Mood Adaptive Display Coloring - Utilizing Modern Machine Learning Techniques and Intelligent Coloring to Influence the Mood of PC Users

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***Abstract*—Humans are able to recognize a wide range of colors and interpret them in many different ways. Besides obvious effects like highlight and beautification, these colors can influence the emotional state of humans in a significant way. While this is no new information and color psychology is a heavily discussed topic in the psychological area, few research has been conducted in the human computer interaction area of this topic. Heavily relying on color in user interfaces of any kind the emotional aspect is often ignored and unwritten rules are applied. The gaming field provides many examples for such rules with red explosives and blue mana. Breaking with this trend, we present a novel mood adaptive display coloring approach. Utilizing psychological studies and state of the art machine learning technologies an intelligent coloring system is implemented. It is able to directly influence the emotion of human users, combating negative emotions and supporting positive feelings. Further a completely functional prototype is implemented. While fully working, there is much work left to refine and improve the project in this heavily neglected area.**

Keywords*—*Advanced Human Computer Interaction; Mood Adapting Coloring; Adaptive Display Coloring; Color Psychology; Emotion Recognition.

I. Introduction

Colors have been an important part of Human Computer Interaction (HCI) since the introduction of multi color displays. Nowadays, it is impossible to imagine software without them, the old default black and white is only used as a stylistic instrument. Even hardware is often produced with ambient lighting as a selling point. Colors are used as an important part of designs for Graphical User Interfaces (GUIs) in software like games, operating systems (OS) and business applications, helping players to get the required overview or leading workers through complex procedures with intelligent coloring.

However, the possibilities of colors do not end with highlighting certain things and improving the quality of life therefore, they can also be used to directly affect the user. Understanding the influence of color on the human user, clever coloring can increase the performance of a worker or calm him down during a difficult period. Such techniques can not only boost the productivity and improve emotional state, they can also have a beneficial effect on the health of users.

Color psychology is a highly disputed topic and the opinions heavily diverge about the facts and scientific evidence. However, thanks to this popularity of the topic much research is conducted in this area, allowing a solid foundation for further research in the HCI environment.

Using state of the art technologies, like facial recognition systems or intelligent devices such as smart watches, the mood of a user can already be recognized and measured quite precisely. The resulting information can be used to classify the emotions and start processes to reinforcing or combating these.

In this work, we introduce a novel approach to interact with users through decent adaptive coloring, providing emotional support and the best conditions to successfully master their current task. This is achieved through Mood Adaptive Display Coloring (MAD-Coloring), a framework to change the color of the display while exposing a generic API for clients to control the color according to the mood of the user. Further two simple clients will be implemented. While one of them provides a minimal boilerplate for further implementations, the second one utilizes state of the art machine learning techniques to recognize mood changes and provide the best suited coloring solution for the detected mood state.

The remainder of this paper is structured as follows: Section II provides background information for a better understanding of the work and introducing required secondary research. Section III describes the general concept of MAD-Coloring, while Section IV explains the currently implemented state of MAD-Coloring. Section V provides an overview of related works. Finally Section VI concludes the paper and lists further research options.

II. Background

This section outlines the elementary information about color psychology and display coloring frameworks, as well as face recognition basics and a survey about the emotional effect of color, conducted during this work.

A. *Color Theory and Psychology*

While color is often accepted as an omnipresent thing without further questioning, it is actually a well defined construct which can be described accurately with its three components: hue, saturation and brightness. The emotional effect of color is closely linked to all three of those, therefore an adjustment of one of its values can lead to a completely different emotional reaction. This means e.g., a green with high brightness and

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saturation has a different emotional effect than a green with the same hue and saturation but low brightness.

Even though color psychology is highly disputed down to its fundamental theories, it is possible to elaborate some general statements which are used in this work. While many animals only see different shades of grey and some can even see with infrared or ultraviolet vision, humans have settled in the middle with a complex color perception. This has lead to the development of a society where colors play an important role in the day to day life, religion, work and freetime. Most people have a favorite color, and every kid, regardless of their origin, knows the red cross, star or moon provides them with help if needed.

