach of web UI, or simply UI, as the one that better fits the daily life of users who have easy access to both computers or mobile devices.

Each UI considered in this study has pros and cons. For UI-1, the use of emojis has its positive point in relation to their presence in the users' daily life. However, the use of a discrete scale with only 8 options decreases the granularity of the individual's expression. In addition, even if it includes the exact emotion felt by the user, they still might have a variable interpretation for each user – as pointed out by Miller et al. (2016) and Tigwell and Flatla (2016).

With regard to UI-2, although it is still one of the most cited instruments and a validated methodology in both the Psychology and the HCI fields. Nevertheless, SAM (BRADLEY; LANG, 1994) might have the same bias about interpretation, as well to losing some granularity owing to the fact that it has a discrete scale.

The UI-3 guarantees the use of a continuous scale, but the use of sliders, even if common in the literature, is poorly visual, which can hinder users who do not understand the four domains presented or who have difficulty correctly measuring their feelings.

UI-4 presents the second version of the prototype presented on Assunção and Neris (2019). In addition to having a good level of intuition, as discussed below, this instrument allows greater granularity, in other words, differentiating similar emotions more accurately in relation to the final answers. With more than 120 emotional terms presented, UI-4 facilitates the specification of an emotion. Likewise, it may confuse the user due to the amount of emotions presented.

With regard to self-report instruments, Desmet (2003) advocates the use of pictorial scales figures due to better intuition, speed and accuracy. Besides these characteristics, the authors mention that the pictorials instruments are universal as they do not require translations. Therefore, we could expect that UI-1 and UI-2 – that present emojis and manikins, respectively – would do better in this comparative study having greater correspondence of the results obtained with those expected.

However, in terms of accuracy, UI-1 had worst results than all the others whilst UI-2 had the same number of equal octants as UI-4, the only UI based on terms. In everyday life, emotional self-reflection is usually expressed using terms in both speech or writing. Thus, instruments that use verbal terms, such as UI-4, can be considered even more intuitive by bringing a form of emotional communication that is inherent and natural for individuals.

It is also worth mentioning that the UI-2 and UI-3 have a point considered neutral, an element that does not exist either in the UI-1 and UI-4 or in the SSES itself (SCHERER, 2005). It is possible that a user in doubt of how they are feeling would express their emotion as neutral. It is worth a reflection on the information lost with the lack of neutral emotion mapping of the UI-2 and UI-3 interfaces.

It is known that, in a comparative study, a fair comparison should be guaranteed – with the highest possible parity – among all the instruments involved. Not only did this work focused on providing an empirical analysis of the pros and cons of each prototype, it also sought to map both the extracts of videos used and the self-report methods into a single method of emotional classification, the SSES (SCHERER, 2005). By using its classification of octants, that is, in regions or set of emotions with common domains, it was possible to perform fair comparisons between the subjective feeling collection instruments.

The mapping phase was determinant for this work. The analysis of the data collected by the instruments UI-1 and UI-4 was simple and objective, because the users' responses could be directly related to one or two octants – in cases where the point indicated in IU-4 was at the border of two emotional regions. However, for the data collected through UI-2 and UI-3, it was necessary to develop a mapping process, the MSIPE Method.

Prior to the creation of the MSIPE method, we tested the application of the mapping method presented in Georgios Kouroupetroglou, Nikolaos Papatheodorou and Dimitrios Tsonos (2013) on both the prototype based on Bradley and Lang (1994) and on the sliders' prototype. The results found, however, were less accurate than the ones we found when using our methodology. While the MSIPE method generated the results presented by Table 2.3, the results obtained by the method of Georgios Kouroupetroglou, Nikolaos Papatheodorou and Dimitrios Tsonos (2013) would keep the numbers "Equal Octants", but reduce the "Neighboring Octants" to 6 and 11, respectively, in UIs 2 and 3.

Analysing the correspondence of the collected responses' in the using both MSIPE method and the method presented by Georgios Kouroupetroglou, Nikolaos Papatheodorou and Dimitrios Tsonos (2013), we have respectively:

- 19 and 12 correspondences out of 22 possibilities in valence domain on UI-2;
- 7 and 15 correspondences out of 25 possibilities in arousal domain on UI-2;
- 19 and 9 correspondences out of 22 possibilities in dominance domain on UI-2;
- 18 and 11 correspondences out of 20 possibilities in valence domain on UI-3;
- 19 and 7 correspondences out of 29 possibilities in arousal domain on UI-3;
- 24 and 10 correspondences out of 26 possibilities in dominance domain on UI-3;
- 22 and 26 correspondences out of 27 possibilities in conducivity domain on UI-3.

Thereby considering only the non-neutral responses for each domain of emotion explored by the UIs, our method fared better in all domains, except in UI-2 arousal measurement. The correspondences described were obtained from the parity levels found in the domains relating user response and related octant. When at least one of the octants found after the mapping had a relationship of polarity and intensity identical to the one expressed by the user, we counted a matching point. In general, the method of Georgios Kouroupetroglou, Nikolaos Papatheodorou and Dimitrios Tsonos (2013) results in only one oitant, or two in the case of octant borders, covering a small part of the user's response on the merits of a more objective response in the UI-2 and UI-3 interfaces.

2.6 Conclusion

In this article, we contributed with an experimental comparison between four different interfaces to collect subjective feelings from users. We conclude that although UI-3 had greater proximity to the expected results, all UIs presented are efficient to collect subjective feelings, each with its own particularity. We also contributed with the development of the MSIPE method, a method of mapping the results of subjective feelings of discrete or continuous scale in octants of Scherer's Emotional Semantic Space (SCHERER, 2005).

The fact that the coincident results in all UIs were not so high do not make the instruments inefficient. Nonetheless, it led us to reflect that even in an controlled environment, individuals can have different emotions to the same stimuli.

As a limitation in our work, there is the fact that we used only one instrument that presented emotional terms. As a possible future improvement, we could use one or more instruments that have lists of emotional terms. Other future work include: a triangulation with the physiological signs of the users, which were also collected in the execution of this experiment; a validation of the Semantic Emotional Space as an instrument for collecting subjective feeling data; and, for better use of this last instrument in our country of origin, conduct a study that validates its translation into the Portuguese-BR language.

Chapter 3

An easy-to-maintain infrastructure to adapt web user interfaces considering users' emotions

Although the user relation with system interfaces has evolved over the years, there are still few frameworks that are designed to focus on the users emotional experience. Even the ones that have been developed with that aim, mostly focus on either changing the user interface to represent the same emotion as the user is feeling or on compelling the user to feel a predetermined emotion. UIFlex 2.0 helps users to achieve a desired emotional state chosen by them. To do so, it collects users emotional data and analyses the system rules to understand what adaptations should be made in the user interface. The adaptations are related to elements of interface, such as background and font colour, font size and family and even content reallocation. The rules are based on previous studies relating several emotions to these elements. Because new forms of data collection and design rules can be added to the system, it was decided to follow an architecture model; in this case, the MAPE-K model. Afterwards, we used SonarCloud, an online solution, to evaluate whether or not this adoption improved the maintainability of the system. By using Software Engineering metrics, the solution concluded that the system had better maintainability following the MAPE-K model, even with more code complexity provided.

Keywords: adaptation rules, framework, MAPE-K

3.1 Introduction

Emotions differ from one person to another. They reflect one's previous experience, memories and associations made by their cognitive system (NORMAN, 2004). Humans may feel them when dealing with various objects and environment, such as interactive systems.

When interacting with the interface of a system, it is expected that the user not only has a positive experience with what concerns usability but also experiences certain emotions when interacting with some elements of design. Once most interactive systems are available on the web, users end up interacting daily with web pages, the fundamental element of a website.

A web page is mainly composed by three design elements: colours, images and textual characters (JIANG et al., 2008; BIANCHI, 2016). When these relate harmoniously to the content of the site, the web page is able to deliver positive emotions (JIANG et al., 2008; CYR, 2013). However this harmony, in addition to user satisfaction, varies from person to person (CYR, 2013).

One way to deal with this issue is to allow web page user interfaces (UI) to adapt at interaction time. This adaptation demands three stages according to Galindo, Dupuy-Chessa and Céret (2017): the correct recognition of emotions; the effective adaptation of interface; and the existence of commands that allow the interface to be able to deal with the emotional changes of users.

It is usual to find frameworks that are related to user's emotional state. Märtin, Rashid and Herdin (2016) developed an adaptive system based on user's behaviour, emotions and intentions to help them achieve a previously defined emotional state. Galindo, Dupuy-Chessa and Céret (2017) architecture, on the other hand, adapts interface elements so the user interface can adapt to the user emotional state. However, it could not be found a framework that helps users achieve an emotional state desired by them.

In order to fulfill this gap, this article presents UIFlex 2.0. UIFlex 2.0 is the second version of UIFlex (PROENÇA; NERIS, 2017; PROENÇA et al., 2021), a framework that adapts user interfaces to provide an accessible experience to users with disabilities. The UIFlex 2.0 benefits from the previously developed version and adapts the questionnaire provided to gather user data about their emotions.

The framework, displayed in a plugin format, capture users' emotional state by interacting with Morphcast [1] API via webcam and asks users about their actual and desired emotional

[1]https://www.morphcast.com/

state. With the information collected, the framework evaluates whether or not the user interface should change and what adaptations should be made.

This process occurs at a four-step-infrastructure model, called MAPE-K (KEPHART et al., 2003). This name is an acronym for Monitor-Analyse-Plan-Execute over a shared Knowledge, the four steps of the model plus a shared knowledge available to be accessed at any time from every step.

To evaluate whether the MAPE-K affected positively the framework, we decided to evaluate the system's maintainability before and after the model adoption. We benefit from the infrastructure provided by SonarCloud [2], a online solution that analyses code quality.

SonarCloud provided an evaluation composed by 5 maintainability metrics. This evaluation was demonstrated both in text and graphically. The solution also provided the total lines of code and the language they were written before and after the adoption.

This article is organized as follows: Section 3.2 presents related works to this article. Section 3.3 presents the first version of UIFlex, focusing on its architecture. Section 3.4 presents the changes made on the updated version: the data collection and further analysis on users emotional state, displayed at Section 3.4.1; and the process of altering the framework architecture into following the MAPE-K model, displayed at Section 3.4.2. Then, Section 3.5 presents the SonarCloud analysis on the framework maintainability and, finally, Section 3.7 concludes the article.

3.2 Related Works

When dealing with users' emotions, there are several instruments that enable the data collection process. In literature, the majority of studies found presents a multi-modal approach, where at least two instruments were used. Siddiqui and Javaid (2020) fusioned speech recognition with visible and infrared images to develop a highly accurate framework to detect emotions. Masui et al. (2020) different formats of emotion collection. They first filmed users while running an electroencephalogram (EEG) and asked for users to self-report their emotions. Then, they compared data gathered with user's facial expressions, heart rate and pupil diameter, all collected in a contactless way. Not only did they find that contactless methods are effective, but also that multimodal analysis provide more accurate results (MASUI et al., 2020).

[2] https://sonarcloud.io/

(GONÇALVES et al., 2017a) also reached this same last conclusion. They provided a multimodal analysis with speech and facial emotion recognition and logical sensors for behavioural tendencies. Based or not on this premise, Koelstra et al. (2011), Kim et al. (2012), Huang et al. (2016), Chaparro et al. (2018), Maia and Furtado (2019), Cimtay, Ekmekcioglu and Caglar-Ozhan (2020), Zhang (2020), Rayatdoost, Rudrauf and Soleymani (2020), Tan et al. (2021) and others chose a multimodal emotional approach to collect and analyse users' emotions.

3.3 The UIFlex Plugin

UIFlex was first presented by Proença and Neris (2017). Their goal with the solution was to assist users with certain disabilities through different websites. To do so, the authors elaborated a five-stage-plugin for the Google Chrome browser[3] (PROENÇA et al., 2021).

On the first stage users have to fulfil a questionnaire with their disabilities. This questionnaire is called "Who Am I?" and it was created to gather information about seven specific groups (ALENCAR; NERIS, 2014). On UIFlex 1.0, Proença et al. (2021) used a simpler version of the questionnaire. It only asked questions about one of the seven groups – skills and abilities – regarding user's arm movement, speech, hearing and vision (PROENÇA et al., 2021).

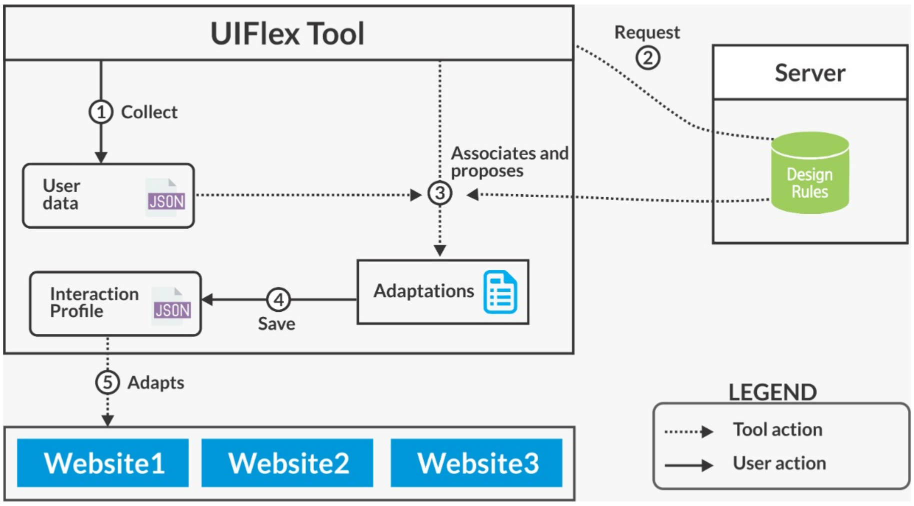
The second stage is when the plugin searches on its knowledge base the rules that fit the data previously collected. This knowledge base is composed by rules developed following guidelines and good design recommendations according to web accessibility laws and authorities, such as W3C, Mozilla Developer Network and Section 508. The rules were written with the intention of applying "injection" of codes written in JavaScript, Cascading Style Sheets (CSS) and HyperText Markup Language (HTML) codes in any page that followed the rules of the authorities mentioned above (PROENÇA; NERIS, 2017; PROENÇA et al., 2021). The final result is a web page with adaptations that would benefit the user according to his or her answers to the questionnaire.

On the next stage, the user will be responsible for deciding the rules they want to be applied. They must remember the adaptations will occur in every page that follows the laws and authorities mentioned above. As soon as they select on the plugin a rule to be applied, the web page will start to transition. This action will repeat for every selected rule.

At least, the user will be able to chose between keeping the adaptation if he/she believes the changes enhanced their online activities or turning the adaptation off. Also, the user may retake the questionnaire if their abilities change or in case they feel the urge to do so.

[3]https://www.google.com/chrome/

Figure 3.1: UIFlex stages and flow schema



Source: Proença et al. (2021).

It is possible to better understand this pathway when following the data flow schema presented in Figure 3.1.

In Figure 3.1, it is possible to observe that both user data and interaction profile are delivered as JavaScript Object Notation (JSON). This format was chosen due to its ease of access, as it is supported by varied computational languages, like C/C++, Java, Hypertext Preprocessor(PHP), Python, Ruby, etc. (PROENÇA; NERIS, 2017; PROENÇA et al., 2021).

Regarding the format of the Design rules, (PROENÇA; NERIS, 2017) also created a JSON pattern that is expressed by three aspects: basic information, context and actions, as it can be seen on Algorithm (Listing) 3.1.

When selected by the user, UIFlex will adapt the websites by injecting JavaScript, Cascading Style Sheets (CSS) and even HyperText Markup Language (HTML) codes (PROENÇA et al., 2021). For a website to adapt, it must follows the suggestions of customization presented by the previously mentioned authorities.

Listing 3.1: JSON of a design rule created

```
{
    "id" : "rule 5" ,
    "name " : "Information without color" ,
    "description " : " ... " ,
    "source " : "Section 508" ,
    "link_source " : "www.section508.gov" ,
    "priority " : "0" ,
    "category" : "web" ,
    "event " : " " ,
    "context " : {
        "user" : {
            "predicate" : "AbilityToDiff ..." ,
            "object" : "no"
        },
    },
    "actions" : {
        "action" : " update " ,
        "type" : "< css , js >" ,
        "element" : "all" ,
        "value" : "no_color"
    }
}
```

Source: Adapted from (PROENÇA et al., 2021).

3.4 UIFlex 2.0

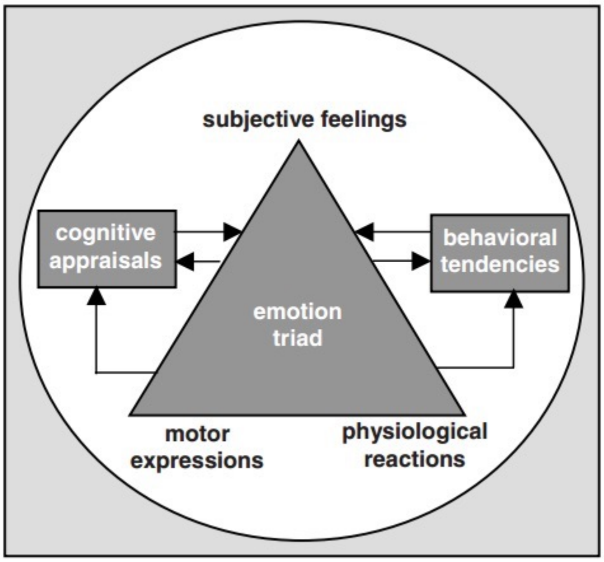
In this work, we evolved UIFlex so it could also help users to achieve a desired emotional state. In order to do so, it was necessary to readjust several items from UIFlex.

3.4.1 Measuring Emotions

The first readjustment was defining how to collect human emotions. To do so, it was of utterly importance to understand what emotions are. Thus, define how they can be collected and then measured.

Scherer (2001) states that emotion is the process related to synchronized changes in the relationships of all or most of the different subsystems of the organism. These subsystem are the subsystem of information processing, support, executive, action and monitor. Each of them

Figure 3.2: Component Process Model of Emotion.



Source: Scherer et al. (1984).

is responsible for one component: cognitive assessment, physiological reactions, behavioral tendencies, motor expressions and subjective feeling. This model became known as Component Process Model of Emotion (SCHERER et al., 1984), presented in Figure 3.2.

The main assumption of this Model is the interdependence of subsystems, implying that when one of them changes, this will probably elicit related changes in other subsystems (SCHERER, 2001). Therefore, it is possible to adopt various methods to evaluate each component separately (XAVIER; NERIS, 2012), an advantage when comparing to other models.

