Color Emotions without Blue Light

Effect of a Blue Light Filter on the Emotional Perception of Colors

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Date: February 16, 2023

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Abstract

Blue light filters have become commonplace in modern technology. While there has been a substantial amount of research into their effects on sleep, there has been little into the effect on the media perceived through them. This study sought to examine whether the mechanisms responsible for the adaptation to ambient light conditions would counteract this effect. To do so, a digital survey was conducted in which participants rated 30 colors on 3 different emotional attributes: warmth, weight, and activity. Participants took the survey with or without a blue light filter active, and with or without external light. The external light was intended to eliminate or reduce the level of adaptation to the screen's altered colors. After comparison between the groups, it was revealed that no significant subjective difference appeared between either of the test conditions. However, with external light, there was a difference in perceived warmth with and without the blue light filter. This implies that some sort of adaptation is involved, and is interfered with by qualities of ambient light. The prevalence of these usage conditions is left to future research, as is whether the specific extent of the difference caused by blue light filters is significant enough to design around.

Keywords

Emotional Response, Blue Light, Blue Light Filter, Color Constancy, Color Perception, Color Emotion

Sammanfattning

Blåljusfilter har blivit vanliga i modern teknik. Även om det har gjorts en betydande mängd forskning om deras effekter på sömn, har det varit lite om effekten på media som uppfattas genom dem. Denna studie försökte undersöka om de mekanismer som är ansvariga för anpassningen till omgivande ljusförhållanden skulle motverka denna effekt. För att göra det genomfördes en digital undersökning där deltagarna betygsatte 30 färger på 3 olika känslomässiga egenskaper: värme, vikt och aktivitet. Deltagarna gjorde undersökningen med eller utan ett aktivt blåljusfilter och med eller utan externt ljus. Det yttre ljuset var avsett att eliminera eller minska nivån av anpassning till skärmens ändrade färger. Efter jämförelse mellan grupperna avslöjades att ingen signifikant subjektiv skillnad förekom mellan någon av testbetingelserna. Men med externt ljus var det skillnad i upplevd värme med och utan blåljusfiltret. Detta innebär att någon form av anpassning är inblandad och störs av egenskaperna hos omgivande ljus. Förekomsten av dessa användningsförhållanden överlämnas till framtida forskning, liksom om den specifika omfattningen av skillnaden som orsakas av blåljusfilter är tillräckligt stor för att kunna designas runt.

Samenvatting

Blauwlichtfilters zijn gemeengoed geworden in de moderne technologie. Hoewel er een aanzienlijke hoeveelheid onderzoek is gedaan naar hun effecten op slaap, is er weinig onderzoek gedaan naar het effect op de media die via hen worden waargenomen. Deze studie probeerde te onderzoeken of de mechanismen die verantwoordelijk zijn voor de aanpassing aan de omgevingslicht omstandigheden dit effect zouden tegengaan. Om dit te doen, werd een digitale enquête uitgevoerd waarin deelnemers 30 kleuren beoordeelden op 3 verschillende emotionele kenmerken: warmte, gewicht en activiteit. Deelnemers namen deel aan de enquête met of zonder een actief blauwlichtfilter en met of zonder extern licht. Het externe licht was bedoeld om het aanpassingsniveau aan de gewijzigde kleuren van het scherm te elimineren of te verminderen. Na vergelijking tussen de groepen bleek dat er geen significant subjectief verschil was tussen beide testomstandigheden. Bij extern licht was er echter een verschil in waargenomen warmte met en zonder de blauwlichtfilter. Dit houdt in dat er sprake is van een soort van aanpassing, die wordt belemmerd door de kwaliteiten van het omgevingslicht. De prevalentie van deze gebruiksomstandigheden wordt overgelaten aan toekomstig onderzoek, evenals of de specifieke omvang van het verschil veroorzaakt door blauwlichtfilters significant genoeg is om rond te ontwerpen.

Trefwoorden

Emotionele respons, blauw licht, kleurconstantie, perceptie, kleuremotie

Acknowledgments

I would like to thank my advisor and examiner for having patience and helping me finish this project, and Corpower Ocean for inspiring the work in the first place.