While most humans see color the same way, it has quite different meanings for them. The context in which a color is experienced and from whom is fundamental for its interpretation. Age is an important factor, as studies prove, that children have different associations with certain colors than adults or elder people. Gender can also play a decisive role [1][2][3].

Elliot and Maier laid the theoretical base for contextual color psychology with their work in 2012 [1], highlighting six key properties of the psychological impacts of color:

- There might be psychological relevant associations with a color.
- Presentation colors might influence psychological operations, including but not limited to basic impulses such as attraction and avoidance.
- Associations with colors might trigger affective, cognitive or behavioral reactions. This happens subconscious or without intention.
- Color meanings and associations are influenced by both trained and inherited behavior.
- The relation between color perception and association is bidirectional. color perception has an impact on psychological processes and psychological processes have an impact on the way color is perceived.
- The psychological effect of color heavily depends on the context. The context is so important, that the influence of the same color might result in opposite effects for different contexts.

Those core statements are used by other research (e.g., [2]) in the field of color psychology and should be considered when targeting a psychological effect utilizing colors.

Li [3] gives a detailed overview over the preferences and effects with different groups of people in a medical context, more precisely during hospital stays. Children prefer brightly saturated colors and overall very colorful environments. These provide distraction from the tense situation and a calming effect, connected to the coloring, could be proven. Adults on the other hand tend to favor clean, cool colors like white, blue and grey. They associate these with a professional environment and thus a higher chance of a successfully treatment. There is also a connected calming effect. However, the effect is achieved through the impression of a professional environment, that evokes the feeling of a qualified treatment when seeking medical care. It is therefore only partially connected to the color and already an effect of the original feeling emitted by the color: professionalism. The author further states, that elder people tend to prefer warmer colors, although not as bright and less saturated than children. These colors help them to relax and effectively reduce anxiety. The professional, cool colors like white or grey even provide a negative effect on elders and sometimes children. This originates from the partly occurring associated with anxiety, loneliness and fear. The phenomenon is known in the color psychology as white scare.

Focusing on the target-context oriented effect of color, Maier et al. outline how the psychological impact of a color changes with the task domain [4]. Stated are the findings of different studies which point out that colors provide a performance enhancing effect in physical competitions. An example for this can be found in sports, where teams wearing red tricots win more games than those wearing any other hue. However, when it comes to an intellectual target-context the color red seems to have no, or even a negative effect, on the performance.

B. *Emotion Recognition*

Facial and Image Recognition is currently one of the most popular fields of machine learning. Elementary face detection is not a technical challenge anymore and a camera input can be analysed in realtime, with only a few dozen lines of code (e.g., [5]).

The popularity of such use cases provides us with the base for emotion recognition through feature detection in the mimic of peoples faces. Combining this technology with display coloring frameworks allows us to design systems which are capable of autonomously detecting emotions and correctly using different color overlays to improve and reinforce them.

Several models have been trained with a fairly high accuracy to detect emotion from images. These models focus on a combination of facial features to detect the emotional state behind pictures of faces. The model of Yang et al. [6] relies on the extraction of the mouth and eyes, achieve successful detection rates of up to 93% for certain emotions and a mean of 87%.

As emotions have a broad impact on the users behavior the detection is not only limited to image recognition. For a precise detection of emotions multiple sources of information can be used. Ghosh et al. suggests an approach to determine emotion based on speech recognition [7]. By combining multiple ways of emotion recognition detection accuracy can be improved even further. However, a background software with recording capabilities is rather problematic from a privacy point of view. Therefore, the improved recognition accuracy does not outweigh the privacy violation.