Another advantage of the Component Model (SCHERER et al., 1984) is the possibility of investigating more complete and comprehensive emotional responses, once a combination of methods and instruments used to measure each component can be made (SCHERER, 2005; XAVIER; NERIS, 2012). These two advantages were the reasons why we adopted Scherer's Component Process Model of Emotion (SCHERER et al., 1984) to collect human data and later extracting them as emotions.

Previous work on collecting emotions when following this model (XAVIER; NERIS, 2012; NISHIKAWA; BRANDÃO; NERIS, 2020) lead us to collect three types of components' information: physiological reactions, motor expressions and subjective feelings. However, due to the pandemic period when this study took place, we were unable to measure the users' physiological reaction.

The motor expressions may refer to facial expressions, body gestures and speech characteristics, such as speed, intensity, melody and sound (XAVIER; NERIS, 2012; SOUZA, 2019). One of the most famous approach to assess facial expression is the Facial Action Coding System (FACS) (EKMAN; ROSENBERG, 1997).

For this framework, we chose to develop an Application Programming Interface (API) based on the Morphcast Software Development Kit. Morphcast was developed to be an interactive video platform that uses Artificial Intelligence to detect user's characteristics, emotions and level of attention as they observe their own API or other web pages.

To do so, they collect user's face expressions and gestures and, based on neural networks and Scherer's Semantic Emotional Space (SCHERER, 2005), detects the user emotional state. Although this model has four dimensions, the API measures only two of them: valence and arousal. Nevertheless, they also collect the quadrant and the "affect" the user should be feeling. It is important to mention, though, that the word "affect" is being misused according to Scherer's beliefs, being "emotional term" the correct description in this case (SCHERER, 2004, 2005).

Finally, subjective feeling is the component that stands out the most. Since it is related to monitoring subsystem, it also regulates the Component Model as it assimilates the changing patterns (SCHERER, 2004).

As this component is composed by different types of information (SCHERER et al., 1984), it is believed that the self-report is the most reliable form of collecting this component, specially using either verbal protocols or a set of rating scales (DESMET, 2003).

For years, many instruments have been developed to allow people to define their emotions. Self-Assessment Manikin (BRADLEY; LANG, 1994) and PrEmo (DESMET, 2003) are two of the most well-known instruments used to collect subjective feeling.

For this framework, a study with four different instruments was made to figure out in which of them the users demonstrated to be feeling what they were actually feeling, according to what was found in literature (SILVA et al., 2020). The study concluded that the instrument that had most fitting answers was a new one, based on Scherer's Semantic Emotional Space (SCHERER, 2005) as seen in Figure 3.3.

The instrument has four scroll sliders, one for each domain of Scherer's Semantic Emotional Space. In every one, the user has to slide the bar to left or to the right to indicate their feeling, suggesting they were feeling, respectively, more negative or more positive about that domain. The bar showed numbers between -1 (left) to +1 (right) when it was slided. If the bar stayed on the center, the 0 would appear (SILVA et al., 2020).

Finally, although the framework was built to work along specific types of components, this can be modified to shape one's needs. For example, during the COVID-19 pandemic, most

Figure 3.3: Instrument created to collect user's subjective feeling. The domains presented in Portuguese refer respectively to arousal, valence, coping potential and goal conduciveness and the options refer to low/high, negative/positive, low/high and low/high.

Source: Adapted from Silva et al. (2020).

people could not share the same objects, thus, the plugin collected two types of components. However, it is possible to connect physiological sensors to guarantee a more accurate data analysis.

3.4.2 Architecture

After a revision of the plugin's architecture, it was decided to modify it to follow a model called Monitor-Analyse-Plan-Execute over a shared Knowledge (MAPE-K) (KEPHART et al., 2003). This model was presented by International Business Machines (IBM)[4] in an internal blueprint on the advances in Autonomic Computing (AC) architecture.

The AC is a direct consequence of the advance of technology. The industry created this concept after adopting technology to manage technology, therefore automating functions that were previously performed by workers (KEPHART et al., 2003; SILVA; SASSI, 2019).

An AC system is also called a Self-Adaptive System (SAS). It may be classified into one out of four categories depending on the aim of the modification (KEPHART et al., 2003; SANTOS, 2020):

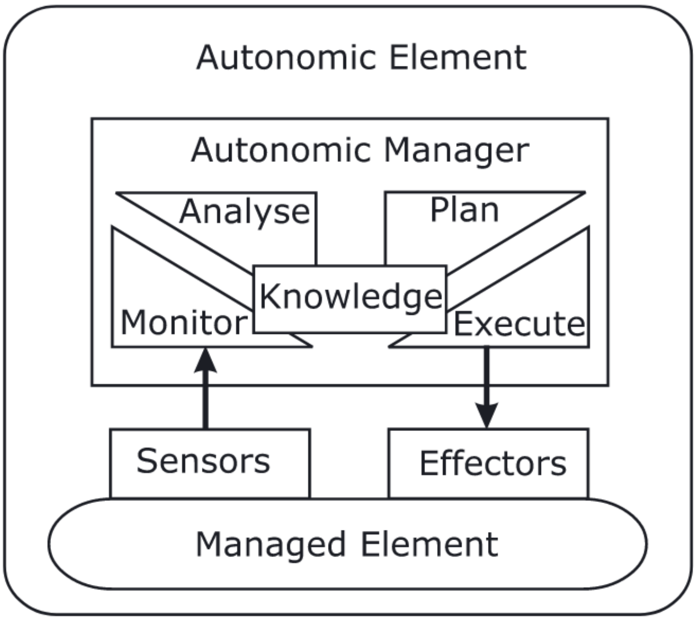
- Self-configuring: systems that adapt themselves respecting high-level objectives and policies, particularly ensuring high productivity;
- Self-healing: systems that are capable of detecting and diagnosing problems hence taking corrective actions;
- Self-protecting: systems that detect and identify threats and protect itself against them;
- Self-optimization: systems that provide internal changes to meet users' or businesses' needs.

Due to UIFlex's nature of adapting websites to improve users' experience, it is classified as a self-optimization system. Nevertheless, all SAS can be consider an Autonomic Element in Figure 3.4.

As Figure 3.4 shows, an Autonomic Element is composed by one or more Managed Element and an Autonomic Manager (SILVA; SASSI, 2019). The Managed Element is either software or hardware components of the architecture (KEPHART et al., 2003). On the other hand, the Autonomic Manager is responsible for a four-stage cicle: monitor, analyse, plan and execute whereas accessing a shared knowledge base. This cicle is known as feedback loop.

[4] https://www.ibm.com/

Figure 3.4: MAPE-K model.



Source: Huebscher and McCann (2008).

Each of the four stages has defined tasks. They are the following (CANTANHEDE; SILVA, 2014 apud SILVA; SASSI, 2019) (SANTOS, 2020):

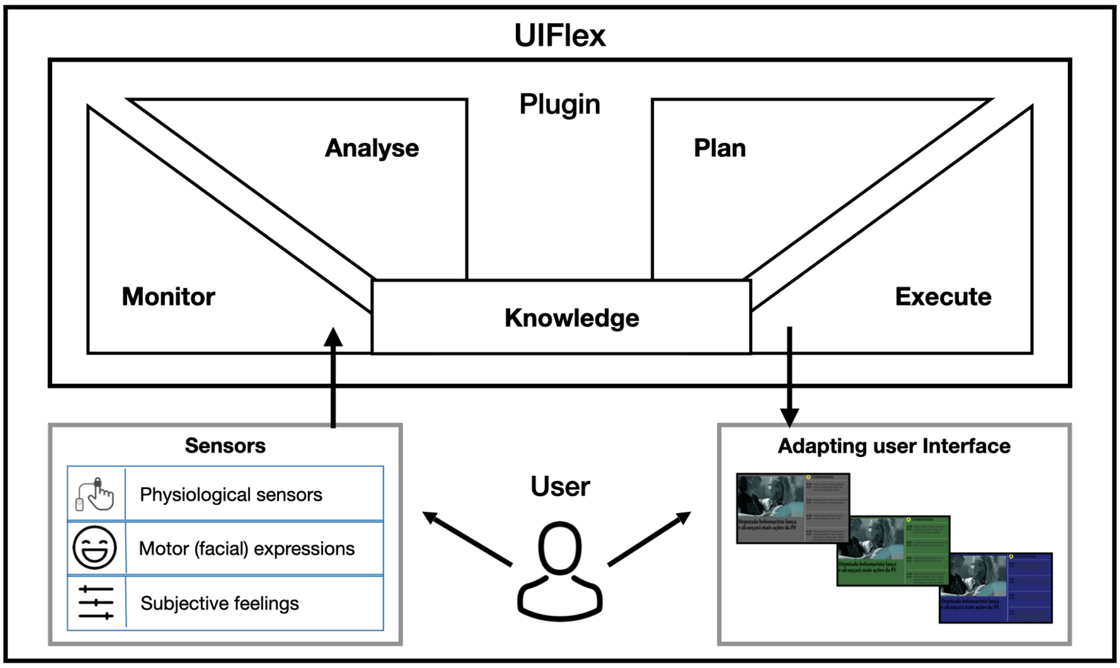
- Monitor: uses mechanisms that collect, aggregate, filter, and present information collected from a Managed Element. The collection is done by means of sensors.
- Analyse: where previously collected data is analysed to identify when interface adaptation should occur.
- Plan: outlines the necessary adaptations to achieve the desired goal. An adaptation plan is created, which will be used in the next phase.
- Execute: changes the system by applying the necessary changes. The adaptations are made by effectors.

In addition, the system has a knowledge base, which stores information that can be accessed and used by the four main components of the architecture. As a result, UIFlex 2.0 is defined as a four-step-framework, as shown in Figure 3.5.

3.4.3 Monitor

As mentioned before, it is currently possible to have up to three types of components connected to the framework: physiological sensors; motor expressions – in this case, facial expres-

Figure 3.5: MAPE-K model used in UIFlex 2.0.



Source: Elaborated by the author.

sions; and subjective feelings. Due to the COVID-19 pandemic, however, we have only been collecting data with the two last ones.

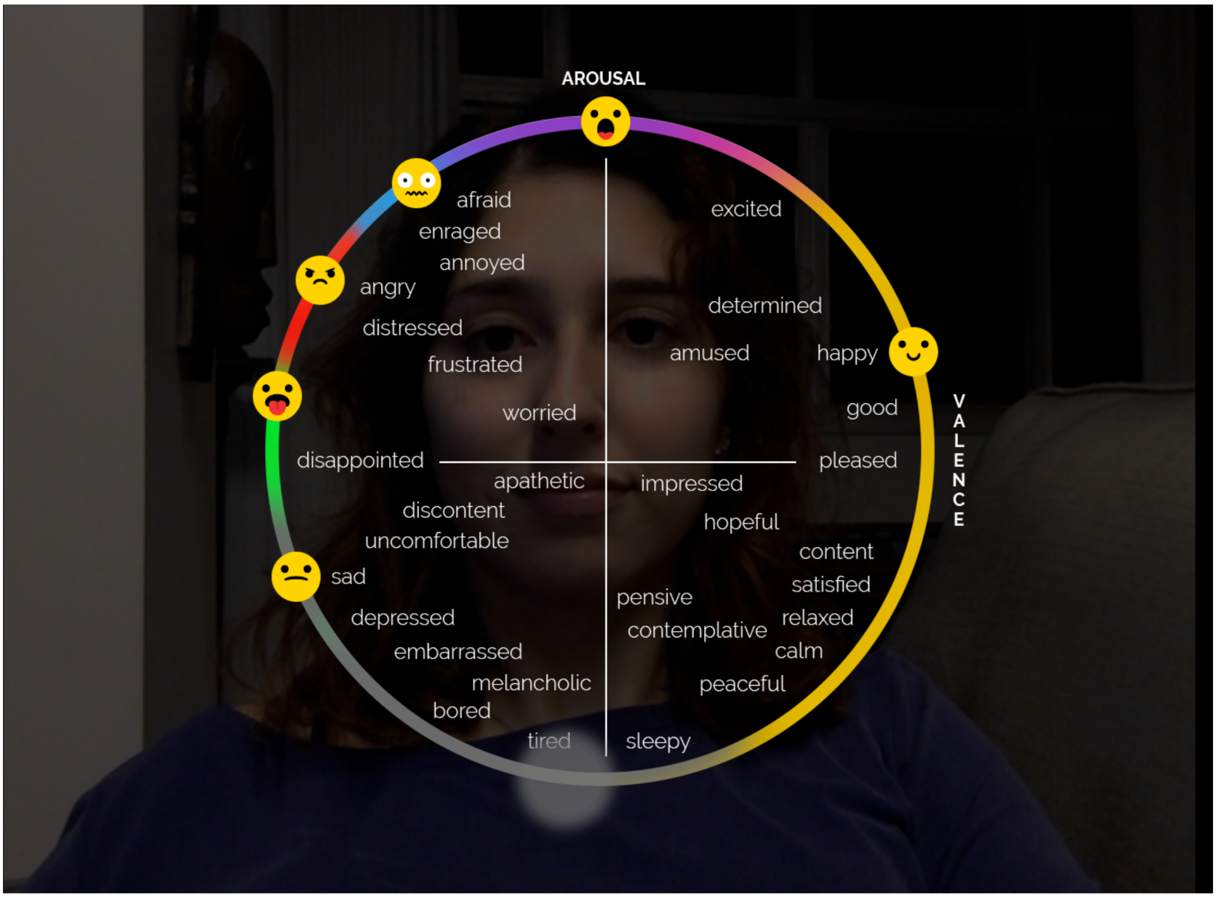
The monitor is responsible for interacting with the sensors to collect information, but also extracting and organizing them. All three sensors send raw data to the framework.

The Morphcast API, Figure 4.5, captures users valence and arousal and send to the monitor, whose job is to calculate which octant of the Scherer's Emotional Semantic Space (SCHERER, 2005) the user is at. This information is stored locally at Google Chrome.

To initialize the capture, the user must click on the first button presented at the plugin's menu (Figure 3.7), where it is written: "Clique aqui para abrir sua câmera", which can be translated to "Click here to open your camera". This interaction will open a new tab where the user can see himself ou herself.

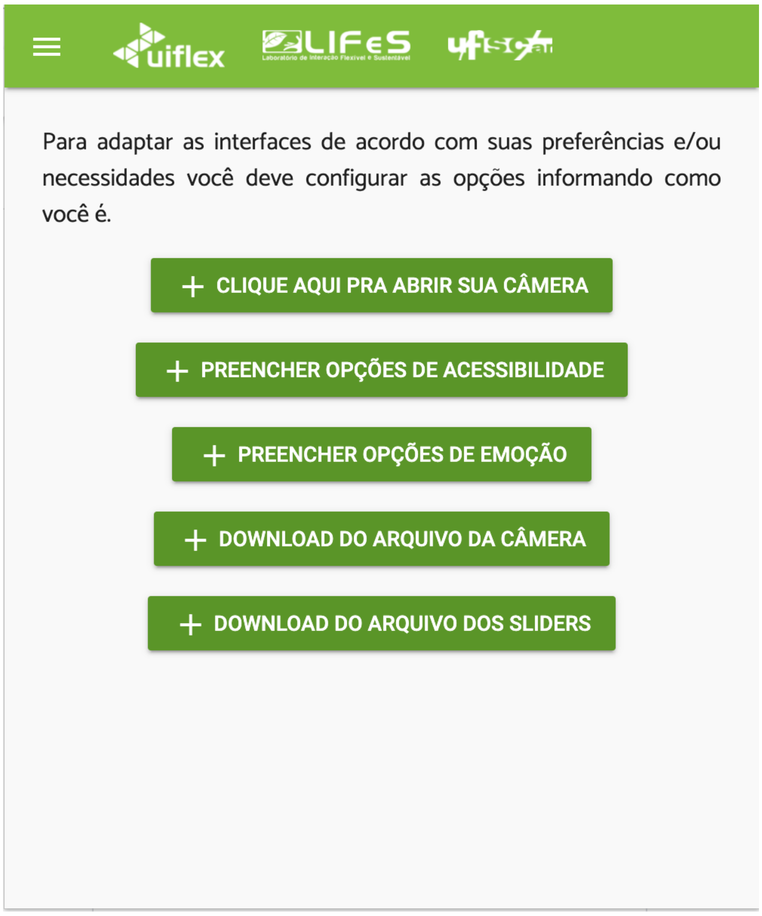
To have his or hers subjective feeling data collected, the user interacts with questionnaires based on "Who Am I?"(ALENCAR; NERIS, 2014). It is suggested that not only the user fulfills the accessibility questionnaire (the second button at the Figure 3.7), but that he or she does it also before the emotional one. This is because some disabilities might need UI adaptations that cannot be overlayed by the ones provided by the emotional adaptations.

Figure 3.6: Capturing user's motor expressions. The main circle is based on Scherer's Semantic Emotional Space (SCHERER, 2005).



Source: Elaborated by the author.

Figure 3.7: Who Am I?, the data collector used. The buttons presented n Portuguese refer respectively to: opening user's camera; fulfill the accessibility questionnaire; fulfill the emotional questionnaire; download the data collected by the camera; and download the sliders' file.



Source: Elaborated by the author.

The accessibility questionnaire is displayed at (PROENÇA et al., 2021) in an English version. On the other hand, the emotional questionnaire is displayed in Figure 3.3 in Portuguese. The user must express, with the sliders, how he/she is feeling at the moment and how he/she desires to feel – as mentioned before, UIFlex 2.0 helps users to achieve a desired emotional state.

With all the values properly collected, the monitor send them to the analyser.

3.4.4 Analyse

As mentioned by Kephart et al. (2003), the analysis is deeply influenced by knowledge base, which is explained later on. Consequently, as soon as the analyser receives the data, it sends them to the knowledge base. This base is responsible for using rules previously stored to understand user's actual and desired emotional state.

When collecting information for the three types of components, the octant that summarizes the actual emotional state is found by calculating the mode of the octants individually found by the rules of the knowledge base. However, the desired state can only be measured using the instrument used to collect subject feeling. So, the octant returned by the knowledge base is the final one.

The knowledge base returns both octants and the analyser must evaluate whether the plugin should or not promote UI adaptations. If the emotional state and the desired one are the same, the process ends and the plugin waits for another requisition. Otherwise, the planner is called.