Stockholm, February 2023
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Chapter 1

Introduction

More than ever, people are now using electronics at all hours of the day. Many will stream shows or movies before bed or while falling asleep, browse social media on their phones in bed, or work on their computer late into the night. While this allows for late night productivity or leisure, it also comes with a downside. Exposure to light at night can alter human circadian rhythms [1] which is known to negatively affect health.

Luckily, this effect of light can be mitigated. Light in the blue spectrum has a far more pronounced effect on the circadian rhythm than other colors, as one study showed wearing glasses before bed which filtered out just blue light increased melatonin, a chemical responsible for signaling the time to sleep, by 58%, and increased time spent asleep by 24 minutes [2].

Shih et al. have shown that it is possible to filter out the specific frequencies which cause the most circadian disruption, and alter the resulting colors so that they are nearly indistinguishable from the original, without the same harmful effects [3]. However, doing so requires high precision notch filters, as screens do not naturally have such fine control over their wavelengths, and may be computationally expensive compared to a more basic blue light filter.

Further, it is unclear if this sort of adjustment is necessary. Color constancy is well documented and indicates that the mind can already compensate for seeing things under different sorts of lighting [4]. The difference in color temperature between noon and sunset is a classic example of color constancy, and is very similar to the effect of a blue light filter.

However, there are dimensions to color perception beyond the identification of colors. Colors are known to evoke specific emotions [5], and affect behavior in indirect ways. It is unclear if color constancy applies to the emotional dimension of color. This is the core question that this research seeks to answer. Do the adaptation and inference that produce color constancy extend to the emotional perception of colors? Are the changes produced by a blue light filter significant enough to change what we perceive? My hypothesis is that the adaptation effects do extend to the emotional perception of color, and there would be minimal or no interaction between emotional response to colors and the presence of a blue light filter.

Chapter 2

Background

2.1 Biological Vision

The front portion of the eye focuses light into an image on the back, the retina. The retina is composed of photosensitive cells which react to the image and send the information along the ocular nerve to the brain. These photosensitive retinal cells are commonly placed in two categories: rods and cones. Rods don't sense color, only brightness, and form a less clear picture, but they work well in the dark. Cones detect color, and come in three varieties, each focused on a different color, giving humans what is called a trichromatic eye. There are short, medium and long cones, also known as S-cones, M-cones, and L-cones. Each of them reacts to a range of wavelengths of light in a roughly normal distribution, around a short, medium, or long wavelength of light respectively. S-cones respond most to blue light, M-cones are centered on green light, and L-cones respond to red light.

2.2 Blue Light Filters

A blue light filter is, broadly, something that reduces the amount of light in the high-energy blue portion of the spectrum which reaches the user's eyes. This takes two main forms, virtual and physical. Virtual filters are programs which alter the light produced by an electronic screen, usually by reducing the blue content of pixels by a set percentage. Many also reduce the green content of pixels by a smaller amount. Overall, this change is called a change in color temperature. This is expressed in degrees Kelvin, approximately corresponding to the type of light that would come off of something at that temperature. This means that lower numbers such as 2700K correspond to warm, yellowish light such as that of a campfire, while high numbers like 6500K correspond to 'cooler', more balanced, or blue light such as the light of the sun. This sort of utility is commonplace enough that modern operating systems such as Android, MacOS, iOS, and Windows almost all come with built-in virtual blue light filters, and third party applications that provide more control in doing the same have tens of millions of downloads [6].

Physical filters are a piece of material placed between the user's eyes and a light source. This usually takes the form of either a thin film layered over an electronic screen, or a set of yellow or orange tinted eyewear. Physical filters can provide tighter control over what frequencies of light are allowed through in what proportions. Most electronic screens emit three different tight ranges of frequencies for their red, green and blue subpixels and use the combinations of different intensities to show color. These screens can only alter the amount and ratio of each frequency that is produced. On the other hand, physical filters such as the ones Shih et al used in their experiment can target specific frequencies dependent on their make and material. However, physical filters are far less common due to their lack of convenience. Physically applying and removing a screen covering or wearing glasses is much less accessible than pressing a button.