Other possibilities to increase the accuracy and therefore the value of automatic emotion detection could be provided by smart wearables like smart watches or fitness trackers. Measurements like the pulse could then be used to determine the stress level and provide other valuable insights. However, as the prototype should be as lean as possible this approach

TABLE I. EMOTIONAL CONNECTION TO COLORS SURVERY, RESPONDENTS = 522, VALUES IN %

Color	Ca	V	Sa	Co	M	St	H
red	3,79	14,86	13,38	7,32	9,37	**35,20**	8,45
orange	8,24	**19,41**	**18,09**	6,02	3,02	16,94	13,49
yellow	3,53	**21,15**	7,21	8,95	3,78	14,31	17,53
green	**22,09**	**18,34**	**15,44**	15,49	2,27	2,96	**24,72**
blue	**25,23**	9,64	**16,32**	**28,74**	7,55	4,77	14,25
violet	11,37	3,35	11,32	5,34	11,48	5,76	6,56
grey	11,11	0,40	5,44	13,08	**27,49**	3,95	2,27
black	12,81	2,68	10,29	13,43	**29,61**	6,74	4,41
pink	1,83	10,17	2,50	1,72	5,44	9,38	8,32

is not further considered in this work. The required multi machine solution with means of communication between devices would cause a too excessive codebase for the aspired simple prototype.

C. Emotional Effects of Colors - a Survey

As our excessive study of related research projects and studies could not provide a common interpretation of the concrete connection between emotions and colors, a simple survey was conducted. This survey however is only used to generate a default profile for the prototype, it is not scientifically representative. In the survey 522 people were asked to think of a color if confronted with an emotion. Multiple answers were allowed, this should allow the detection of patterns, e.g., all warm colors are connected with emotion X. The emotions which could be chosen in the survey were (Ca)lm, (V)italising, (Sa)fety, (Co)ncentrated, (M)elancholy, (St)ressed and (H)appieness. The possible answers consisted of colors which can easily be displayed on a display and provide strong contrasts to each other, allowing a meaningful implementation.

The surveys findings match well with the general statements from Rider [2]. While warmer colors (orange, yellow) have an arousing effect, cooler colors (blue, green) have a relaxing, calming effect. Rider further mentions the wide spread of possible emotions connected to green depending on brightness, saturation and context. As we only asked for the hue the subjects could not differentiate between different types of green. Therefore, green is strongly connected with most positive emotions, which, however, most likely refer to different types of green.

The survey results also concur with the findings of Kido [8], reinforcing the calming effect of green and blue. The deafening effect of red, determined by Kido, also matches the very strong association with stress by our survey.

The strong association of orange with safety, which cannot be found in other studies or surveys, most likely is caused by a bias of our survey. The poll was conducted on a group of people from the same community, where orange is a frequent and positively interpreted color, which could explain this behavior.

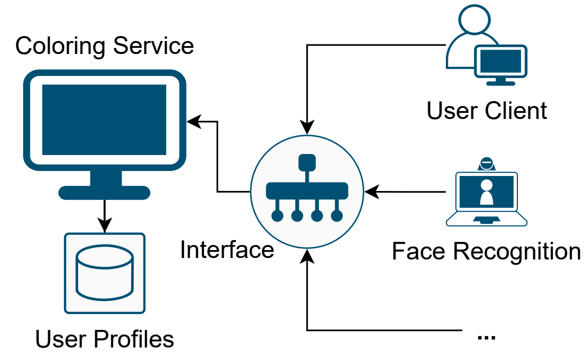

Figure 1. MAD-Coloring modular architecture concept.

D. Display Overlays

Display overlays are no new research topic and many refined products are available. In the gaming area they are omnipresent with the most popular example being steams ingame-overlay, other popular examples being the Nvidia Geforce Experience overlay, the Discord overlay or Overwolf. However, these are all limited to the gaming use cases and only Overwolf allows great modification freedom.

Other overlays with more modification freedome include OnTopReplica, Hudkit and pqiv. The pqiv image viewer is able to display transparent pictures and can easily be placed on top of other windows. Due to its implementation in Python, cross platform capabilities are provided. Missing click through support however requires extensive extension work to create a functional non blocking overlay.

OnTopReplica, a C# project, supports the display of selected windows on top of others on Windows systems. While it supports click through and adjustable opacity, it is limited to Windows and requires an additional overlay-window. This not only decreases the compatible systems but also increases the overhead significantly.