3.4.5 Plan

The planning is the stage where design rules are chosen to be applied on the UI, according to the data provided. Past studies have been made about the effects of UI elements in emotions (NORMAN; ORTONY, 2003; HOLTZE, 2006; JIANG et al., 2008; LIM et al., 2008; BIANCHI, 2016). The initial and desired emotional states are sent to the knowledge base, where rules on adaptation have been previously saved. These rules were developed according to Bianchi and Neris (2015) studies and are presented on Table 3.1. An example of the created rules is displayed at Algorithm (Listing) 3.2.

Listing 3.2: Example of Rule

```
// Dark Blue, Purple, Dark Green, Gray
if (json[i].id == "rule40" && (
(data.resultante_inicial == 1 ||
data.resultante_inicial == 2)
&&
(data.oitante_resultante1 == 3 ||
data.oitante_resultante1 == 4)
)){
    chrome.storage.local.set ({ 'rule40': '1'});
}
```

Source: The author.

As it is showed in Algorithm (Listing) 3.2, Rule 40 is applied every time the user is at the octant 1 or 2 and wants to be at the octant 3 or 4. The comment on top of the code briefly mentions the main adaptation provided by the rule: the adaptation of the background colour. The implementation of the Rule is provided on 3.3, at Section 3.4.6.

Table 3.1: List of colour transitions based on initial and final octant.

		Desired Octant							
		1	2	3	4	5	6	7	8
Actual Octant	1	-	Black	Dark Bue Purple Dark Green Gray	Dark Bue Purple Dark Green Gray	Light Blue Lilac Light Green	Light Blue Lilac Light Green	Red Orange Yellow	Red Orange Yellow
	2	Red Orange Yellow	-	Dark Bue Purple Dark Green Gray	Dark Bue Purple Dark Green Gray	Light Blue Lilac Light Green	Light Blue Lilac Light Green	Red Orange Yellow	Red Orange Yellow
	3	Red Orange Yellow	Black	-	-	Light Blue Lilac Light Green	Light Blue Lilac Light Green	Red Orange Yellow	Red Orange Yellow
	4	Red Orange Yellow	Black	-	-	Light Blue Lilac Light Green	Light Blue Lilac Light Green	Red Orange Yellow	Red Orange Yellow
	5	Yellow Orange Red	Black	Gray Dark Green Purple Dark Blue	Gray Dark Green Purple Dark Blue	-	-	Yellow Orange Red	Yellow Orange Red
	6	Yellow Orange Red	Black	Gray Dark Green Purple Dark Blue	Gray Dark Green Purple Dark Blue	-	-	Yellow Orange Red	Yellow Orange Red
	7	Yellow Orange Red	Black	Gray Dark Green Purple Dark Blue	Gray Dark Green Purple Dark Blue	Light Green Lilac Light Blue	Light Green Lilac Light Blue	-	-
	8	Yellow Orange Red	Black	Gray Dark Green Purple Dark Blue	Gray Dark Green Purple Dark Blue	Light Green Lilac Light Blue	Light Green Lilac Light Blue	-	-

Source: The author.

3.4.6 Execute

Finally, the executor is responsible for applying the changes chosen by the planner. As in the previous version, the executor will apply JavaScript, CSS and HTML code on the web page if it has been built according to some structure patterns of web design. However, on this version, the intention of the adaptation is helping the user to achieve the desired emotional state.

Following the example presented at Section 3.4.5, Algorithm (Listing) 3.3 presents the code of Rule 40. It provides an animation to ensure that the background colour will change to all of the colours that are related to the desired octant according to Table 3.1. It also changes the colour of the font so it has better contrast and, consequently, it is better for the user to read the page.

Listing 3.3: Example of Rule

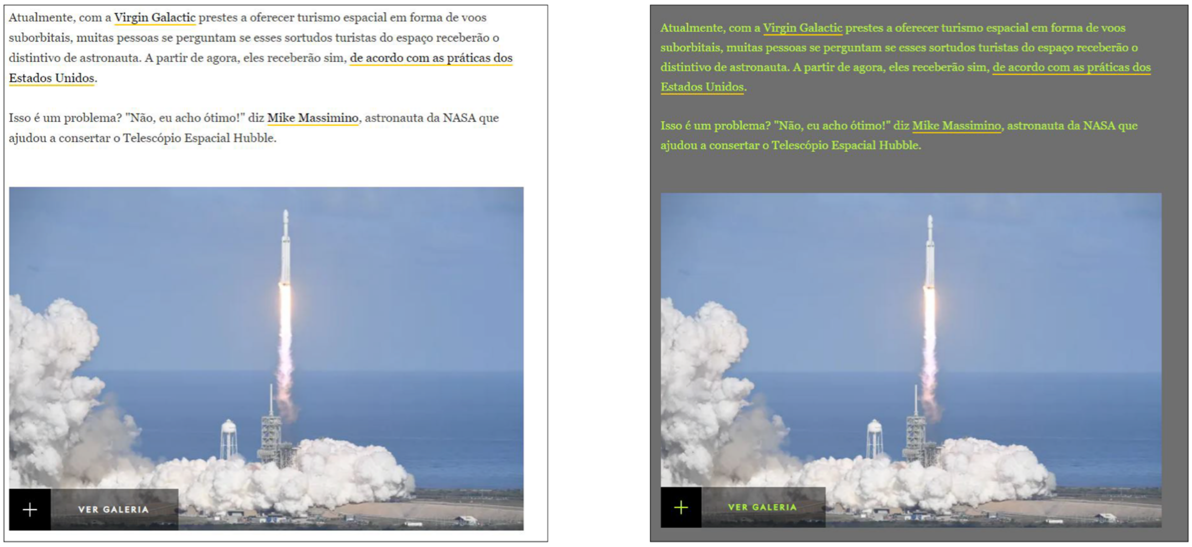
```
// Dark Blue, Purple, Dark Green, Gray
if ( data.rule40 == 1 && data.flag_cor == 0) {
    var css = 'span, h1, h2, h3, h4, a, p, em, text, th, td, table {
        animation :12 s multicolor_fonte forwards
    } body, header {
        animation :12s multicolor forwards
    } @keyframes multicolor {
        0% { background-color : current-background-color ;}
        45% { background-color : #262C7F ;}
        66% { background-color : #5E1E66 ;}
        80% { background-color : #267F3F ;}
        100% { background-color : #6F6F6F ;}
    } @keyframes multicolor_fonte {
        0% { color : current-color ;}
        100% { color : #BAF73C ;}
    }',
    head = document.head || document.getElementsByTagName('head')[0],
    style = document.createElement ('style');

    style.type = 'text/css';
    if (style.styleSheet ) {
        style.styleSheet.cssText = css;
    } else {
        style.appendChild (document.createTextNode (css));
    }
    head.appendChild ( style );
}
```

Source: Elaborated by the author.

Finally, Figure 3.8 demonstrates an example of when the executor “injects” Rule 40 on the website.

Figure 3.8: Same interface before and after the application of Rule 40.



Source: Elaborated by the author.

In Figure 3.8, there are only two moments represented: the first one, when the "injection" has just started and, therefore, the animation is at 0%; and the second one, when the "injection" is completed, so both background colour and font colour have totally changed.

However, the only case where there is one change in the background colour is when the desired emotional state is octant 2. Otherwise, when the page is updated, a transition with 3 to 4 colours will start. The other injection rules are presented at Appendix **??**.

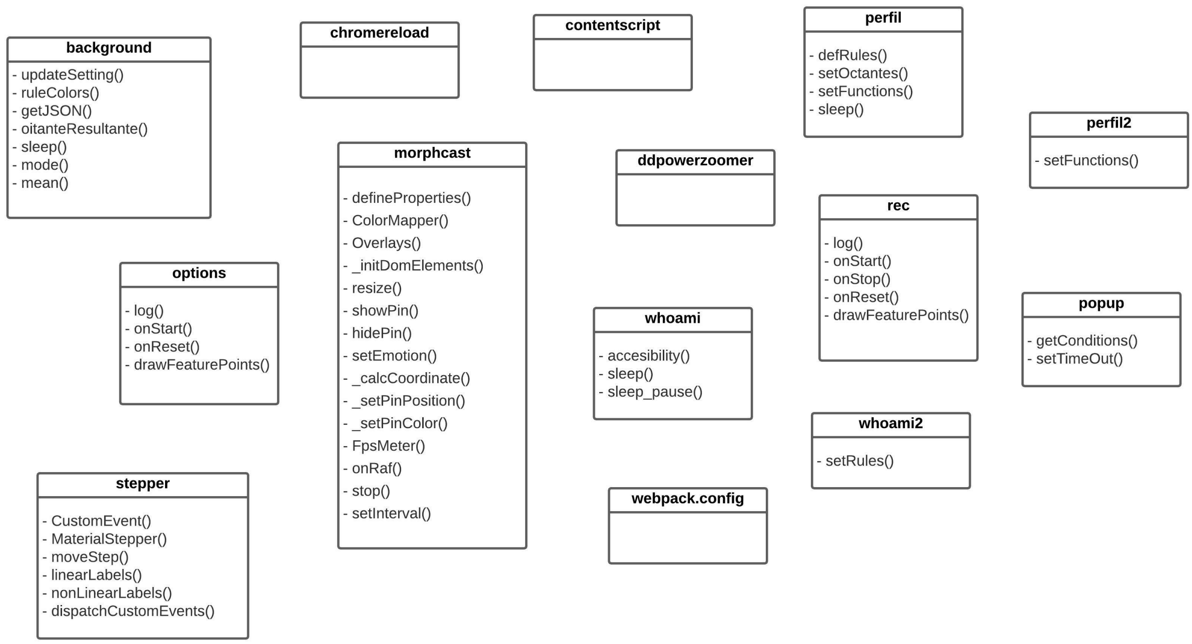
To evaluate whether the framework helped or not users to achieve their desired emotional state, a case study was presented at Guimarães, Souza and Neris (2022).

Despite the effect on users, the framework had important structural changes. To understand whether they brought improvements to the plugin or not, we decided to evaluate the quality of the software after the adoption of the MAPE-K.

In terms of code, the final architecture uses mainly Javascript files that interact with browser through Google Chrome Local Storage. These files and their functions are displayed in Figure 3.9.

It is possible to see that not all scripts have functions and, therefore, are presented as null boxes. Also, there is not a directly connection between scripts – usually represented by the presence of therms such as "import" or "require" in the files. Therefore, it is the build environment that connects them.

Figure 3.9: Scripts diagram.



Source: Elaborated by the author.

3.5 Quality Evaluation

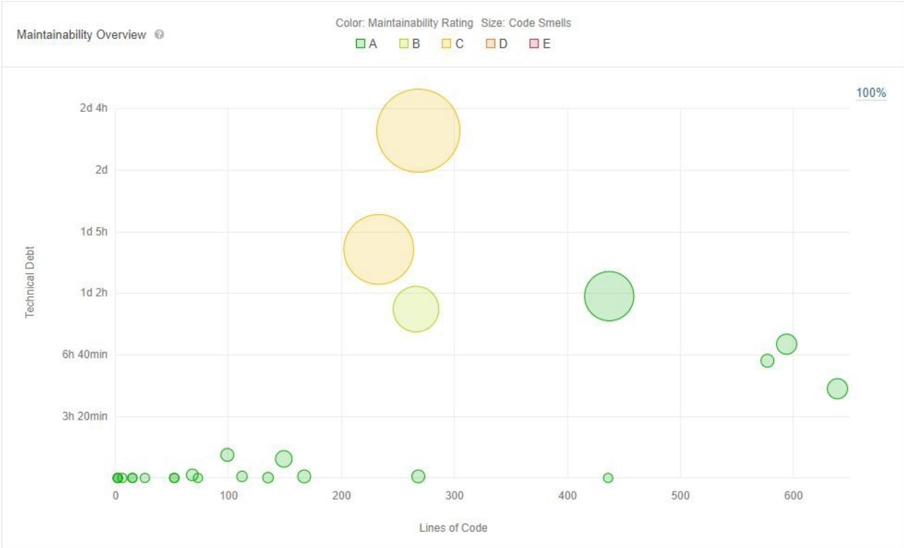
To evaluate whether the addition of the MAPE-K model had or not impacted on the UIFlex architecture, it was decided to measure the framework's maintainability before and after the alteration. The Sonar Cloud was chosen for being a recognized tool both in academia and industry, in addition to its ease of use.

The code maintainability is one of the most important aspects to consider when developing code (COLEMAN et al., 1994). At UIFlex it is of paramount importance to consider this aspect due to the framework's volatility and ability to adapt. For example, other instruments that capture the users actual or desired emotional state may be plugged in or off the solution. Another example is the adaptation rules, that can be added or changed to allow other interface elements to adapt.

Figures 3.10 and 3.11 represent the general maintainability of the UIFlex 2.0 with and without the adoption of the MAPE-K model according to SonarCloud evaluation.

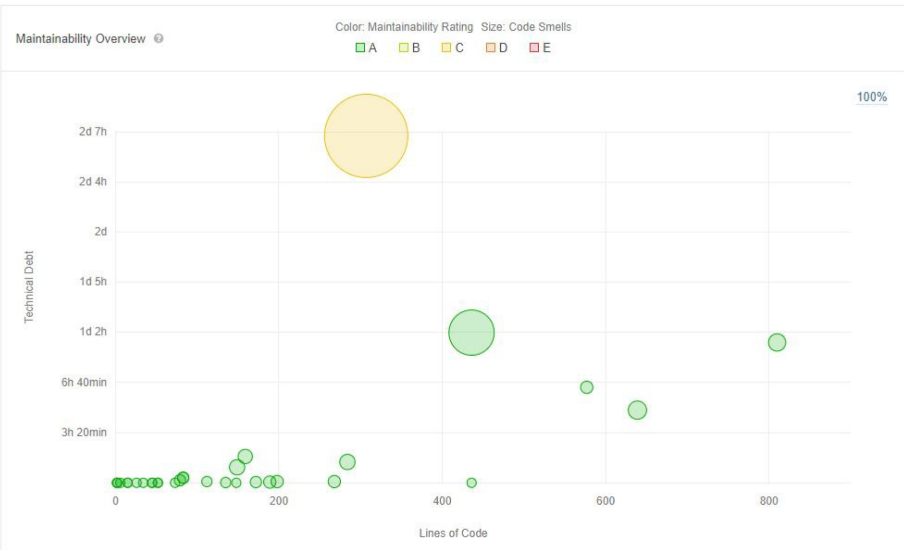
The circles presented in both Figures 3.10 and 3.11 are different files of the overall UIFlex 2.0 code. There are three characteristics that can be seen in each circle: their colour, size and where they are located in the graph.

Figure 3.10: Global vision of UIFlex 2.0 maintainability without MAPE-K adoption according to SonarCloud evaluation.



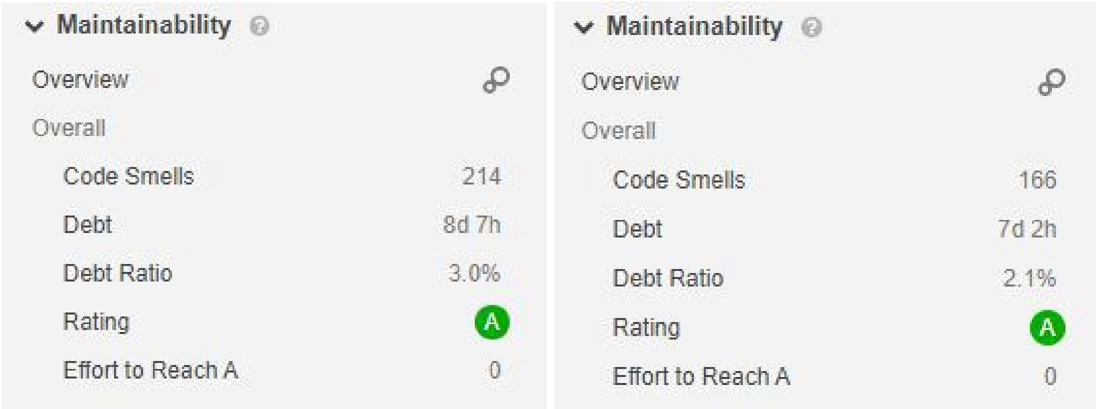
Source: Elaborated by the author.

Figure 3.11: Global vision of UIFlex maintainability with MAPE-K adoption according to SonarCloud evaluation.



Source: Elaborated by the author.

Figure 3.12: Maintainability metrics before and after MAPE-K adoption respectively.



The closer the circle is to the X axis, the less technical debt it has. According to Seaman and Guo (2011), technical debt is a piece of code that might have been written fast, but has low quality. This means that they will affect further activities related to software development, thus being understood as a debt the developers have with the framework. It is reckoned as the time of extra work both in development and maintenance of the code.

The size of the circle is related to code smells. This is a term for code snippets with maintainability problems, mostly due to poor implementation choices (KHOMH; PENTA; GUEHENEUC, 2009). Last, the colour of the circle indicates its maintainability rate, from A (green) to E (red).

Analysing both graphs, it can be seen that, although there are more circles on the second graph (Figure 3.11), most of the circles have a small ratio and are displayed closer to the X axis. This means that both code smells and technical debt have decreased. Also, only one out of approximately 30 circles is classified with B in maintainability rate instead of 3 out of 17 circles from the version without the adoption of the MAPE-K model.

This analysis is validated with the data presented by Figure 3.12. These images show a next stage of SonarCloud, where the software presents some metrics related to code maintainability.

Source: Elaborated by the author.

The comparison between both of them shows:

- Decrease in the technical debt from 8 days and 7 hours to 7 days and 2 hours, which means 14,57% of reduction or 1 day and 5 hours less debt;
- Decrease in the debt ratio from 3.0% to 2.1%, corresponding to a 30% shrinkage;
- Code smells reduction from 214 to 166, approximately 22,4%, even though the recent code presents more features than the previous one.

Figure 3.13: UIFlex 2.0 content with and without MAPE-K adoption respectively.

Source: Elaborated by the author.

Finally, Figure 3.13 shows how the project complexity has grown from one version to another. UIFlex 2.0 has 20% more lines – most of them are CSS code due to the new rules added. This explains why there are more circles in the current version when compared to the past one, as more files have been added. Despite the raise in the code size the metrics have been reduced, confirming that the adoption of the MAPE-K model has risen the framework maintainability.

3.6 Acknowledgment

This study was partly financed by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001 and by the Fundação de Amparo à Pesquisa do Estado de São Paulo - FAPESP (Process number 2015/24523-8).

3.7 Conclusion

In this article, we presented UIFlex (PROENÇA; NERIS, 2017), a plugin designed for Google Chrome that can adapt elements of interface. It was first built to assist users with disabilities. They would fulfill a questionnaire based on “Who Am I?” (ALENCAR; NERIS, 2014) and would have their profile created. According to their needs, rules would be applied to web pages based on guidelines and good design recommendations according to web accessibility laws and authorities, such as W3C, Mozilla Developer Network and Section 508.