Past health and light studies have shown that exposure to high energy blue light can be a major component in retinal damage and various eye diseases, so some people at risk for these conditions wear blue light filtering eyewear as a preventative measure. However, these studies deal with high intensity light such as staring into the sun or welding. There is no evidence that the levels of light emitted by common electronics carry any of the same risks, even with extended use [7].

2.3 Circadian Rhythms

However, light from household devices can alter human circadian rhythms [1]. Disruption in these circadian rhythms has been shown to cause numerous deleterious effects, primarily getting less sleep, but also including increased rates of breast cancer, prostate cancer [8], seasonal affective disorder, and obesity [3]. Circadian rhythm disruption may also be the root cause behind a variety of increased risk factors experienced by night shift workers [9].

Interestingly, these effects can extend even to the blind. In some but not all cases of blindness, bright light can still affect melatonin levels and sleep rhythms [10]. It was later concluded that this was due to the presence of another type of photoreceptor beyond the well-known rods and cones, known as intrinsically photosensitive retinal ganglion cells, or ipRGCs. These cells are sensitive to a different set of frequencies than any of the cones. The peak sensitivity is between the peaks of the S and M cones, but their sensitivities overall overlap mostly with the S-cones [3], responsible for detecting short wavelengths such as blue. As ipRGC stimulation affects melatonin levels [11], this means that blue light, and to a lesser extent green light, cause circadian disruption.

Blue light filters help to solve this problem by reducing the brightness of light within the ipRGCs' response range. However, there is a downside to using these filters. Without blue, the colors which the screen can display are more limited. Yellow and white become difficult to distinguish, as do blue and gray, and the differences between other colors are narrowed. Counterbalancing this, the human mind is very good at compensating for these sorts of changes to vision. For example, in a relatively famous experiment by Theodor Erismann, participants wore goggles that flipped their vision upside down, and after six days of uninterrupted wear, they began to perceive the world as right side up again [12]. A similar sort of phenomenon has been observed with colored lenses as far back as 1694 [13], and can easily be seen in the fact that everything looks different immediately after putting sunglasses on, but after wearing them for a while the world looks normal with them on.

2.4 Color Constancy

This phenomenon is broadly known as color constancy. Over the course of about a minute, a person's vision adapts to a perceived change in lighting [14], though there are some components of adaptation which act more quickly in the 10-100 millisecond range. There may even be a component that varies on a seasonal time scale [4], as well as a more directly biological component, as it has been shown that the cones in our eyes maintain near-identical ratios of stimulation when looking at different points, even if the lighting changes [15]. Color constancy appears to be consistent across a wide range of stimuli, from 3D natural scenes, to 2D representations of abstract patterns on an RGB monitor. The complexity of the stimuli was also shown not to have a significant effect on the consistency of color constancy [4]. However, these experiments have all focused on altering the lighting in a space. Blue light filters simulate the same sort of color change but confined to a screen, and through different means. Additionally, while the perceptual, conscious matching of colors is very well studied, the more subconscious emotional reaction to colors is unexamined in relation to color constancy.

2.5 Shades of Color Perception

Color perception can greatly adapt to context and circumstances in terms of identification, however it is less well established whether the emotional impact of colors follows the same adaptation. Children as young as 3-4 years old already associate colors with specific emotions, though some of the specific associations are different in adults [5]. Exactly what color is associated with what emotion can vary significantly, and preference even more so. However, some patterns do emerge and appear consistent. According to one study on nursing home residents, yellow is the best color for communal spaces because it is in the middle of the spectrum, while green is best for bedrooms as a cool color near the edge of the spectrum [16]. According to another, blue is good color for classrooms [17]. The color of the environment can even affect performance, as one study found that preschool children in a pink room had more physical strength and positive mood than those in a blue room [18], while another found that filtered pink light and pink prison cells reduced muscle strength of their occupants [19]. So while color and lighting definitely have subconscious and emotional effects, the specifics of how a color will affect a demographic are largely unknown and not easily predicted. The same holds true for how a difference in color will change the effect.