Hudkit is a C based framework with an exposed JavaScript-API [9]. The framework supports all Linux X-desktops and some OS X systems. It's main HTML page can be modified like Overwolf overlays using HTML and JavaScript. The page can then receive new input via established APIs like Websocket or WebGL and change the display accordingly. Multiple monitors and click through events are supported by default. Providing a powerful small footprint framework.

III. SOLUTION CONCEPT

This section provides insights in the architecture and concept for the MAD-Coloring prototype. The modular architecture approach is shown in Fig. 1.

The architecture is separated in 3 sections. The coloring service, the clients accessing and controlling the coloring and the interface, enabling communications between the clients and the display coloring.

The display coloring has to be able to project a color adjustable overlay on top of all connected monitors. To fully leverage the psychological effects the overlay must not be limited to gamma or brightness adjustments but must be able to display any color. The display must not reduce the productivity and therefore has to enable all actions which are possible without an overlay, e.g., right/left clicking or text selection. Further, the vision quality and readability of displayed content must not be reduced any further than necessary. This will be compared against the light constraints coming with night lights, e.g., reduced contrast and slightly changed colors. The coloring service further gets supplied with at least one user profile file. This allows users to adjust the color optimally for themselves and maximize the effect of MAD-Coloring.

The communication between clients and coloring should be kept as simple as possible to fit into the modular approach. This should enable easy access to the coloring service for new clients as well as the replacement of the Coloring implementation itself, e.g., if required by a change of the OS. To achieve this a simple interface should be created, supplying all required functionality for the coloring and client programms. New implementations could then simply use this interface and would be able to be used with the old clients/Coloring. This further enables the exchange of the communication framework with changes to only the interface itself. Clients and coloring would not be affected and could be used without any changes. The underlying communication framework should be chosen OS specific and use existing infrastructure rather than implementing something new. Therefore, reducing the implementation effort, requirements and overhead caused by MAD-Coloring.

Due to the interface, client programms can be created with minimal restrictions. For the prototype two client applications are planed. A manual user client, allowing the selection of moods by the user via text input, and a face recognition background service, detecting the mood via a webcam and changing the display coloring accordingly.

Thanks to the highly adjustable user profiles, changes or fine tuning of the color mapping in the implementation are always possible with little to none programming experience. This allows interested psychologists, therapists and doctors to use the MAD-Coloring on their own. Enabling them to adjust the system according to their own knowledge and research in the area of color psychology, highly tailored to their target group needs. Further, users trying the prototype on their own can adjust their profile as they most see fit, according to their own preferences.

IV. MAD-Coloring

This section gives insight in the implemented MAD-Coloring prototype for Linux systems, as well as the created simple user client and emotion detection client.

A. Interface

The interface is build on top of the D-Bus, as it represents the default solution for inter-process communication of most Linux desktop environments and therefore already is available on the system. This removes the need to install new software frameworks, perfectly fitting into the low overhead architecture of the solution concept.

The interface itself is separated into two parts. The main (top level) interface, providing simple python functions and a bottom level interface consisting of a D-Bus service and a corresponding client.

To ease the use of the interface, and allow easy interchangeability of the underlying system, the the top level interface has been implemented which only exposes the core functionality to client developers. It can be considered as a wrapper around the bottom level interface, providing the two required functionalities to implement new clients or a coloring service. These is a getter function, which is awaiting a new mood, and a setter function, to set the mood. Clients make use of the setter to specify the mood, while the coloring service uses the getter to detect mood changes originating from the clients.

While the top level interface is rather simple, the bottom-line D-Bus communication is more extensive. The D-Bus service specified by it exposes an interface with three methods on the D-Bus session bus. However, only one of the three methods is currently used in the top level interface, a setter for the mood. The other methods provide a getter for the currently active color code and the possibility to change the user profile on the fly, providing a boilerplate for coming extensions. For the top level interface setter function a connection to the exposed D-Bus interface is opened and the provided bottom level interface setter method is used to send the color change via the D-Bus.