This work presents the second version of the plugin, named UIFlex 2.0. This version adds emotional questions on the previous questionnaire, so we can gather information about the user emotional state at the moment he/she enters a website and the emotional state he/she wants to achieve.

To help them achieving this new emotion, UIFlex 2.0 “injects” HTML, CSS and Javascript code to adapt the user interface. The adaptation is based on rules developed according to studies on interface elements (as colour and fonts, mainly) and emotions.

In addition to adding the new design rules, this study focused on adapting the framework infrastructure to the MAPE-K model, proposed by Kephart et al. (2003). To evaluate whether this change had positive effect on the framework or not, we evaluated its maintainability with and without the adoption of the MAPE-K model.

According to SonarCloud analysis, MAPE-K improved code maintainability as metrics showed a reduction in 3 of the 5 metrics: code smells, debt and debt radio. The other two metrics have not changed from one version to another. It is important to reinforce that this changes occurred even though the framework had increased its size. Therefore, future additions, from new data collection instruments to new design rules, will be add within less time spent.

Chapter 4

A MIXED FACTORIAL EXPERIMENT WITH COLOURS AND ADAPTIVE WEB USER INTERFACES TO CHANGE EMOTIONS

4.1 Introduction

Emotions affect our relation not only with other people, but also with the world we live in. In the technology field, for example, if one has a positive emotion when dealing with an interactive systems, the more presumably he or she will access again that same system (BENTLEY; JOHNSTON; BAGGO, 2005). In other words, our experience with computational ambiences acts as stimuli to our emotions to show.

However, because emotions reflect the associations made by the cognitive system (NORMAN, 2004), each person feels them differently. Consequently, to guarantee that most users feel satisfied when accessing a system or web page, the ambient must deliver personalised experience.

A common way of doing so is providing user interface (UI) adaptation. When altering either one or more UI elements, one may feel more relaxed or excited when navigating the web. Adaptation requires data collection, more specifically, data that represents emotional states. This concept was applied on UIs on Xavier and Neris (2014), where the authors based their work on Scherer's Model of Components (SCHERER et al., 1984) and Scherer's Semantic Emotional Space (SCHERER, 2005).

To do so, it is possible to use webcams, microphones, and other measuring tool to capture subjective feeling and physiological data (SCHERER, 2001; MAHLKE; MINGE, 2008; MEUDT et al., 2016). It is also possible to use more than one form of data collection as emotion are responsible for affecting different systems from the human body (SCHERER, 2004).

On their work, (GALINDO; DUPUY-CHESSA; CÉRET, 2017) present an architecture developed to alter the UI of web pages also according to emotions. The solution is connected to different types of sensors responsible for collecting emotional data. This data is later sent to an emotional detection tool (GALINDO; DUPUY-CHESSA; CÉRET, 2017; GALINDO, 2018). When an emotion is classified into either positive, negative or neutral, this information is sent to an Adaptation Engine, where the adaptation rules will be scanned in order to find which one best suits the emotional group. Finally, the Interactive System apply the correct rule or rules on the UI. Peso2u (GALINDO, 2018) brings advances to the state of art for being the first solution that generates UI adaptation based on emotions in runtime (GALINDO; DUPUY-CHESSA; CÉRET, 2017). However, not only it has an small set of emotions, it also bases the code "injection" on the current emotional state of the user.

Donati, Mori and Paternò (2020) proposes a study of transition of elements of interface that lead users feeling negative emotions to positive ones. This emotions were previously chosen according to another study. The users could choose, however, which negative emotion they would start the study and which positive emotion they would like to end feeling. The emotions were: hate, anxiety and boredom (negatives) and love, serenity and fun (positives).

A solution that provides software adaptation is UIFlex 2.0 (GUIMARÃES et al., 2022). Firstly developed with the proposal of enhancing accessibility (PROENÇA; NERIS, 2017; PROENÇA et al., 2021), UIFlex 2.0 had new rules added in order to also provide emotional adaptation.

In this work, we describe a mixed factorial experiment with 44 participants in which each one should perform two tasks: reading and transcription. The participants were randomly designed to start at one of the tasks. They were asked to enter a web page, enter some emotional data on a plugin and then perform the tasks. The plugin presented was either UIFlex 2.0 or UIFlex 3.0. The difference between them is that UIFlex 2.0 was presented for the control group and UIFlex 3.0, for the placebo group. Therefore, UIFlex 3.0 would not apply any changes on the UI.

UIFlex 2.0 collects emotional data providing an emotional form for users to answer their emotional state at the beginning of the collection and the emotional state they wanted to achieve. The framework also relies in face expressions collection via webcam. We analyse the data and applied the Chi-Squared statistical test to evaluate whether or not UIFlex 2.0 helps users to achieve a desired emotional state.

Also, with all the information collected, we represented the emotional paths for the participants while performing the two tasks separately. We than analyse the most common emotional paths performed by participants. Although we had the majority of participants reaching their desired emotional state (D.E.S.) on both control and placebo group, we did not have statistical evidence to prove that UIFlex 2.0 were more likely to achieve the D.E.S.

We conclude this work with the graphs of incidence of the path followed by the participants throughout their interaction with both web pages. It is possible to visualise that most participants chose the octant 7 as their D.E.S. This octant is described as the only one where all the domains of the Sherer's Semantic Emotional Space (SCHERER, 2005) are all positive. We believe this information is of great importance for future studies on emotions in HCI.

4.2 Fundamental Concepts

4.2.1 Emotions

Although being part of Computer Science, Human-Computer Interaction (HCI) is also connected to areas such as social and cognitive science (CARROLL, 2006). Thus, there are studies in HCI related to the easiness and usability of web sites, but also studies aiming at understanding the emotions users have when interacting with them. There is no consensus on what one might consider an emotion (QUIGLEY; LINDQUIST; BARRETT, 2014). Thus, it is important to highlight the definition that most relates to one's research when working with this theme. In this work, we adopt the concept that an emotion is a process related to synchronized changes in the relationships of all or most of the different subsystems of the organism (SCHERER et al., 1984; SCHERER, 2004, 2005). Each of these subsystems is responsible for a component.

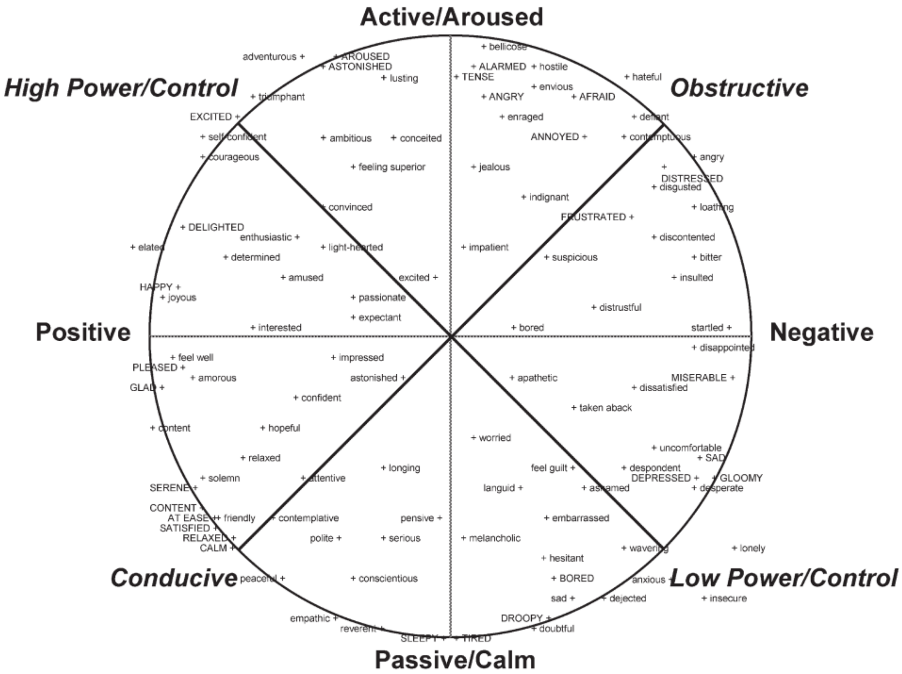
According to Scherer (2004), there are five components:

Cognitive appraisals: assessments made in a situation that contains one or more objects or events. The Central Nervous System (CNS) is responsible for evaluating several aspects of them and reaching to a conclusion about them;

Physiological reactions: these are also called body symptoms, they regulate the Neuroendocrine System (NES), Autonomic Nervous System (ANS) and CNS;

Behavioural tendencies: also called action tendencies, they are responsible for preparing actions taken in the CNS and directing them;

Figure 4.1: Semantic Emotional Space.



Source: Scherer (2005).

Motor expressions: can be translated into communications performed by the Somatic Nervous System (SNS), which controls both skeletal muscle reaction and behavioral intentions. Some examples are facial and vocal expressions;

Subjective Feelings: also called emotional experience, they monitor the internal state of the CNS and the interaction of the organism with the environment in which the user is at.

The relation between these components is established in the Component Process Model of Emotion (SCHERER et al., 1984). This model allows one to choose specific methods to evaluate each component as they can be measured separately (XAVIER; NERIS, 2012). Thus, another advantage of the Component Model is the possibility of investigating more complete and comprehensive emotional responses since a combination of methods and instruments used to measure each component can be made (SCHERER, 2005; XAVIER; NERIS, 2012). This work benefits from these ideas and we combine the use of the Facial Action Coding System (or FACS) (EKMAN; ROSENBERG, 1997) to evaluate motor expressions and the Self-Assessment Manikin (SAM) (BRADLEY; LANG, 1994) for collecting subjective feelings.

As a result years of study about emotions, Scherer (2005) also developed a scheme for classifying emotions. Based on Russell (1980), the researcher developed the Emotional Semantic Space (SCHERER, 2005). In this model, 108 emotional terms are arranged along a circle with their exact location represented by a positive symbol (+). The figure 4.1 presents this model.

This circle is crossed by 4 straight lines that intersect in the center, forming an angle of 45º between every two of them. This angle defines a space called octant. As a circle has 360º degrees, that results in 8 octants, numbered clockwised, starting by the one at the top right.

Each of the four lines represents a dimension of the emotional experience, which are: arousal, valence, control and goal conduciveness. Each point of these lines has a value, ranging from -1 to 1. The positive extremes of the dimensions are, respectively: active/aroused, positive, high power/control and conducive. Contrariwise, the negative extremes are, in the same order: passive/calm, negative, low power/control and obstructive.

Emotion can be also described as how individuals shares the experiences they had throughout their lives (LIM et al., 2008). On web pages, the stimuli reach users through the UI. Interface elements such as colours, images and typographic characters are responsible for generating these stimuli, which lead users to reach certain emotional states (JIANG et al., 2008; BIANCHI, 2016).

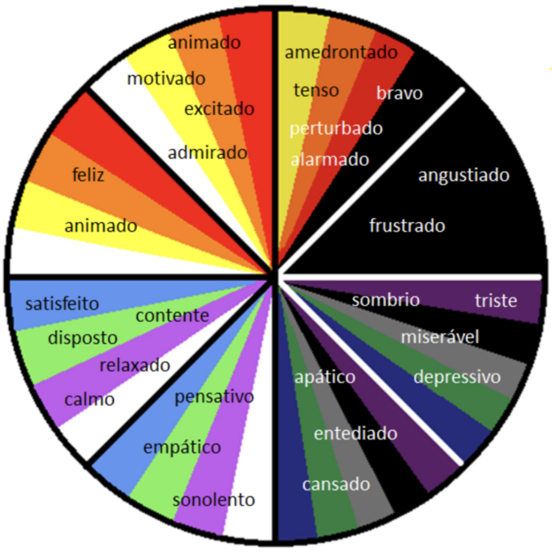
Because humans react differently to the same stimulus, researchers have sought how to alter the emotional state of users when they access websites – usually, to evoke a positive reaction. Most of them found that personalized interfaces can help users to have a better experience, thus, it is more likely they return to that same site at a later date (BENTLEY; JOHNSTON; BAGGO, 2005).

When searching for related work, it is noticeable the increasing number of studies in which one or more interface elements are changed with the intention of causing a specific emotional reaction to the user. Considered the main element of an interface, the colour palette plays an important role in the success of a website (HOLTZE, 2006; JIANG et al., 2008). In their study, Bianchi and Neris (2015) mapped the colours according to Scherer's Semantic Emotional Space (SCHERER, 2005) and created a model with the results obtained. It has been named Bianchi's colour Circle and is shown in Figure 4.2.

Bianchi's colour circle specifies a relationship between colours and emotions (BIANCHI; NERIS, 2015). The emotions found in previous studies were then compared with the emotions present in Scherer's Semantic Emotional Space Scherer (2005) and, hence, placed in the corresponding octants.

As mentioned above,characters are other example of interface elements capable of evoking emotions (JIANG et al., 2008; ALTABOLI, 2013; BIANCHI; NERIS, 2015). According to Jiang et al. (2008), age, location, font style – serif or not, markup – bold, italic or none, colour and font size are all characteristics that induce different emotions for users.

Figure 4.2: Bianchi's Colour Circle.



Source: (BIANCHI; NERIS, 2015).

4.2.2 User Interface Adaptation

Adaptation can be understood as an adjustment, a change. When related to user interfaces, it is used when one does not know what is responsible for the change. Otherwise, the system is referred to as adaptable – when the user chooses the alterations – or adaptive – the system automatically changes the UI according to usage patterns (ALVAREZ-CORTES et al., 2007).

If a UI is said adaptive, it monitors user's activity and, based on an algorithm, automatically adjusts interface components to satisfy the user (STUERZLINGER et al., 2006; ALVAREZ-CORTES et al., 2007). On the contrary, an adaptable interface will address the control of the changes to the user (STUERZLINGER et al., 2006; ALVAREZ-CORTES et al., 2007). It may offer guidance to their users, but it is up to the user to decide whether or not to want such help.

Although positive, both options may present disadvantages if they are not developed correctly. Adaptive interfaces can remove items needed for page navigation whereas adaptive interfaces may not support the screen desired by the user (STEUNEBRINK, 2010). One way to solve this might be a combined alternative, which allows either the user to initiate the adaptation or the system can perform it automatically (ALVAREZ-CORTES et al., 2007), according to the situation of use and the users' preferences.

4.3 Related Work

The studies on UI adaptations may relate to several motives: facilitate the learning process (OPPERMANN; RASHER, 1997), develop interactive conversational systems (GUSTAFSON et al., 2000), help people with disabilities (PROENÇA; NERIS, 2017; BRAHAM et al., 2021), provide better user experience (CHUJKOVA; AIDINYAN; TSVETKOVA, 2020), among other intentions.

As HCI scholars understood the importance of emotions in daily activities (NORMAN, 2004; CRISTESCU et al., 2008), they also noticed that the emotional state could affect how the user understood the usability of interactive interfaces (LIM et al., 2008; DALVAND; KAZEMIFARD, 2012). Therefore, the change in emotional state became a subject of some studies in the area.

At their work, Mori, Paternò and Furci (2015) related elements of design with the evoke of specific emotions – hate, anxiety, boredom, fun, serenity, love. Meudt et al. (2016) uses a multi-layered architecture that saves the system interaction history and the consequently emotional response of the user. Therefore, it can propose more accurate adaptations in the long term in order to evolve the interaction between system and user to a more empathic level.

The colour scheme is considered the main element of an interface (HOLTZE, 2006; JIANG et al., 2008). At their work, Dalvand and Kazemifard (2012), Bianchi and Neris (2015), Donati, Mori and Paternò (2020) studied the colour adaptation and how it affected users. Other work combine the adaptation of colour with other types of adaptation. Herdin and Märtin (2020) present colour adaptation along with content and media adaptation (such as pop-ups, product comments and types of charts).

Galindo, Dupuy-Chessa and Céret (2017) developed an architecture that seeks to adapt UI elements – such as font size, audio, screen brightness, as well as the UI structure itself – at run time based on different user emotional states. According to the authors, this choice of emotions was defined based on Russel's Dimensional Model (RUSSELL, 1980). It is worth mentioning that this model acted as a precursor to Scherer's Semantic Emotional Space (SCHERER, 2005).

However, work related to generating or altering an emotional response in users is still scarce in computing. Most studies found adapt interfaces in order to provide better usability or improve the site's aesthetics (REINECKE; BERNSTEIN, 2011; DUPUY-CHESSA; LAURILLAU; CÉRET, 2016).

An important aspect of studying emotions is the defining the how the data is going to be collected. One of the most varied form of collection is using assessments of subjective feelings. Self-Assessment Manikin (BRADLEY; LANG, 1994) is an instrument cited on several studies Mahlke, Minge and Thüring (2006), Xavier and Neris (2012), Maia and Furtado (2019), Silva et al. (2020). It is also possible to have a likert scale (with or without scrolls) (GHIANI; MANCA; PATERNÒ, 2015; BIANCHI; NERIS; ARA, 2019; DONATI; MORI; PATERNÒ, 2020; SILVA et al., 2020; BRAHAM et al., 2021) and other instruments created by HCI specialists, such as (DESMET, 2003; HASSENZAHL; BURMESTER; KOLLER, 2003; LARSON; CSIKSZENTMIHALYI, 2014).

The collection of motor expressions, which mainly relates to facial and body expression and gestures (SCHERER, 2001; MAHLKE; MINGE, 2008), usually involves the application of FACS (EKMAN; ROSENBERG, 1997), a coding system for detecting emotions. Different API are based on this system, such as FaceReader (TERZIS; MORIDIS; ECONOMIDES, 2010; GALINDO; DUPUY-CHESSA; CÉRET, 2017) and FaceTracker (MANO et al., 2020).

Because of the variety of components, the physiological reactions are regularly present in emotional studies. The electroencephalogram (EEG) (SCHALL, 2014; SOURINA; LIU, 2014; SOUZA, 2019; MAIA; FURTADO, 2019); electrocardiography (ECG) (SOUZA, 2019); heart rate (LISETTI; NASOZ, 2004; MAIA; FURTADO, 2019) galvanic skin response (GSR) (LISETTI; NASOZ, 2004; SCHALL, 2014; SOUZA, 2019; MAIA; FURTADO, 2019); pupillometry (WANG et al., 2013; GALINDO; DUPUY-CHESSA; CÉRET, 2017; MAIER; GRUESCHOW, 2021) and eye tracking (CHENG; LIU, 2012; SCHALL, 2014; GUNTZ, 2020) are the most common information collected from users.