In one particular study by Ou et al., participants placed 20 colors on 10 different emotion scales such as clean-dirty, active-passive, and hard-soft. They found that the associations with specific colors were consistent across cultures between Chinese and British participants, as well as between male and female participants, with a few exceptions for individual colors. The researchers used factor extraction and coordinate determination to group the emotion scales which were consistent across demographics into an emotional color space with three dimensions, labeled color activity, color weight, and color heat. Essentially, they experimentally examined the various scales in table 2.1, and determined that they varied in three distinct groups, Activity,

Color Activity	Color Weight	Color Heat
Active-Passive Fresh-Stale Clean-Dirty Modern-Classical	Heavy-Light Hard-Soft Masculine-Feminine	Warm-Cool

Table 2.1: Color emotion categories according to Ou et al.

Weight, and Heat. For example, if two colors have very different positions on the Fresh-Stale scale, they would also have very different positions on the Active-Passive scale, but both colors might have the same position on the Heavy-Light scale [20].

Chapter 3

Methodology

3.1 Setup

3.1.1 Overview

To accurately assess whether there is a relationship between blue light filtering and emotional perception of colors, a quantitative online perceptual experiment was performed. Participants were shown a color and placed it on three different sliding scales corresponding to the emotional color space devised by Ou et al. Participants were divided into a two by two factorial design, the condition determining whether their blue light filter was active, and whether they had an outside frame of reference for color temperature.

Due to the restrictions that the Covid-19 pandemic placed on in-person interactions and space sharing, it was decided that this experiment would be conducted virtually, so as to preserve the health and well-being of all participants. As such, an online survey was selected as the most expedient method of performing this experiment.

3.1.2 Recruitment

Participants were recruited from among the researcher’s friends, family, and acquaintances, as well as through personal contact in online communities. No incentives other than gratitude were offered for participation in order to avoid ‘professional’ participants.

Screenshots of the survey for participants in a well-lit room can be found in Appendix B. The survey for the participants in a dark room differed only in the description of the room. The survey itself consisted of four parts:

3.1.3 Informed Consent

First, the participants were shown a page outlining the study which can be seen in appendix B3, including the procedure for each step, the risks associated with extended computer use, the general purpose of the study, and the ways in which the data collected would be used. They were also encouraged to ask questions about anything unclear. The participants were then asked to indicate their consent and understanding, and reminded that they could leave the study at any time.

3.1.4 Technical Setup

Second, the participants were instructed on installing f.lux, the blue light filter used for this experiment. They were each randomly assigned to one of two groups, the control group that would use their computers without blue light filtering active, or the group that would adjust the color temperature of their screens from 6500K to 2700K. This setting was the strongest that f.lux could consistently produce across platforms without special installation, and the default setting.

Participants were further divided into four groups, two of which performed the experiment in a dark room, and the other two which performed the experiment in a well-lit room. Participants in the well-lit groups were told to find a brightly lit room, ideally with natural daylight; participants in the dark groups were told to find a completely dark room, and remove or cover any sources of light such as charger LEDs, as well as to not use their phones for the duration of the experiment. The division was not ideally random, as the participants for the dark room were recruited first, and the light room participants afterwards, but as they were both recruited via the same methods, without repeats, it was judged that this difference would not introduce a significant bias in color perception.

Participants were asked to find an appropriately lit room. It is unfortunate that it was not practical to perform the tests in a single location with properly controlled lighting, as the variance in lighting conditions both between participants and during the experiment may have been a confounding variable and obfuscated some results. However, in-person testing of this sort was not possible during the pandemic conditions, and in theory the difference between the two conditions should be far larger than the variance within them. Participants self-reported that they had the correct color balance and room lighting, confirmed against an informal check-in at the end of the survey. There was one case in which the participant misread the instructions, and their results were edited to reflect the conditions they used. Participants were asked to use their computers for 15 minutes while acclimating to the new white balance of the room and screen, and asked to fill out demographic information at the same time. Participants were asked to give their gender and age, as both of these have been shown to have an effect on color perception [21, 22]. Additionally, they were asked to mention if they had any color vision deficiency, and the display they used to view the experiment.