It is up to the client if the communication is done via interface provided in this work or directly via the D-Bus. On the one hand the baseline D-Bus service provides a richer API and might be used with any programming language or due to some universal command line interface tools. On the other hand however using the Python interface instead is less complex and allows an easy exchange of the underlying D-Bus framework, which might be required due to the change of the OS. Requiring only the getter and setter pair at the top level interface allows an easy exchange of the base interface, as the new framework must only realize this two functions. When sticking to Linux Desktops the D-Bus provides more extensive functionality and grants the exchange of the programming language, but the provided python interface grants interchangeability of OS and base interface. Choosing the right interface is up to the developer and should be decided individually according to the needs of the implementation.

B. User Profiles

The profiles are implemented as .conf files. Using this well known and easy to use standard allows the modification of these files without any knowledge of programming. This is important, as for now the prototype provides no GUI to edit the user profiles and the users have to edit their profiles with a text editor on their own.

In the scope of the prototype, a default configuration is provided. The emotions and their respective coloring are

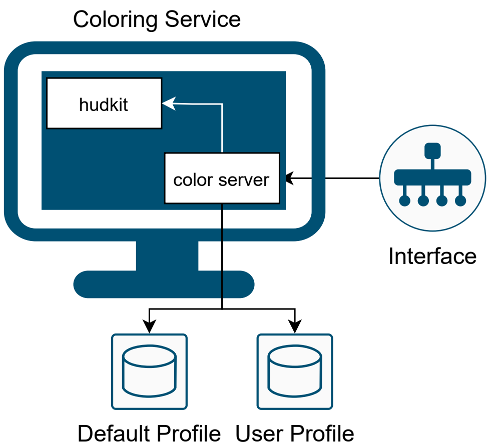

Figure 2. MAD-Coloring color service.

according to the survey in Section II. If the user wants to change the color of an emotion she can either change the default profile or create a new user profile. Following an override approach, the coloring service will always check the specific user profile first, if the emotion is not included the service will fallback to the default profile. This makes it quite comfortable to specify some custom mood/color pairs, while keeping default settings for most.

It is also possible to define new emotion/color pairs in the user profiles, wich are not defined in the default profile. However, in order to be used by the clients the emotions have to be added to their codebase as well.

C. Coloring-Service

For the coloring service a combination between a modified version of hudkit, introduced in Section II, and a self-made Python Color server is being used (Fig. 2).

Hudkit handles the display coloring. The color server provides the color services interface and control unit. This is achieved by implementing the earlier introduced Python interface and accessing the user profiles. Utilizing the Python interface, the server listens to changes of the mood send by a client. If a mood change is detected the server resolves the color according to the used profile. First the user specific configuration is read, if no entry for the specific mood is found the default config is read.

After resolving the color, the server sends a signal with the determined color to the hudkit webserver. Should a mood not be defined in the configuration files, the color server defaults to black with low saturation and displays an error. With this error handling a missing emotion does not lead to further problems durring the runtime, but clearly signals the user that a problem with the used client has ocurred. This error color will not be interpreted as an emotion by the user, as black is not used by the default configuration and we highly discourage the usage of black as it is mostly related to negativ emotions (cf. Table I). To counter possible negative emotions associated with black, the low saturation and higher brightness creates a grey overlay

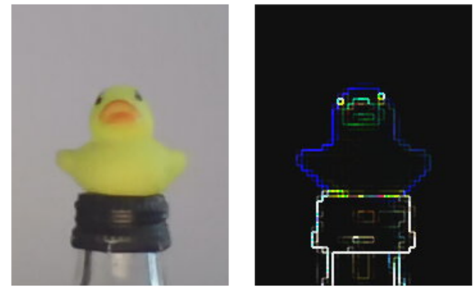

Figure 3. Face detection symbol image - feature highlighting.

in the Hudkit server. This can be interpreted by users as boring, but will not trigger negative emotions.