Nevertheless, few studies cite the possibility of using different forms of data collection to guarantee a more accurate result, as proposed by the Component Model (SCHERER et al., 1984). Another gap relates to the absence of studies interested on helping users to achieve a desired emotional state. They are mostly focused on lead the user to feel emotions chosen by the authors. They generally are positive emotions, in other words, emotions with high arousal and positive pleasure as we can see in Donati, Mori and Paternò (2020) for example. This choice is not arbitrary, though, as the change from negative to positive emotions may result on loyal users of a website (CYR, 2013).

This study intends to fill both gaps: (1) providing a solution that uses at least two instruments of collection (but is designed to allow more options to be plugged in) as it is based on Scherer's Component Model (SCHERER et al., 1984); and (2) also offering the user a change to approach any emotional state he/she might want to at interaction time (rather than at design time).

4.4 Experiment

To evaluate our solution, we chose to apply a mixed factorial experiment. This indicates an experiment with at least a within-subjects factor and at least one between-groups factor. It is a within-subjects as users from both groups will perform both tasks. However, it is a between-groups because there is one control group and one placebo group. The experiment is also defined as double-blinded as neither the participant nor the experimenters know which group does a participant belongs to.

The experiment was approved by the local Ethical Committe Board through certificate number 42671121.3.0000.5504.

4.4.1 Planning

On this experiment, our goal was to evaluate whether users could achieve a desired emotional state by promoting adaptations in UI elements. The user must access an online questionnaire – displayed at LimeSurvey[1] and follow its instructions. He or she must download the UIFlex 2.0 plugin (GUIMARÃES et al., 2022) and create an accessibility and an emotional profile. This profiles will help to promote the correct adaptation.

Each user had to perform two types of tasks: reading and transcription. Because human beings are so diverse, the idea of adding two tasks to every participant intends to minimize extraneous variables. In this case, those might be one's ability at any of the tasks.

Also, to prevent users from having a better performance at one task due to learning and consequently transfer, the participants were divided into groups so that each group started with a different activity.

We also opted for adopting a control group. The participants of this group were guided to download UIFlex 3.0. The difference between the two versions is that, although it created the accessibility and emotional profile, UIFlex 3.0 did not adapt any web pages.

The choice to have a control group – also known as placebo – is due to the belief that some users might say they had their emotional state altered only by resolving the asked tasks. Thus, we analyse if users from both groups (control and adapting group) had changed their emotional state. However, neither did we or the participants knew whether they were part of the control or the experimental group. Therefore, the experiment is defined as double-blind.

[1] https://www.limesurvey.org/pt/

Both the adapting and the control version were randomly assigned to a user when accessing the questionnaire. Therefore, we had four groups in this study, as displayed at Table 4.1.

Table 4.1: Group options divided into categories.

	Not Placebo - UIFlex 2.0	Placebo - UIFlex 3.0
First task: Reading	Group 1	Group 3
First task: Transcript	Group 2	Group 4

Source: The author.

The groups were randomly assigned as it follows: first, whether the participants would have access to UIFlex 2.0 or 3.0 – in other words, if it was going to be control group or not. After that, if the participants of the group would start with the reading or the transcript task.

After finishing each task, the user provided their subjective feeling, one of the components of the Component Process Model of Emotion (SCHERER et al., 1984). To do so, an instrument of collection was provided using scroll sliders. We opted for this solution based on a study that compared 4 different types of instruments for collecting users' subjective feelings(SILVA et al., 2020).

This instrument was presented three times: on the first one, it collected the user actual emotional state; at the second, it collected the desired emotional state; finally, it collected the user emotional state after the user finished the task. This last data collection was made available by a questionnaire.

UIFlex was built not to send the users' preferences to any web server to ensure privacy. Therefore, for the propose of this study, the user was asked to download and attached the data gathered while anonymously answering the final questionnaire. This information was analysed as demonstrated in Section 4.5.

4.4.2 Tasks

As mentioned, there were two tasks to be performed by each user. Each task was composed by a group of steps that should be performed and a video demonstrating them was made available.

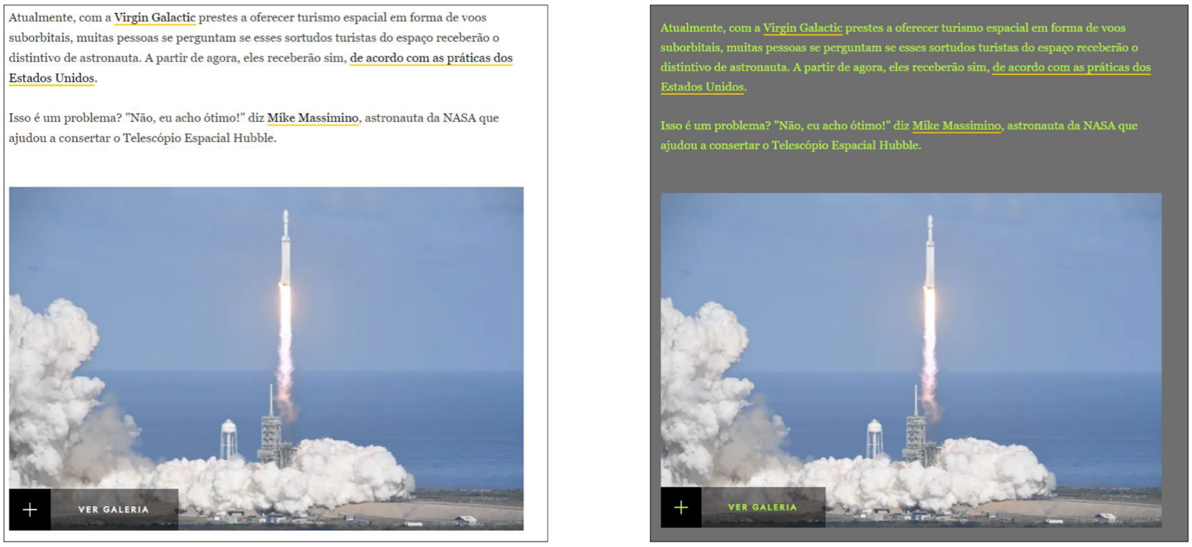
For the reading activity, the user must head to a National Geographic post[2] and read the entire page. This page was chosen because (1) the page must not be altered by its authors during

[2]https://www.nationalgeographicbrasil.com/espaco/2019/01/onde-exatamente-comeca-o-espaco-sideral-depende-de-quem-ira-responder-pergunta

the study or the final results would not be consistent; and (2) it is a scientific text. In other words, it is supposed to be on a neutral subject and rarely brings up any emotional connection to the user, preventing eventual bias that could be generated if the user felt related to the text.

One example of the adaptations that could be "injected" is presented by Figure 4.3.

Figure 4.3: Web page adaptation provided by UIFlex 2.0.



Source: (GUIMARÃES et al., 2022)

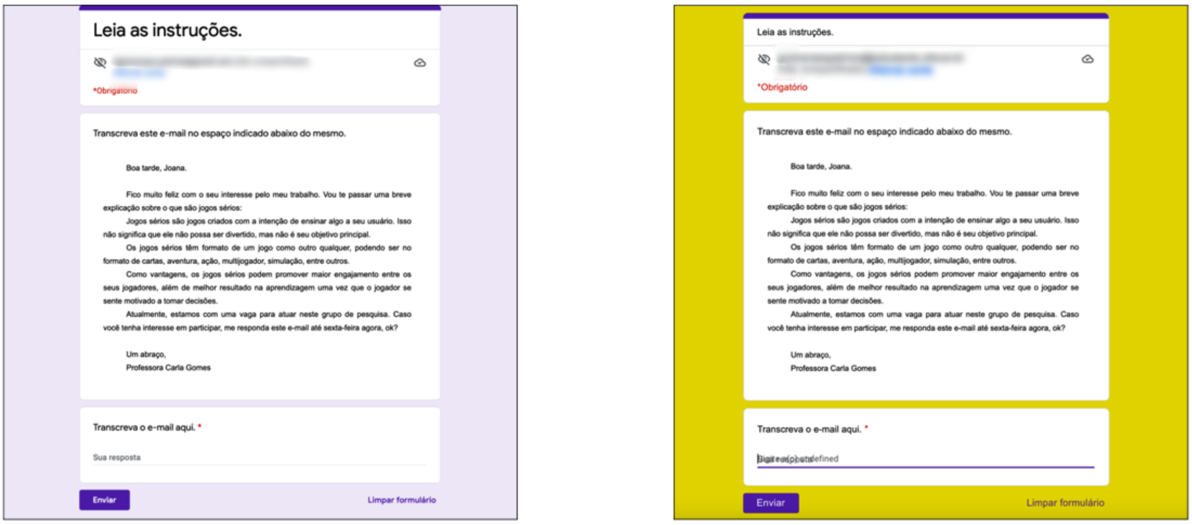
It is possible to see that the final background colour is gray and the text is written in green. According to the rules presented in Guimarães et al. (2022) and based on Bianchi and Neris (2015), this user was emotionally at the octant 1 or 2 and wanted to be at the octant 3 or 4.

On the other hand, for the typescript activity, we created an online form using the Google Form tool[3]. The user should once again enter the form web page presented on the steps of the task, where a text would be displayed. The text presented was an e-mail from a professor to a student mostly explaining about serious games.

According to Dörner et al. (2016), serious games are the ones created to achieve another goal among the entertainment, such as learning. Moreover, it must be developed digitally. Once again, this subject was chosen due to its impartiality as participants may or not know about it. Even if they have previous knowledge, it is a subject hardly connected to any value judgments.

[3]https://www.google.com/forms/about/

Figure 4.4: Another web page adaptation provided by UIFlex 2.0.



Source: The author.

Figure 4.4 provides an example of adapted web page according to UIFlex rules. In this case, the background colour it yellow. Consonant to the previously mentioned rules, the actual octant measured is between 1 to 4 and the desired octant is either 7 or 8.

4.4.3 Recruit and Inclusion Criteria

For this study, participants were invited through an email sent to university departments and several posts made on social networks. The inclusion criteria for the subjects were: age greater than 18 years; access to a desktop computer or notebook with webcam (embedded in them or not) and internet connection. In addition, they should have the Google Chrome browser installed – since the plugin was developed only for this platform. Exclusion criteria were: people with any degree of facial paralysis as the motor expressions sensor could miscalculate their expression.

4.4.4 Demographic Data and Guidance

After reading the consent form and agreeing to the document, participants answered some demographic question. They were asked questions about demographic characteristics, such as gender, age, academic level and average use of desktop computer/notebook and average Internet use.

Before answering the usability questionnaire, the users were explained how to download the UIFlex according to the group they belong to. This explanation is done via text and video. Therefore, he/she should be part of either Group 3 or 4.

The questionnaire counted also with videos explaining the necessary steps to be followed at each task and one describing the process of uploading the data collected.

4.4.5 UIFlex 2.0

UIFlex 2.0 is an update of UIFlex (ALENCAR; NERIS, 2014; PROENÇA et al., 2021). The solution was firstly designed to improve the experience of people with disabilities at web pages. On a second step, UIFlex 2.0 focus on the emotional experience of the user.

In spite of leading the user to have a better experience at a website, as most works in this field intends to, UIFlex 2.0 was designed to help the user to experience a different emotional state according to what he/she is doing at the moment. For example: if a student has to study for a test, but he/she is overwhelmed with a football match, UIFlex 2.0 might help him/her concentrate on the text that must be studied.

The solution is a plugin found at Chrome Web Store[4]. After downloading and activating it, the user is showed a menu, where he/she will fill out two forms, one relate to accessibility and the other to emotion. The answers given will generate a user profile. In other words, the user needs will be saved locally in the users' computer, allowing the framework to perform better adaptations to meet these necessities.

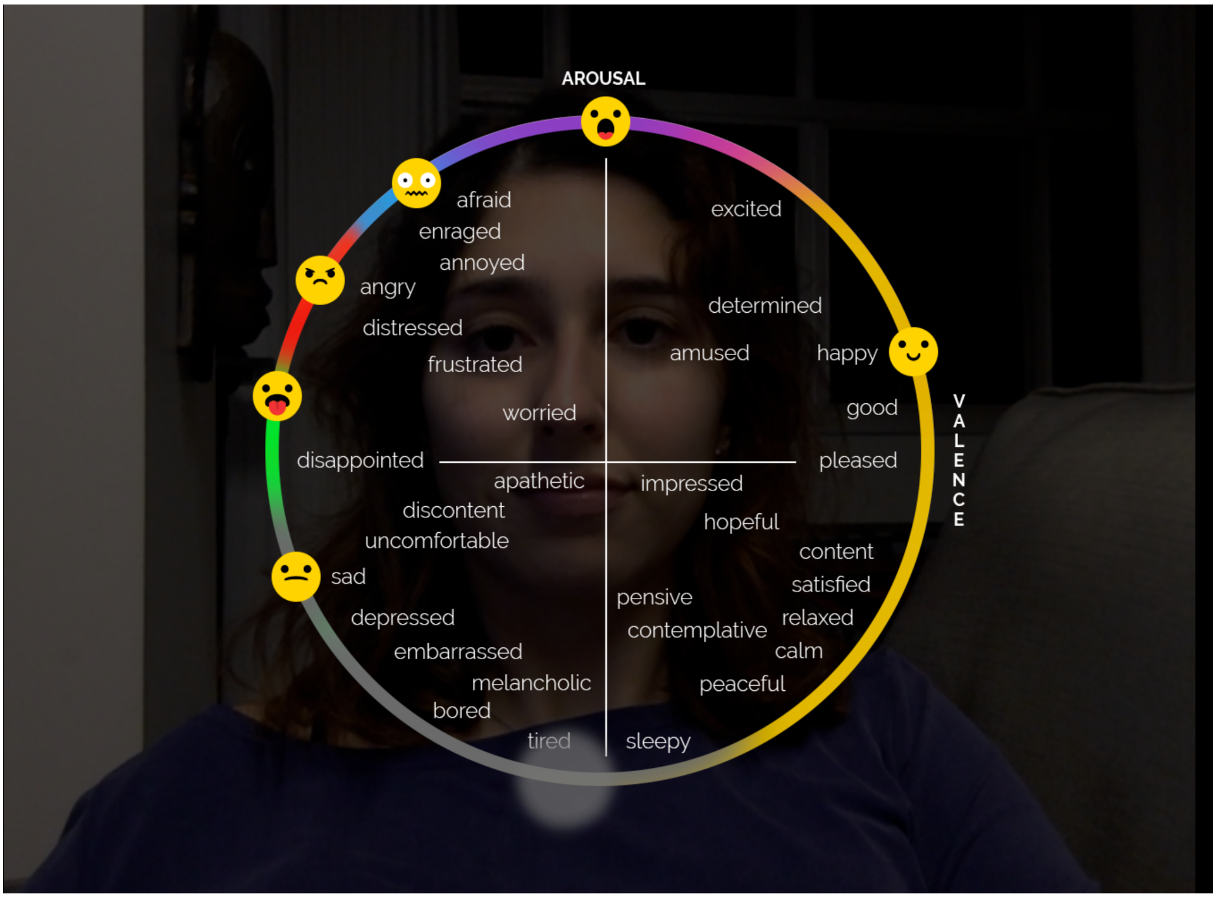
The adaptations are based on knowledge published by authorities, experts and scholars on accessibility and emotion. This knowledge has been translated into rules that, when activated, "inject" CSS code and, consequently, alter colour background, links, audio control, among others (PROENÇA et al., 2021; GUIMARÃES et al., 2022).

The collection process starts with the user's webcam gathering facial expression data – part of the components of the motor expression – and classifying them into arousal and valence data according to Scherer's Emotional Semantic Space (SCHERER, 2005).

The information is collect every second until the user finishes filling the emotional form. This data is stored to be accessed later. Figure 4.5 shows the API used to collect and process the information.

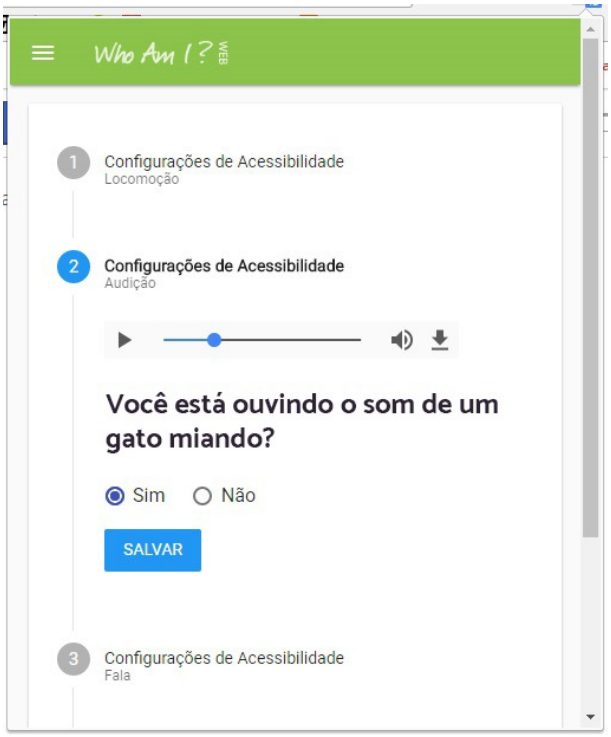
[4]https://chrome.google.com/webstore/category/extensions?hl=pt-BR

Figure 4.5: Capturing user's motor expressions. The main circle is based on Scherer's Semantic Emotional Space (SCHERER, 2005).



Source: (GUIMARÃES et al., 2022).

Figure 4.6: UIFlex tool screen related accessibility data collector.



Source: (PROENÇA; NERIS, 2017)

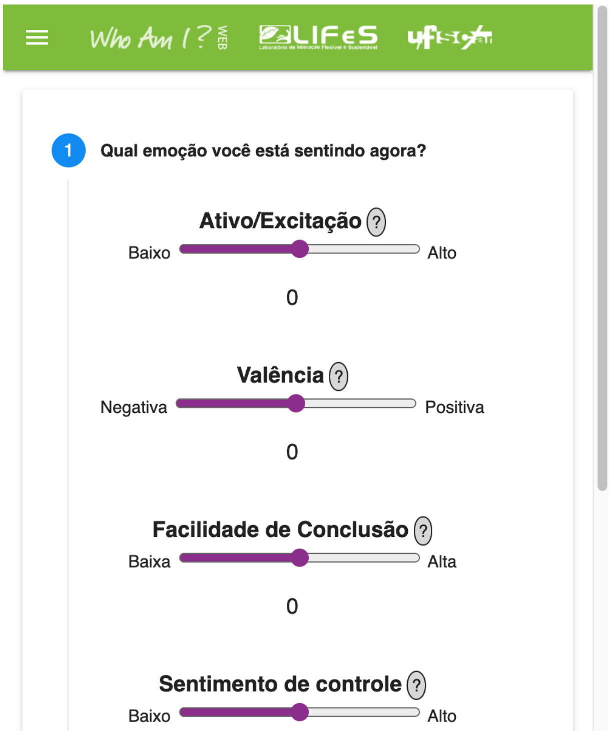
The user then starts fulfilling the accessibility form, presented by Proença and Neris (2017). The questions asked relate to motor, auditory, visual or speech impairment, in addition to colour blindness. The Figure 4.6 presents the form briefly, with items written in Portuguese. This is how it is being displayed to the users. However, an English version is presented by Proença et al. (2021).