3.2 Color Evaluation

The participants were presented with a colored square on a grey background. A sample page of the survey can be seen in Figure 3.1. They were asked to evaluate it based on three different metrics, those indicated by Ou et al. as the axes of their three dimensional emotional color space: warmth, weight, and activity [20]. Each pair of emotions represents one of the categories. The warmth category is a category of one, represented by Cool-Warm. The weight category is represented by Heavy-Light, and includes Hard-Soft and Masculine-Feminine. The activity category is represented by the Active-Passive scale, and includes Fresh-Stale, Clean-Dirty, and Modern-Classical. While there are other models for color emotion, this one was used because the three variables were proven to be largely independent and adequately cover the variance, while consisting of few factors. This reduced the number of questions needed per color, thus allowing for more colors to be evaluated without unduly imposing on the participants' time.

Next was the evaluation of the colors. The colors were selected to be relatively evenly spread in the RGB color space, with a focus around the light and dark shades, as it was expected these would be affected the most by the color shift. A total of 30 colors were evaluated, which was judged as a good balance between evaluating a wide range and not being an undue burden on the participants' time. Specific RGB values can be found in Appendix A.

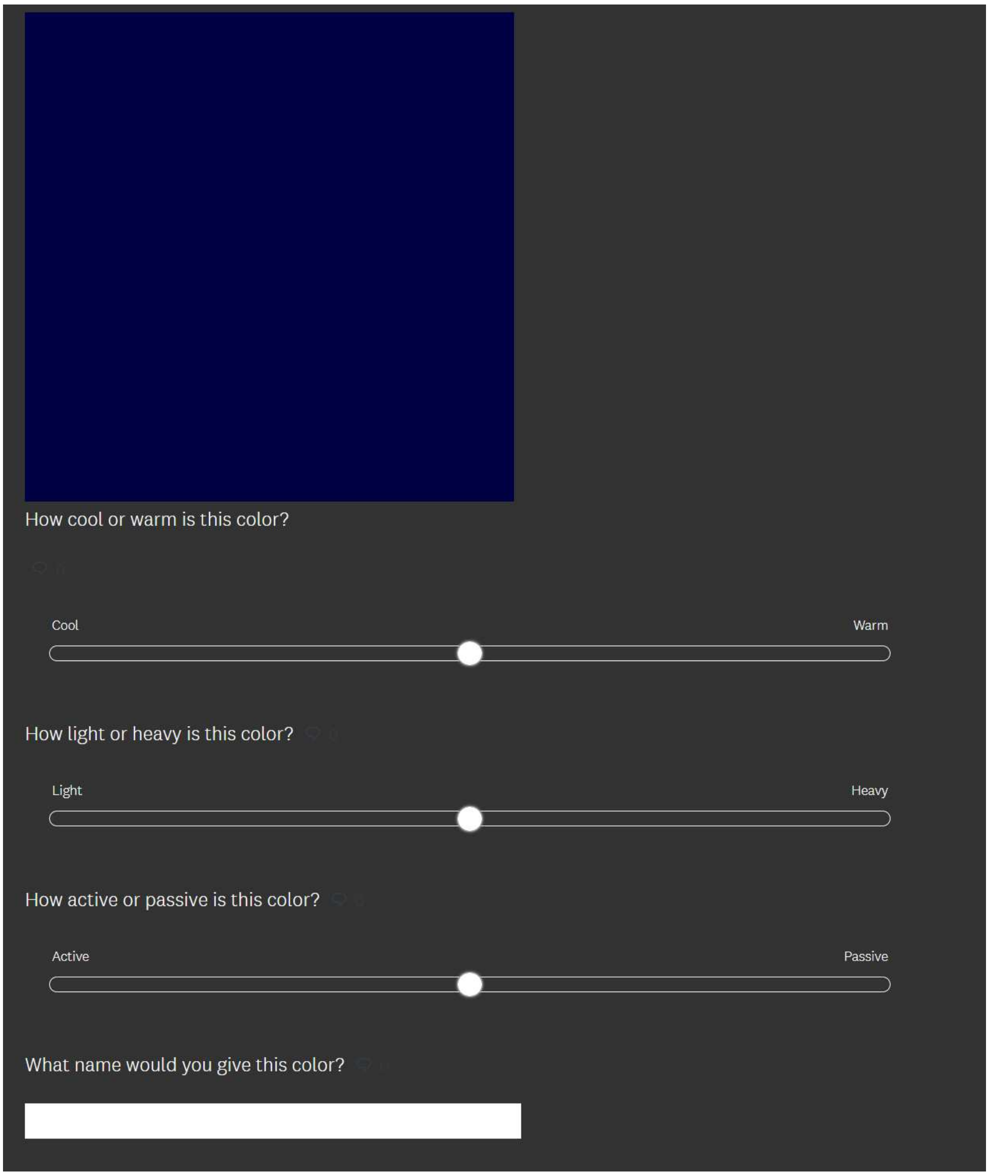

Figure 3.1: A sample color question.