D. Clients

The prototype includes two clients. A simple user client and a intelligent emotion detection client. The simple client provides a basic GUI to enter the current emotion and change the display coloring accordingly. It is implemented in Python and directly accesses the D-Bus instead of the Python wrapper interface.

The second client is an emotion recognition client, detecting the current emotional state of the user via image processing of a webcam feed. As a foundation the work of Rovai was used, creating a face recognition system utilizing a webcam with Python and OpenCV [5].

However, the final implementation differs fundamentally, as the client was extended to enable emotion recognition and connected to the Python interface to communicate with the coloring service. Further, a multi face detection was implemented, preventing a flickering color change if two or more faces are detected. As a result the client will not send emotional changes to the coloring service, until only one face is left in its field of view. A simplified version of the used feature detection can be found in Fig. 3. The eyes are clearly detected in white and the mouth in green. This allows the usage of the features in the neural network to determine the mood.

V. Case Study

Our current team solely consists of researchers from the IT domain, we have not yet consulted any psychological/medical experts. Thus we conducted a technical case study instead of a psychological evaluation of our prototype. The study was conducted on a Lenovo ThinkPad with 14GB RAM, an AMD onboard graphic chip, using a GNU/Linux operating system with a gnome X.Org desktop. During the test runs checks regarding usability impairments were conducted.

To pre-empt ethical concerns without the approval of an ethic-committee our test user simply controlled MAD-Coloring and rated possible concerns regarding the readability and usability of the desktop with activated MAD-Coloring. However, he was not exposed to the software for longer

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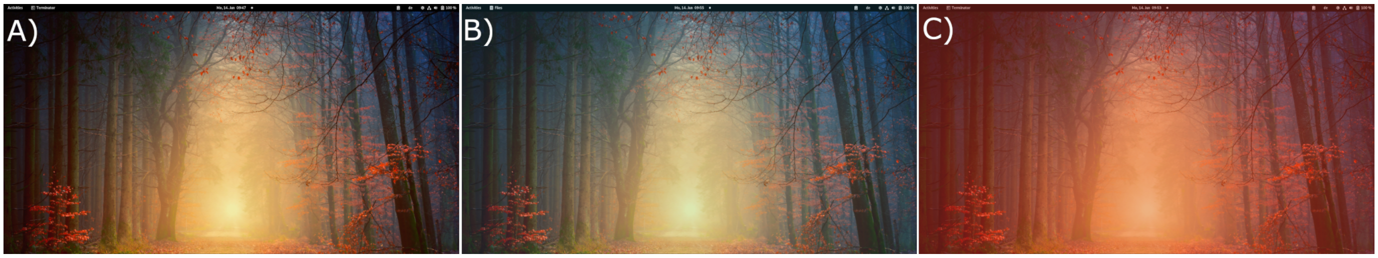

Figure 4. MAD-Coloring in effect for moods A) neutral B) mad C) bored.

periods. The face recognition was triggered with prepared photos instead of live images of the test user.

As a scenario a computer science student with no prior experience of MAD-Coloring was instructed to start the MAD coloring client and conduct a manual color change via the simple user client. Afterwards the face recognition client had to be started. He was supplied with a computer which had a preinstalled MAD-Coloring service and the madservice's linux manual page.

The user was able to activate the service, change the color and start the face recognition client in less than a minute. All color changes and emotion detections worked without any problems. The user did not experience any problems regarding reduced readability, yet the usability in color sensitive applications like image editing was highly impaired because of MAD-Coloring's color overlay. However, this was an expected side effect as mentioned in our solution concept (cf. Section III). The effect of MAD-Coloring for some emotions can be seen in Fig. 4.

Following, we suggest a method for measuring the effects of MAD-Coloring in coming evalutions, which still needs to be reviewed by psychological experts. Since MAD-Coloring is designed to be used in daily routines and any kind of test scenario might cause indifferences, we strongly recommend to evaluate MAD-Coloring integrated in the daily life of subjects.