Last, the user must complete the emotional form. This step relies on Scherer's Component Process Model of Emotion (SCHERER et al., 1984) as collectors from different components can be plugged at UIFlex 2.0 to generate user's emotional state with more accuracy (GUIMARÃES et al., 2022). Due to the pandemic situation, the plugin is currently working with an API responsible for collecting motor expressions and the emotional for subject feeling.

As mentioned before, the subject feeling is collected with the use of scroll sliders. The instrument was coupled on UIFlex 2.0 and showed two times to the user: the first time, it asked the user current emotional state; and the second time, the desired state. Figure 4.7 shows the first question.

The data provided by the emotional form will result on one or more initial octants and one or more desired octants – a synonym for the emotional state. To understand which rules fit

Figure 4.7: Emotional form. The domains presented in Portuguese refer respectively to arousal, valence, coping potential and goal conduciveness and the options refer to low/high, negative/positive, low/high and low/high.



Source: The author.

better the situation, UIFlex 2.0 performs the Mapping Self-report Instruments by Intensity and Polarity for Emotions (MSIPE) Method (SILVA et al., 2020).

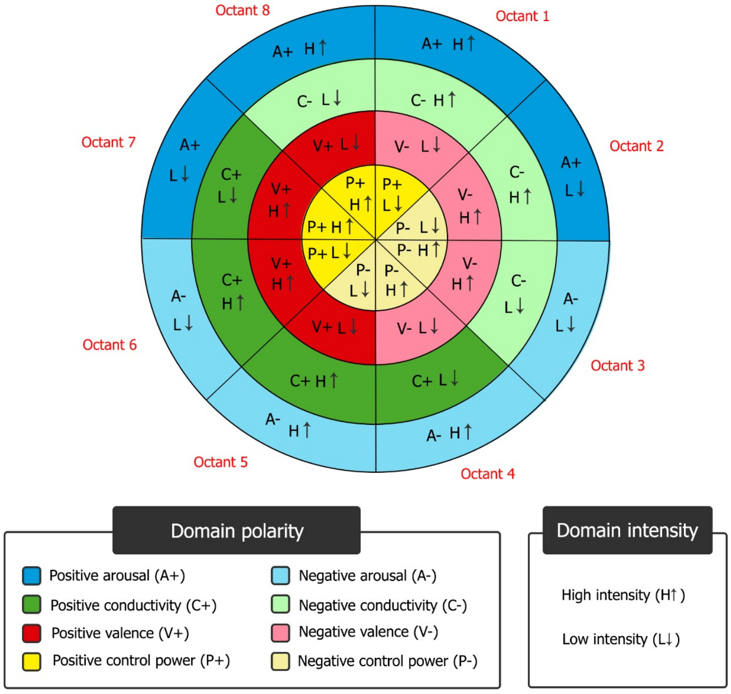
According to the the value of the scroll, this value is defined as its polarity and intensity. The polarity of a number means it is either negative (from -0.1 to -1) or positive (from +0.1 to +1). On the other hand, the intensity is either high (from 0,51 to 1 in absolute values) or low (from 0,5 to 0,01 in absolute values). It is important to notice that the 0 is excluded from both intervals. Therefore, if a participant leaves any of the scrolls on the 0, he/she had his/hers data disregarded.

As previously stated, the motor expressions are collected through an API called Morphcast[5]. It access the user webcam and captures his or hers face movements. Then, the API classifies the movement with a value of valence and another of arousal according to Scherer's Emotional Semantic Space (SCHERER, 2005).

All these data is analysed and the values are calculated in order to inform the octant the user is at. We then apply the mode operation on all the octants. This is the octant of the motor expression.

[5]https://www.morphcast.com/

Figure 4.8: MSIPE method.



Source: (SILVA et al., 2020)

The set of octants from the subject feeling and the octant from the motor expression are grouped. Another mode is performed on these numbers. The final result is the initial emotional state. Is there are more then one octant, we perform the mean operation on the octants.

4.5 Analysis

To understand if the framework helps the user, we first analysed the octants at every stage: the actual (or initial) emotional state (I.E.S.), the D.E.S, the meanwhile emotional state (M.E.S.) and the final emotional state (F.E.S.).

4.5.1 I.E.S.

To find the octant (or octants) that correspond to the user's I.E.S., it is necessary to analyse the data collected by the UIFlex 2.0.

We firstly use the MSIPE method to analyse the data gathered from the emotional form. This method was presented by (SILVA et al., 2020) and it is based on the differences in polarity and intensity of the domains in the octants. Figure 4.8 presents how these two characteristics are measured.

Table 4.2: Example of an application of the MAIPE method to the four domains of the the Emotional State.

Valence Value	Valence Octant(s)	Arousal Value	Arousal Octant(s)	Conduciveness Value	Conduciveness Octant(s)	Power Value	Power Octant(s)	Final Octants
-0.7	2,3	-0.7	4,5	-0.67	1,2	-0.7	3,4	2,3,4

Source: The author.

Table 4.3: IES

ID	I.E.S. (subj. feel.)	I.E.S. (motor exp.)	I.E.S. (mode)	I.E.S (mean)
1	1,3,4	4	4	4
2	1,2	6	1,2,6	3

Source: The author.

Because each domain varies between -1 and +1, the polarity is defined as positive or negative. When an octant has values closer to +1 or -1 in a certain domain, it is considered of high intensity on that domain. Otherwise, it is considered of low intensity. Table 4.2 shows an example of a transformation from values to final octants.

When the user presses the save button on the emotional form, the API stops collecting information so that the last set (time, valence and arousal) are stored. With the last two items, the framework calculates the octant. Then, a mode is calculated between the actual octant(s) collected by the form and the octant saved from the facial expression instrument collector. However, if the final result is a set of octants, an average is performed to understand what would be the closest octant to the user's true emotional state. Table 4.3 presents two examples of this process. The complete tables with the values for 44 participants in both tasks is found at Tables B.2 and B.2 on the Apendix.

4.5.2 D.E.S.

The D.E.S. is also collected by the emotional form. Therefore, it is necessary to apply the MSIPE method to find the correspondent octant (SILVA et al., 2020).

If the application of MSIPE (SILVA et al., 2020) results in more than one octant, it is necessary to perform the mode operation on the octants, so we can have only one D.E.S.

4.5.3 M.E.S.

As previously mentioned, the API stores a set of time, valence and arousal collected every 1 second until the save button on the form is pressed. The valence and arousal info are used to calculate the octant the user is at.

The M.E.S is the appliance of the mode in the octants discovered. The information is downloaded by the user at UIFlex and upload by him/her at the questionnaire. Thus, we could have access to these data only for the purpose of this study.

Table 4.4: M.E.S. data collection.

ID	Task	Time	Valence	Arousal	Degrees	Octant
4	Reading	0				
4	Reading	1				
4	Reading	2				
4	Reading	3	-0,10361387580633101	-0,22934302687644903	294,31276706707905	7
4	Reading	4	-0,1072455091	-0,3208058674	288,4847989747037	7
4	Reading	5	-0,219170959	0,049516706977682005	167,26905531671656	4
4	Reading	6	-0,1101436865	-0,1517729074	305,96890829043394	7
4	Reading	7	-0,1197660678	-0,27214527082676604	293,75340107374933	7
4	Reading	8	-0,19039272721821202	-0,2104080314	312,1411217420534	7

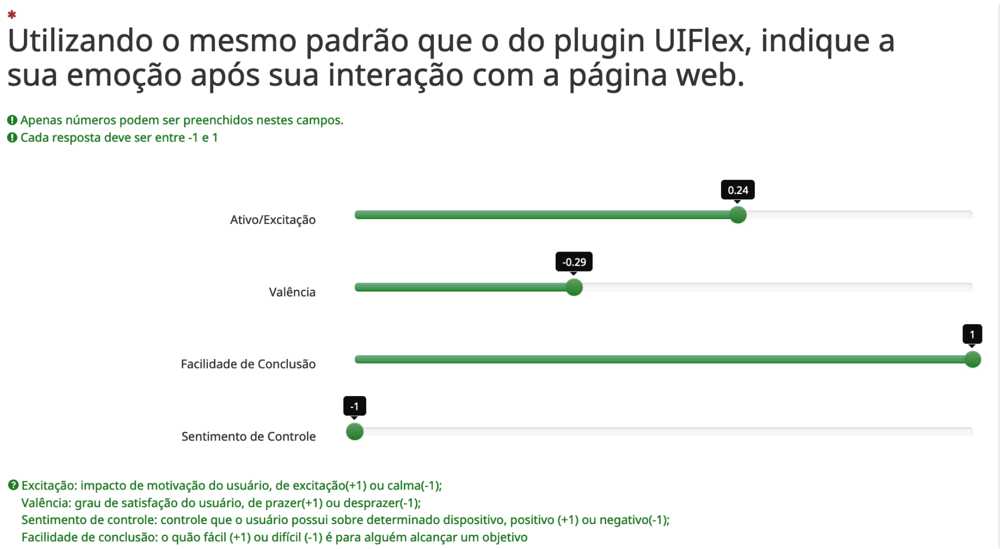
Table 4.4 shows values produced by the FACS system API for valence and arousal. Considering the position of these values in the SE (degrees), it is possible to associate with octants. To calculate the M.E.S., it is necessary to apply the mode on the octant column. In the example, the result would be the octant 7.

4.5.4 F.E.S.

The F.E.S. is collected using the same slider principle presented by the UIFlex plugin. However, this information is only collected at the questionnaire. Consequently, the F.E.S. is only collected through an subjective feeling instrument. Figure 4.9 presents the collection process of the F.E.S.

On the questionnaire, it was presented a briefly description of each of the domains and the meaning of the extremes values.

Figure 4.9: Scroll Slider Added to the Questionnaire to Collect Emotional Data. The header is asking the user to use the same pattern as he/she would use to fulfill the information at the plugin.



Source: Elaborated by the author.

4.5.5 Statistical Test

To evaluate whether UIFlex helps or not users to achieve a desired emotional state, we selected two main variables: the amount of users that achieved the desired emotional state and the one's that had their web page adapted. Therefore, we defined the following hypothesis:

- H_0: users that interact with UIFlex 2.0 are not more likely to reach the D.E.S. when comparing to users that interact with UIFlex 3.0.
- H_1: users that interact with UIFlex 2.0 are more likely reach the D.E.S when comparing to users that interact with UIFlex 3.0.

To run the hypothesis test, we must analyse data from the both the control and the placebo group. To accept H_1, participants' from the control group must have a bigger amount of equal values on their D.E.S and F.E.S on both tasks. Tables B.3 and B.4, from Appendix B present the data collected from all participants during both tasks.

Evaluating the data gathered, 27 from the 44 participants achieved the D.E.S. on the reading task: 14 of them were on the placebo group and 13 on the control group. On the transcript task, 13 participants from the placebo group achieved the D.E.S., whereas 16 participants of the control group did.

The placebo group is composed by 19 participants. This means that 73,68% of them have matching D.E.S. and F.E.S. on the reading task and 68,42% on the transcription task. On the other hand, 52% of the 25 participants of the control group achieved the D.E.S. on the reading task and 64% on the transcription task. It is possible to assume that we are going to reject H_0.

To confirm this assumption, we ran a Chi-Square test. We created a table for the observed data and one for the expected data for each task. They are presented on both Tables 4.5 and 4.6.

Table 4.5: Observed and Expected Data Obtained from Reading Task.

(a) Reading Task - Observed Data.

Do D.E.S. and F.E.S. match?	Placebo	Control	Total
Yes	14	13	27
No	5	12	17
Total	19	25	44

Source: The authors.

(b) Reading Task - Expected Data.

Do D.E.S. and F.E.S. match?	Placebo	Control	Total
Yes	11,6591	15,3409	27
No	7,34091	9,65909	17
Total	19	25	44

Source: The authors.

Table 4.6: Observed and Expected Data Obtained from Transcript Task.

(a) Transcription Task - Observed Data.

Do D.E.S. and F.E.S. match?	Placebo	Control	Total
Yes	13	16	29
No	6	9	15
Total	19	25	44

Source: The authors.

(b) Transcription Task - Expected Data.

Do D.E.S. and F.E.S. match?	Placebo	Control	Total
Yes	12,5227	16,4773	29
No	6,4773	8,5227	15
Total	19	25	44

Source: The authors.

On the reading task we obtained p-value$_R$ = 0,1434064648, whilst the data from the transcription task resulted in p-value$_T$ = 0,7592649585. Considering α = 0,05, we then reject H_1 in favour of H_0, i.e., users that interact with UIFlex 2.0 are not more likely to reach the D.E.S. than users that interact with UIFlex 3.0.

It is important to reinforce that this variable does not measures if the adaptation could have helped the user, but if the user had his or hers emotional state changed when using UIFlex 2.0. Besides the adaptation, other factors that could help one to change their emotional state: having memories or experiences related the texts themes; fearing of disappointing in case the expected resulted is not achieved; feeling anxious or excited about taking part in an study; wanting to achieve the chosen emotional state; engaging in other activities whereas taking part in the study, among others. Although effort has been made to avoid these events, the lack of a controlled ambient may result on unexpected results.

Although the H_1 was already rejected, it is important to evaluate two other points: firstly, the total number of users from the control group that had their UI adapted; secondly, whether the UIFlex 3.0 helped users' from the placebo group to change their emotional state.

There can be situations in the control group where no code will be "injected". This happens when the I.E.S. and the D.E.S are in the same adaptation rule. For example, octants 3 and 4 have the same colours according to Bianchi's Colour Circle (BIANCHI; NERIS, 2015) and, consequently, share the same adaptation rule. It is important to check this number of occurrences to analyse if they impact on the hypothesis test.

Tables B.6 and B.5 present the I.E.S and the D.E.S. mean from all participants of the control group. On the reading task, 8 of them did not have any code "injected" on the UI whereas on the transcript task, 14 participants did not see the interface adaptation. This equals to 32% and 56% of the users respectively.

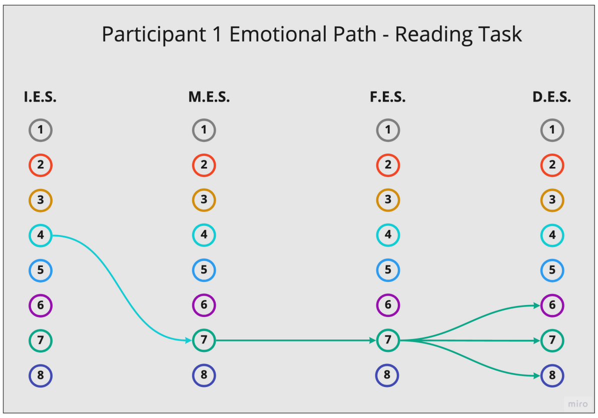
Subsequently, we evaluated the second point, which states that UIFlex 3.0 help users to change their emotional state, even if they do not reach the D.E.S. To do so, we compared the I.E.S. and the F.E.S. from the participants of the placebo group on both tasks. From the 19 participants of the placebo group, 13 had their F.E.S. different from their I.E.S. on the reading task and 14 on the transcription task. This is equivalent to 68% and 73% of the participants.

It is suggested a new study on the future that new tests are taken after the addition of new rules of adaptation to evaluate whether the result of the test changes.

4.5.6 Graphs of Incidence

Despite this conclusion, the data collected allows us to trace the emotional path of the participants during the capture process on the four groups in graphs. Figure 4.10 demonstrates the process of organizing the data for one participant.

Figure 4.10: Emotional path of participant 1 during the reading task.



Source: The authors.

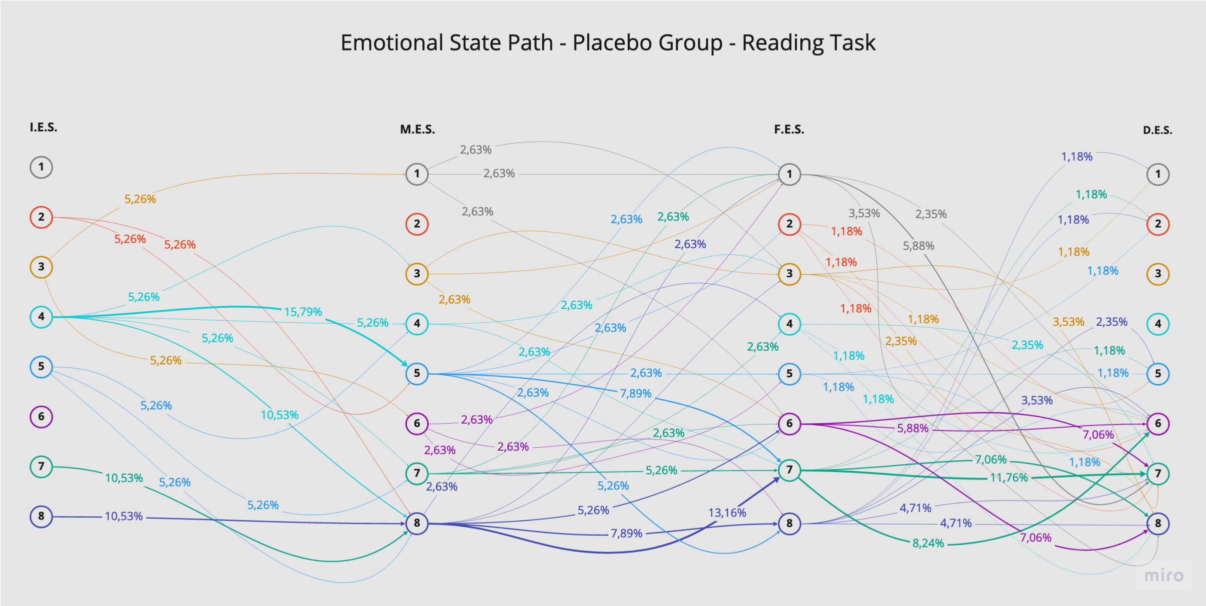
The edge that connects I.E.S and M.E.S. is responsible for demonstrating the path followed by the participant from the beginning of the experiment in order to achieve the D.E.S. For example: as participant 1 started at the octant 4 and wanted to achieve either octants 6,7 or 8, the M.E.S. was expected to be an octant among 4 an 8, indicating the user was being directed to the D.E.S. If the M.E.S was octant 2, it would indicate that the participant was distancing himself/herself for the D.E.S.