To quantify MAD-Coloring, we introduce the concept of an mood diary where subjects record their emotional condition, and whether they are able to concentrate for work or not. The subjects might write this mood diary for a reasonable period (2-4 weeks). Afterwards, based on these diaries, basic emotional profiles can be created for all subjects.

In the second phase we recommend to split up the subjects into three groups. Group A will be working with our MAD-Coloring and the preconfigured color profile (based on scientific work from the color psychology domain and our own survey). Group B is working with MAD-Coloring as well, but with "anti"-colors, which have been associated to be negative according to a specific mood (e.g., red if the subject is already mad). Group C is the control group, which continues working without any influence from MAD-Coloring. This phase should be conducted over a larger time period (2-4 months or longer), as most likely some time is required to get used to the color changes. Especially at the beginning these changes could have a negative impact on the subjects.

By comparing the deltas of the three groups the essential effects of MAD-Coloring can be determined and whether the effect depends on specific colors or just generally on shifting these. Afterwards further evaluations can be planned targeted on the existing data.

VI. Related Research

While the idea of color psychology is not new, there is to our best knowledge no closely related research in the HCI context. However, some other research topics in the context can be viewed as relevant.

A. Blue Light Filtering

At the first sight blue light filtering software seems to differ quite significantly from our solution, but the fundamental ideas are quite similar. Both software solutions modify the color shade of the display to obtain effects on the human user. However, blue light filtering is based on different medical effects (cf. [10]) and in most cases it is implemented completely different than MAD-Coloring.

While MAD-Coloring is based on the psychological effect of colors and the emotions triggered by colors, the idea of blue light filtering, as described in [11] is based on physical and bio-chemical effects [12]. They determine that blue light emitted by screens contains more energy than any other color. Further, it is more exhaustive for the human eye than other colors. In addition to the physical aspects blue light suppresses the production of the sleeping hormone melatonin which can cause sleeplessness.

As aforementioned, blue filtering software is often implemented completely different than our solution. Its common among blue filters to adjustments the alpha channel to suppress parts of the blue light. The resource costs for this approach can be expected to be less than those for overlay based filters. This is due by the fact, that the graphics card is not required to compute a translucent overlay in. However, for our MAD-Coloring system an alpha shift approach does not fit the requirements since the software needs to display tints in various colors.

B. Colors and Trust in Userinterface Design

Hawlitschek et al. [13] thematize the influence of colors on the trustworthiness of user interfaces. They analyzed the moods and meanings associated to different colors via an experiment.

In this experiment, the probands had to pass a finance based trust experiment. The were provided with GUIs in different hues and small amount of money was handed to each proband. Then, by transfering money to other probands, they where able to increase the value of their sum by trading between each other. The experiment tried to determine if the color of their GUI had a impact on the trust they have in the other probands. However, they where not able to gain meaningful results from this experiment.

VII. Conclusion

In this paper, the novel MAD-Coloring framework was presented. Respecting the basics of color psychology a small footprint prototype was implemented, providing a transparent, color adjustable overlay for Linux X-desktop systems. Further, two clients were implemented, ready to be use with MAD-Coloring. A simple input client, allowing the manual change of the display color and an emotion recognition client, detecting the users current emotional state via a webcam and adjusting the display color accordingly. Also a Python-API was implemented, easing the creation and integration of new clients.

MAD-Coloring, in combination with this clients, is capable to display a decent, transparent overlay over multiple desktops according to the users current emotion. It can therefore be used by everyone, from people wanting to improve their experience on PCs to therapists working with color psychological approaches with their patients.

While fully functional, further work is required to refine and improve the system. On the one hand, medical studies are required to evaluate the psychological impact of the system and therefore confirming its usefulness. Following this further studies are required to find optimal color profiles to maximize the effect. On the other hand, some technical improvements can be conducted. The coloring service, heavily relying on Hudkit can be further slimed down, reduce the performance footprint to a minimum. Further, the support of more desktop environments could be realized. Finally more clients should be implemented, allowing more specific use cases and optimal support for more kinds if needs. These clients could also use smart devices like watches or fitness tracers, allowing the integration of blood pressure into the emotion recognition.

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