Similarly, the edge that connects M.E.S and F.E.S. indicates the emotional path of the user when performing the designed task and then answering the final questionnaire. In this case, participant 1 maintained at the octant 7.

Finally, the last edge is the most important one for this experiment once it shows if the participant has or not achieved the D.E.S. Because of the fact that this state is measured only with the scroll sliders, the final answer can be more than one octant. For example, on the graph displayed by Figure 4.10, the participant wanted to achieve either octants 6, 7 or 8. Because he/she finished the study at octant 7, it means he/she achieved the emotional state he/she wanted.

Following the scheme presented above, we present Figures 4.11, 4.12, 4.13 and 4.14. They present the path of the participants according to the group to which they were assigned.

Figure 4.11: Emotional path of the participants of the placebo group during the reading task.

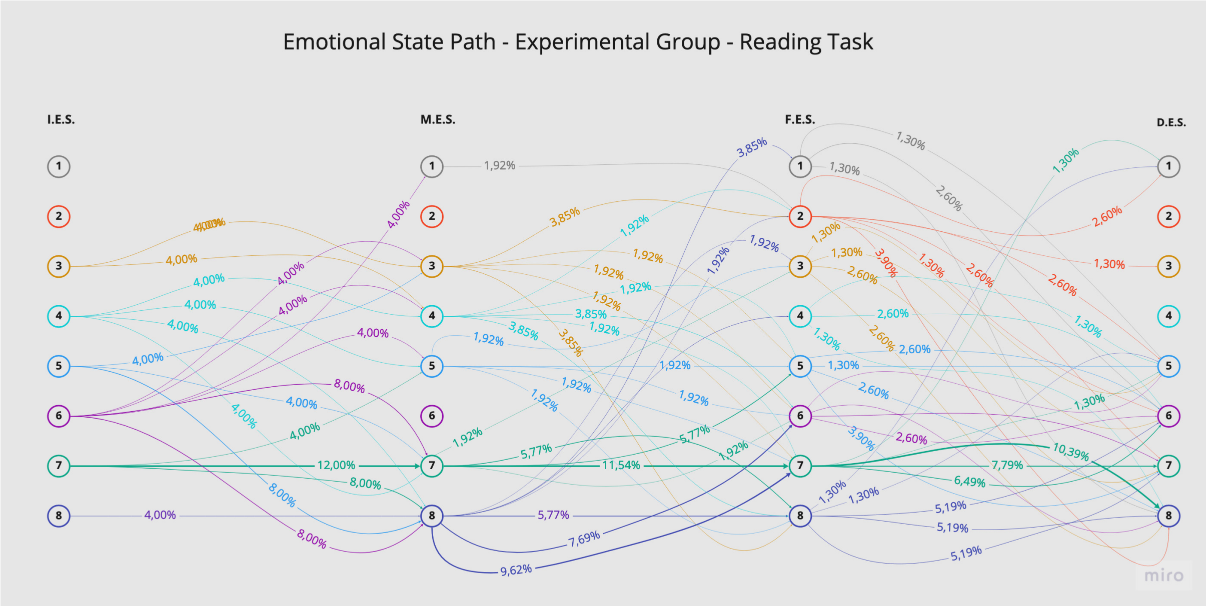


Source: The authors.

Ideally, members of the placebo group would have a straight line from I.E.S and F.E.S. once their web pages do not adapt. However, it is possible to notice in Figure 4.11 that most edges were curvy, indicating the change in octants. Most participants started on octant 4 and ended the reading task at octant 7.

Despite the impossibility to adapt the interface, most participants desired to achieve the octant 7 (around 37,65% of the users). Together with octants 8 and 6, they are responsible for the majority of the responses – around 25,88% and 24,70% of the participants respectively, totalling 88,23%.

Figure 4.12: Emotional path of the participants of the experimental group during the reading task.



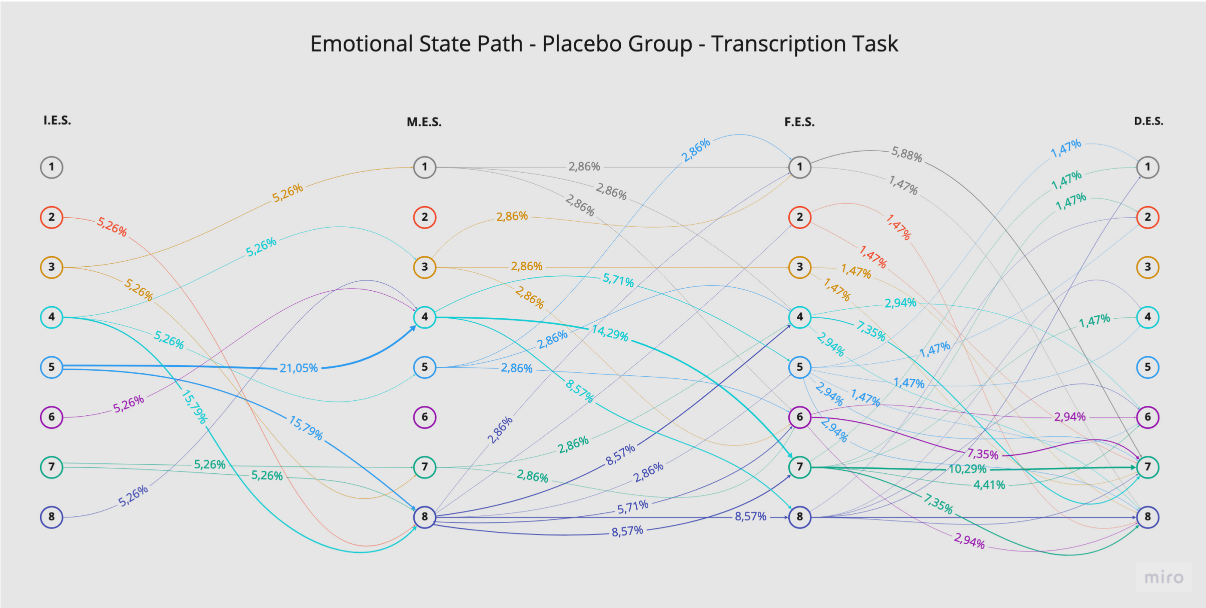
Source: The authors.

Figure **??** shows that the control group had most of its participants starting the experiment at octant 6 (32,00% of the total), but none of them stayed on it during the experiment. Instead, the majority of the participants finished the task with their F.E.S. being either octants 7 and 8 – 27,27% and 18,18% respectively.

It is also worth highlighting straight line that connects all vertices that represent octant 7. The edge that connects the vertex 7 on the I.E.S. and the vertex 7 on the M.E.S. equals to 12,00% of the participants. Next, the edge that links both vertices 7 on M.E.S. and F.E.S. corresponds to 11,54%. Finally, in the last step, the edge that connects both vertices 7 represents 7,79% of the participants. Actually, in this step, the most desired octant was octant 8, with a percentage of 29,87% of the participants whereas octant 7 was the second one, with 27,27% of the choices.

Yet, if the participant had octant 7 as his/hers I.E.S. and wanted to achieve octant 7 (or 8), there will not be any adaptations on the user interface. This occurs because the new rules created for UIFlex 2.0 are based on Bianchi's colour circle (BIANCHI; NERIS, 2015), where both octants have the same characteristics. Therefore, more studies should be done in order to find new interface elements that differ from one octant to another so new rules may be created to help the user to achieve the truly desired emotional state.

Figure 4.13: Emotional path of the participants of the placebo group during the transcription task.

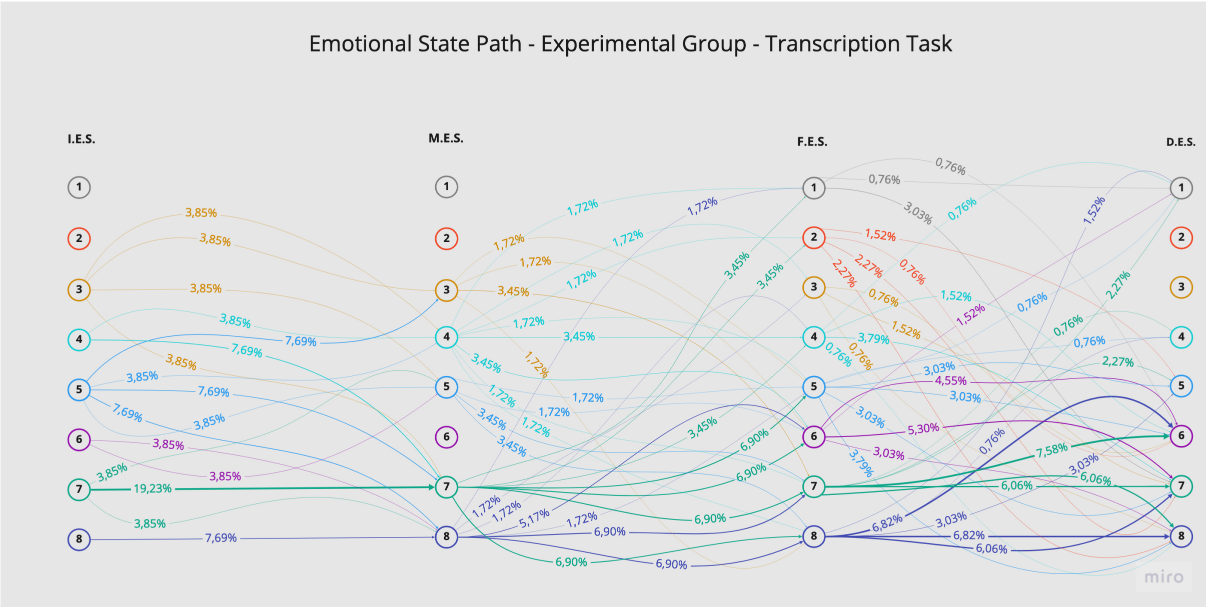


Source: The authors.

Figure 4.13 presents the results of the placebo group when performing the transcription task. As mentioned in 4.11, this version do not provide ant changes on the interface. Nonetheless several participants had their emotional state altered once again. Whereas 36,84% started the transcription task at octant 5, they moved to either octants 4 or 8 during the experiment.

However, in the end, most participants finished on octants 7 (26,47%) or 8 (22,06%). The same octants were the most desired ones: 41,18% and 27,94% respectively, totalling 69,12% of the participants' desire.

Figure 4.14: Emotional path of the participants of the experimental group during the transcription task.



Source: The authors.

At the transcription task, the majority of the control group started the experiment at octant 5 (30,77%) follow by octant 7 (26,92%) as seen in Figure 4.14. It is important to notice though that 19,23% started at the octant 7 and maintained on it during M.E.S. From those, 6,90% finished on the same octant.

Regardless of the octant the user ended at, 31,05% of them wanted to achieve octant 7, 25,75% octant 6 and 23,48% octant 8.

Finally, 21,21% of the users reached the desired octant. 17,42% of this total are from users that succeeded on achieving octants 6, 7 or 8.

4.6 Acknowledgment

This study was partly financed by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001 and by the Fundação de Amparo à Pesquisa do Estado de São Paulo - FAPESP (Process number 2015/24523-8).

4.7 Conclusion

The present study presented UIFlex 2.0. This framework not only helps user with certain disabilities to have a better interaction with web pages they access, but also adapts elements of interface.

We collected data from 44 participants in a user case to evaluate if UIFlex 2.0 could help users to achieve a desired emotional state (also called D.E.S.). We developed an incidence matrix with 2 out of the 4 variables collected and applied the chi-squared test.

Our results showed that, although the high percentage found on our study, UIFlex 2.0 does not help users to achieve the D.E.S. Therefore, we suggest adding more adaptation rules before performing another test.

Although the statistical results were negative, this work also presents 4 graphs related to the path the users made during the resolution of tasks with and without the aim of UIFlex 2.0. Results show that a great number of users achieved the D.E.S. (from both the placebo and the control group) and that the majority of D.E.S. had at least 3 positive domains of the Scherer's Semantic Emotional Space (SCHERER, 2005). This final information can help futher research as it shows that, even when it is possible to choose, most participants wanted to feel somehow happier.

Chapter 5

CONCLUSION

Technology is closer than ever. We use computational systems to access our bank accounts, web pages to read daily news and even our communication with other people is made through video calls – during work with our colleagues or in our free time with friends. Every person has its own needs when dealing with an user interface (UI), and they can change even in the same they. Therefore, this work presents UIFlex 2.0, a Google Chrome plugin that adapts UIs to meet users' needs, it's architecture and also an experiment ran with 44 participants.

This chapter is structured as follows. Section 5.1 highlights the main contributions of this dissertation. Section 5.2 presents the future work suggested according to the limitation cited on the same section. Finally, 5.3 presents the final considerations on this work.

5.1 Summary of Contributions

The main contribution made by this thesis is related to a new tool that changes the colour of UI elements according to their initial, desired and final emotional state. The key contributions can be summarised as:

- a study comparing four subjective feeling collection instruments with different approaches in order to understand which one led users to inform subjective feelings closer to the mapped on the literature for a given stimulus (Chapter 2);
- the updated version of the plugin UIFlex – UIFlex 2.0, a framework with rules for emotional adaptation – and the new set of rules added to UIFlex 2.0 (Chapter 3);
- a placebo version of UIFlex 2.0 – UIFlex 3.0; a double-blind experiment with 44 participants to evaluate their emotional response to either UIFlex 2.0 or UIFlex 3.0; a statistical

analysis about whether or not UIFlex 2.0 helps users to achieve the desired emotional state (Chapter 4);

- a set of graphs of incidence demonstrating the emotional path of the participants during their interaction with UIFlex 2.0; a discussion about the data analysed (Chapter 4).

5.2 Limitations and Future Work

Due to the COVID-19 pandemic, we were unable to test one of the proposed instruments of data collection: the electroencephalography (EEG), electrocardiogram (ECG) and Galvanic Skin Response (GSR), all physiological sensors that were previously presented by Souza (2019). Therefore, it is necessary another investigation after the addition of these collectors. It is also suggested that other instruments for collection are investigated in order to understand the more convenient form of collecting ephemeral information such as emotions.

In addition, when analysing the data collected from the study case, it is perceptible the amount of users that started to fill the questionnaire but did not finished. Our main belief is that, although the instructions of the study had been given both via text and video, most users were confused due to the amount of actions related to setting the system correctly and sending the data collected. Thus, improvements in the research design are recommended, specially an in-person environment where data collection for research would be performed in a more smooth way not totally relying on the participants. Besides, the researcher responsible for the study could fix any problems that arouse during the conduction of the test.

Finally, future studies should be done to develop new rules on adaptation. Not only should they include the adaptation of different elements of interface, but also understand how to lead the user to only one octant. After these adoptions, it is suggested that another study case (or an experiment) is taken, with the application of a new statistical test.

5.3 Final Considerations

Throughout this research, some key aspects were considered important highlights. The first one is the previously mentioned lack of similar studies in the literature. Although it indicates the theme is innovative and that there are several aspects that can still be explored, it also brings about an uncertainty on how to advance the art with the necessary academic rigour.

The second aspect is the need for adaptation when facing obstacles. The COVID-19 pandemic has severely affected people from all over the world. The social distancing, one of the strategies to avoid the pandemic to spread, compelled many researchers to change their studies. Particularly with respect to this study, it was necessary to discontinue the use of physiological sensors as an instrument of data collection and investigate the other components in order to the social distance fomented all around the world. Thus, another instrument of collection had to be studied and added in the middle of the research so we would not loose one of the most important aspects of this work: the importance of collecting emotional data from different components.

Finally, it is desirable that this research project demonstrates the importance of UI adaptation – specially in a context where our daily lives are increasingly connected to technology – and the necessity that this field continues to be studied and developed.

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Apendice A

RULES

The rules developed for UIFlex 2.0 followed the scheme presented by Proença and Neris (2017), which are presented on Algorithm 3.1 presented at Chapter 3, Section 3.3. However, due to changes on the content of the rules, they now contain the following characteristics: id, name, description, action, type and value.

For UIFlex 2.0, seven rules were added to the previous database.

Listing A.1: Rule 39

```
Rule 39
Name: Red, Orange, Yellow Transition
Description: Transition Rule associated to octants 7, 8 and 1
from the Semantic Emotional Space
Action: include
Type: css
Value: "body,header animation: 12s multicolor forwards
@keyframes multicolor
    0% background-color: current-background-color;
    45% background-color: #E90000;
    66% background-color: #EC5F00;
    100% background-color: #E6DB00;"
```

Source: Elaborated by the authors.

Listing A.2: Rule 40

```
Rule 40
Name: Dark Bue, Purple, Dark Green, Gray Transition
Description: Transition Rule associated to octants 3 and 4
from the Semantic Emotional Space
Action: include
Type: css
Value: "span,h1,h2,h3,h4,a,p,em,text,div,th,td,table animation: 12s
    multicolor_fonte forwards
body,header animation: 12s multicolor forwards
@keyframes multicolor
    0% backgroundcolor: current-background-color;
    45% background-color: #262C7F;
    66% background-color: #5E1E66;
    80% background-color: #267F3F;
    100% background-color: #6F6F6F;
@keyframes multicolor_fonte
    0% color: current-color;
    100% color:#BAF73C;"
```

Source: Elaborated by the authors.

Listing A.3: Rule 41

```
Rule 41
Name: Light Blue, Lilac, Light Green Transition
Description: Transition Rule associated to octants 5 and 6
from the Semantic Emotional Space
Action: include
Type: css
Value: "body,header animation: 12s multicolor forwards
@keyframes multicolor
    0% background-color: current-background-color;
    45% background-color: #5A95F2;
    66% background-color: #C35BEF;
    100% background-color: #7BEF5B;"
```

Source: Elaborated by the authors.

Listing A.4: Rule 42

```
Rule 42
Name: Yellow, Orange, Red Transition
Description: Transition Rule associated to octants 7, 8 and 1
from the Semantic Emotional Space
Action: include
Type: css
Value: "span,h1,h2,h3,h4,a,p,em,text,div,th,td,table animation: 12s
    multicolor_fonte forwards
body,header animation: 12s multicolor forwards
@keyframes multicolor
    0% backgroundcolor: current-background-color;
    45% background-color: #E6DB00;
    66% background-color: #EC5F00;
    100% background-color: #E90000;
@keyframes multicolor_fonte
    0% color: current-color;
    100% color:#FFEE00;"
```

Source: Elaborated by the authors.

Listing A.5: Rule 43

```
Rule 43
Name: Gray, Dark Green, Purple, Dark Blue Transition
Description: Transition Rule associated to octants 3 and 4
from the Semantic Emotional Space
Action: include
Type: css
Value: "span,h1,h2,h3,h4,a,p,em,text,div,th,td,table animation: 12s
    multicolor_fonte forwards
body,header animation: 12s multicolor forwards
@keyframes multicolor
    0% backgroundcolor: current-background-color;
    45% background-color: #6F6F6F;
    66% background-color: #267F3F;
    80% background-color: #5E1E66;
    100% background-color: #262C7F;
@keyframes multicolor_fonte
    0% color: current-color;
    100% color:#BAF73C;"
```

Source: Elaborated by the authors.

Listing A.6: Rule 44

```
Rule 44
Name: Light Green, Lilac, Light Blue Transition
Description: Transition Rule associated to octants 5 and 6
from the Semantic Emotional Space
Action: include
Type: css
Value: "body,header animation: 12s multicolor forwards
@keyframes multicolor
    0% background-color: current-background-color;
    45% background-color: #7BEF5B;
    66% background-color: #C35BEF;
    100% background-color: #5A95F2;"
```

Source: Elaborated by the authors.

Listing A.7: Rule 45

```
Rule 45
Name: Black Transition
Description: Transition Rule associated to octant 2
from the Semantic Emotional Space
Action: include
Type: css
Value: "span,h1,h2,h3,h4,a,p,em,text,div,th,td,table animation: 12s
    multicolor_fonte forwards
body,header animation: 12s multicolor forwards
@keyframes multicolor
    0% backgroundcolor: current-background-color;
    100% background-color: #000000;
@keyframes multicolor_fonte
    0% color: current-color;
    100% color:#FFFFFF;"
```

Source: Elaborated by the authors.

Apendice B

TABLES

Table B.1: IES Data From All Participants During the Reading Task.

ID	I.E.S. (subj. feel.)	I.E.S. (motor exp.)	I.E.S. (mode)	I.E.S (mean)
1	2,3,4	4	4	4
2	1,2	6	1,2,6	3
3	1,2,4,5,7,8	3	1,2,3,4,5,7,8	4
4	2,5,8	8	8	8
5	6	4	4,6	5
6	7,8	8	8	8
7	1	4	1,4	2,5
8	1,5,6,8	4	1,4,5,6,8	4
9	7,8	4	4,7,8	6
10	1,4,6	8	1,4,6,8	4
11	6	4	4,6	5
12	3	8	3,8	5
13	1,6	3	1,3,6	3
14	2	4	2,4	3
15	8	4	4,8	6
16	8	7	8,7	7
17	6	4	6,4	5
18	7	2	7,2	4
19	8	5	5,8	6
20	7	8	7,8	7
21	7	8	7,8	7
22	1,4,7	7	7	7
23	7	4	4,7	5,5
24	3	2	2,3	2,5
25	2,3	8	2,3,8	4
26	5	7	5,7	6
27	2	8	2,8	5
28	5,6	4	4,5,6	5
29	7	7	7	7
30	7	8	7,8	7
31	1,8	4	1,4,8	4
32	1,3,4,6	7	1,3,4,6,7	4
33	1,4	4	4	4
34	6,7,8	7	7	7
35	6,7,8	2	2,6,7,8	5
36	2,5,8	4	2,4,5,8	4
37	6	7	6,7	6
38	6,7,8	4	4,6,7,8	6
39	2	5	2,5	3,5
40	5,7,8	5	5	5
41	1,4,6	5	1,4,5,6	4
42	5,7,8	7	7	7
43	2,5,8	8	8	8
44	1,3,6	8	1,3,6,8	4

Table B.2: IES Data From All Participants During the Reading Task.

ID	I.E.S. (subj. feel.)	I.E.S. (motor exp.)	I.E.S. (mode)	I.E.S (mean)
1	1,3,4	4	4	4
2	3	6	3,6	3
3	1,4,5,6,7,8	4	4	4
4	2,5,8	8	8	8
5	1,4,5,6,7,8	4	4	7
6	3,6	8	3,6,8	5
7	7	4	4,7	5
8	7	4	7,4	5
9	7	7	7	7
10	1,4,7	4	4	4
11	2	6	2,6	4
12	2	8	2,8	5
13	4,5	2	2,4,5	3
14	2	4	2,4	3
15	2,5,7	5	5	5
16	3	7	3,7	5
17	2,3,4	6	2,3,4,6	3
18	7	5	5,7	6
19	8	5	5,8	6
20	4,7	4	4	4
21	6,7,8	5	5,6,7,8	6
22	7	7	7	7
23	7	4	4,7	5,5
24	5,8	4	4,5,8	5
25	3,5,8	8	8	8
26	3,5,8	7	3,5,7,8	5
27	3	8	3,8	5
28	7	4	7,4	5
29	2,5,7	7	7	7
30	2	5	2,5	3
31	7	4	4,7	5
32	7	7	7	7
33	1,4	8	1,4,8	4
34	6,7,8	8	8	8
35	7	4	4,7	5,5
36	3	8	3,8	5
37	2,3,5,6	7	2,3,5,6,7	4
38	6	4	4,6	5
39	1,3,6	4	1,3,4,6	3
40	7	7	7	7
41	2,3,4,5	6	2,3,4,5,6	4
42	6,7,8	7	7	7
43	7	7	7	7
44	1,2,4,5	4	4	4

Table B.3: D.E.S. and F.E.S. of the participants of both placebo and control on the reading task.

ID	Placebo? (UIFlex 3.0)	D.E.S	F.E.S	Do D.E.S. and F.E.S. match?
1	N	6,7,8	7	Y
2	Y	5,6	2,5,8	Y
3	Y	6,7	7	Y
4	N	7	6	N
5	N	7,8	3,7	Y
6	Y	7	1,4,7	Y
7	Y	7	7	Y
8	N	7	6	N
9	N	5,6,8	1,4,7	N
10	N	6	1,4,7	N
11	Y	5,7,8	7,8	Y
12	Y	6	7	N
13	N	8	2	N
14	N	7	2,5,8	N
15	N	5	2,5,8	Y
16	N	7	6	N
17	N	5,7,8	3	N
18	N	8	7	N
19	N	6	3,6,8	Y
20	Y	6,7,8	6	Y
21	Y	6,7,8	6,7,8	Y
22	N	6,7,8	5,7,8	Y
23	Y	6,7,8	7	Y
24	Y	6,7,8	6,7,8	Y
25	Y	7	3	N
26	N	7	7	Y
27	N	1,4,5,6,7,8	2	N
28	N	6,7,8	6,7,8	Y
29	N	5,8	6	N
30	N	7	5	N
31	Y	6,7,8	7	Y
32	Y	6,7,8	1,4,6,7	Y
33	Y	2,7	5,7,8	Y
34	N	6,7,8	6,7,8	Y
35	N	6,7,8	6,7,8	Y
36	Y	1	3	N
37	N	8	5,7,8	Y
38	N	6,7,8	6,7,8	Y
39	Y	6,7,8	1,3,6	Y
40	N	1,8	2,7,8	Y
41	Y	7	1,2	N
42	N	6,7,8	5,7,8	Y
43	Y	1,8	8	Y
44	Y	7,8	1,3,6	N

Table B.4: D.E.S. and F.E.S. of the participants of both placebo and control on the transcription task.

ID	Placebo? (UIFlex 3.0)	D.E.S	F.E.S	Do D.E.S. and F.E.S. match?
1	N	6,7,8	2,3,4	N
2	S	6,7,8	4	N
3	S	6	6	Y
4	N	7	1,4,6	N
5	N	5,6,7,8	7	Y
6	S	1,8	8	Y
7	S	8	5,7,8	Y
8	N	5,6	5,7,8	Y
9	N	5,6,7,8	7,8	Y
10	N	1,6,7	1,4,6	Y
11	S	7,8	2,4,7	Y
12	S	6,7,8	7	Y
13	N	1,8	6,7,8	Y
14	N	7	1,4,6	N
15	N	5	5	Y
16	N	6	6	Y
17	N	5,7,8	2	N
18	N	4,7	5,7,8	Y
19	N	1,6	7	N
20	S	6	4	N
21	S	6,7,8	5,7,8	Y
22	N	6,7,8	5,7,8	Y
23	S	7	7	Y
24	S	6,7,8	7	Y
25	S	7	7	Y
26	N	5,7,8	2,5,8	Y
27	N	7	3	N
28	N	6,7,8	6,7,8	Y
29	N	7	1,4,6	N
30	N	1,5,6,8	5,8	Y
31	S	6,7,8	8	Y
32	S	6,7,8	6	Y
33	S	1,2,4,7	5,7,8	Y
34	N	6,7,8	6,7,8	Y
35	N	1	7	N
36	S	7	1,4,6	N
37	N	8	5	N
38	N	6	6,7,8	Y
39	S	7	1,4,6	N
40	N	6,7,8	6,7,8	Y
41	S	7	1,4,6	N
42	N	6,7,8	5,7,8	Y
43	S	7	8	N
44	S	3,8	1,3,6	Y

Table B.5: Comparison between I.E.S. data collected and D.E.S. data truncated during reading task.

ID	Placebo?	I.E.S.	D.E.S. (trunc)	Was there a change on interface elements?
1	N	3	7	Y
2	Y	2	5	N
3	Y	8	6	N
4	N	4	7	Y
5	N	6	7	Y
6	Y	6	7	N
7	Y	2	7	N
8	N	8	7	N
9	N	6	6	N
10	N	4	6	Y
11	Y	7	6	N
12	Y	5	6	N
13	N	3	8	Y
14	N	3	7	Y
15	N	6	5	N
16	N	8	7	N
17	N	7	6	Y
18	N	6	8	Y
19	N	6	6	N
20	Y	5	7	N
21	Y	5	7	N
22	N	7	7	N
23	Y	5	7	N
24	Y	4	7	N
25	Y	4	7	N
26	N	6	7	Y
27	N	1	7	Y
28	N	6	7	Y
29	N	7	6	Y
30	N	8	7	N
31	Y	4	7	N
32	Y	4	7	N
33	Y	4	4	N
34	N	6	7	Y
35	N	6	7	Y
36	Y	8	1	N
37	N	6	8	Y
38	N	6	7	Y
39	Y	1	7	N
40	N	5	4	Y
41	Y	3	7	N
42	N	7	7	N
43	Y	8	4	N
44	Y	4	7	N

Table B.6: Comparison between I.E.S. data collected and D.E.S. data truncated during transcript task.

ID	Placebo?	I.E.S.	D.E.S. (trunc)	Was there a change on interface elements?
1	N	4	7	Y
2	Y	5	7	N
3	Y	5	6	N
4	N	8	7	N
5	N	7	6	Y
6	Y	5	4	N
7	Y	7	8	N
8	N	7	5	Y
9	N	6	6	N
10	N	7	7	N
11	Y	4	7	N
12	Y	1	7	N
13	N	3	7	Y
14	N	3	3	N
15	N	4	5	Y
16	N	3	6	Y
17	N	3	2	Y
18	N	6	6	N
19	N	4	7	Y
20	Y	7	4	N
21	Y	6	6	N
22	N	5	6	N
23	Y	7	7	N
24	Y	8	7	N
25	Y	8	7	N
26	N	5	5	N
27	N	4	3	N
28	N	7	7	N
29	N	7	3	Y
30	N	1	6	Y
31	Y	7	8	N
32	Y	7	6	N
33	Y	4	6	N
34	N	8	7	N
35	N	7	7	N
36	Y	4	3	N
37	N	4	5	Y
38	N	5	7	N
39	Y	1	7	N
40	N	7	7	N
41	Y	3	7	N
42	N	7	7	N
43	Y	7	7	N
44	Y	3	5	N

Table B.7: Placebo - Reading task.

ID	I.E.S.	F.E.S	Are I.E.S. and F.E.S. different?
2	2	2,5,8	N
3	8	7	Y
6	6	1,4,7	Y
7	2	7	Y
11	7	7,8	N
12	5	7	Y
20	5	6	Y
21	5	6,7,8	Y
23	5	7	Y
24	4	6,7,8	Y
25	4	3	Y
31	4	7	Y
32	4	1,4,6,7	N
33	4	5,7,8	Y
36	8	3	Y
39	1	1,3,6	N
41	3	1,2	Y
43	8	8	N
44	4	1,3,6	Y

Source: The authors.

Table B.8: Placebo - Transcription task.

ID	I.E.S.	F.E.S	Are I.E.S. and F.E.S. different?
2	5	4	Y
3	5	6	Y
6	5	8	Y
7	7	5,7,8	N
11	4	2,4,7	N
12	1	7	Y
20	7	4	Y
21	6	5,7,8	Y
23	7	7	N
24	8	7	Y
25	8	7	Y
31	7	8	Y
32	7	6	Y
33	4	5,7,8	Y
36	4	1,4,6	N
39	1	1,4,6	N
41	3	1,4,6	Y
43	7	8	Y
44	3	1,3,6	N

Table B.9: Incidence of IES x MES on Reading Task

(a) Placebo Group.

		M.E.S.							
		1	2	3	4	5	6	7	8
I.E.S.	1	0	0	0	0	0	0	0	0
	2	0	0	0	0	1	0	0	1
	3	1	0	0	0	0	1	0	0
	4	0	0	1	1	3	0	1	2
	5	0	0	0	1	0	0	1	1
	6	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	2
	8	0	0	0	0	0	0	0	2

Source: The authors.

(b) Control Group.

		M.E.S.							
		1	2	3	4	5	6	7	8
I.E.S.	1	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0
	3	0	0	1	1	0	0	0	0
	4	0	0	0	1	1	0	1	1
	5	0	0	1	0	0	0	1	2
	6	1	0	1	1	1	0	2	2
	7	0	0	0	0	1	0	3	2
	8	0	0	0	0	0	0	0	1

Source: The authors.

Table B.10: Incidence of IES x MES on Transcript Task

(a) Placebo Group

I.E.S. \ M.E.S.	1	2	3	4	5	6	7	8
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	1
3	1	0	0	0	0	0	1	0
4	0	0	1	0	1	0	0	3
5	0	0	0	4	0	0	0	3
6	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	1
8	0	0	0	1	0	0	0	0

Source: The authors.

(b) Control Group

I.E.S. \ M.E.S.	1	2	3	4	5	6	7	8
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	1	1	1	0	1	0
4	0	0	0	1	0	0	2	0
5	0	0	2	1	1	0	2	2
6	0	0	0	0	1	0	0	1
7	0	0	0	0	1	0	5	1
8	0	0	0	0	0	0	0	2

Source: The authors.

Table B.11: Incidence of MES x FES on Reading Task

(a) Placebo Group.

M.E.S. \ F.E.S.	1	2	3	4	5	6	7	8
1	1	0	1	0	0	1	0	0
2	0	0	0	0	0	0	0	0
3	1	0	1	0	0	1	0	0
4	0	0	1	0	0	0	1	0
5	1	1	0	0	1	1	3	2
6	1	0	0	0	1	0	0	1
7	1	0	0	1	0	1	2	0
8	1	0	1	1	0	2	5	3

Source: The authors.

(b) Control Group.

M.E.S. \ F.E.S.	1	2	3	4	5	6	7	8
1	0	1	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	2	0	0	1	1	1	2
4	0	1	0	0	1	2	1	2
5	0	0	1	0	1	1	1	1
6	0	0	0	0	0	0	0	0
7	0	0	1	0	3	1	6	3
8	2	1	1	2	0	4	5	3

Source: The authors.

Table B.12: Incidence of MES x FES on Transcript Task

(a) Placebo Group

M.E.S. \ F.E.S.	1	2	3	4	5	6	7	8
1	1	0	0	1	0	1	0	0
2	0	0	0	0	0	0	0	0
3	1	0	1	0	0	1	0	0
4	0	0	0	0	2	0	5	3
5	1	0	0	1	0	1	0	0
6	0	0	0	0	0	0	0	0
7	0	0	0	1	0	1	0	0
8	1	1	0	3	1	2	3	3

Source: The authors.

(b) Control Group

M.E.S. \ F.E.S.	1	2	3	4	5	6	7	8
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	1	1	2	1
4	1	1	1	2	1	2	1	1
5	0	0	0	0	1	1	2	2
6	0	0	0	0	0	0	0	0
7	2	2	0	2	4	4	4	4
8	1	0	1	1	1	3	4	4

Source: The authors.

Table B.13: Incidence of DES x FES on Reading Task

(a) Placebo Group.

F.E.S. \ D.E.S.	1	2	3	4	5	6	7	8
1	0	0	0	0	0	2	5	3
2	0	0	0	0	1	1	1	0
3	1	0	0	0	0	1	3	2
4	0	0	0	0	0	1	2	1
5	0	1	0	0	1	1	1	0
6	0	0	0	0	0	5	6	6
7	0	1	0	0	1	7	10	6
8	1	1	0	0	2	3	4	4

Source: The authors.

(b) Control Group.

F.E.S. \ D.E.S.	1	2	3	4	5	6	7	8
1	0	0	0	0	1	2	0	1
2	2	0	0	1	2	1	2	3
3	0	0	0	0	1	1	2	2
4	0	0	0	0	1	2	0	1
5	0	0	0	0	1	2	3	2
6	0	0	0	0	1	2	4	2
7	1	0	0	0	1	5	6	8
8	1	0	0	0	1	4	4	4

Source: The authors.

Table B.14: Incidence of DES x FES on Transcript Task

(a) Placebo Group

F.E.S. \ D.E.S.	1	2	3	4	5	6	7	8
1	0	0	0	0	0	0	4	1
2	0	0	0	0	0	0	1	1
3	0	0	0	0	0	0	1	1
4	0	0	0	0	0	2	5	2
5	1	1	0	1	0	1	2	2
6	0	0	0	0	0	2	5	2
7	1	1	0	1	0	3	7	5
8	3	1	0	1	0	2	3	5

Source: The authors.

(b) Control Group

F.E.S. \ D.E.S.	1	2	3	4	5	6	7	8
1	1	0	0	0	0	1	4	0
2	0	0	0	0	2	1	3	3
3	0	0	0	0	0	1	2	1
4	1	0	0	0	0	2	5	1
5	1	0	0	1	4	4	4	5
6	2	0	0	0	0	6	7	4
7	3	0	0	1	3	10	8	8
8	2	0	0	1	4	9	8	9

Source: The authors.