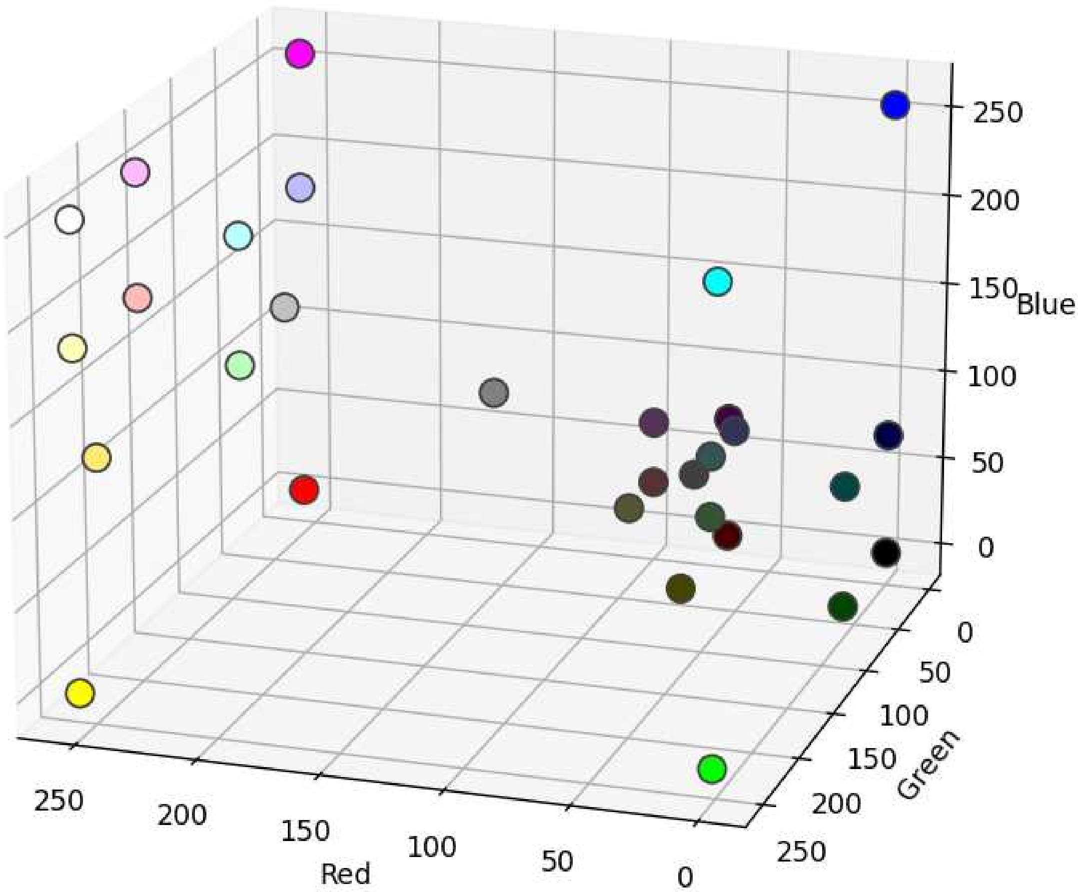

Figure 3.2: The colors displayed in the RGB color space. Color codes are listed in Appendix A

Figure 3.3: The 30 colors selected.

Each scale was evaluated with a separate slider, corresponding to values from 0 to 100. The participants were not shown the number they selected to avoid the desire to assign round numbers disturbing the data.

The participants were then asked to write a name for the color. This was unrelated to the quantitative portion of the study, and was included in case obvious and noteworthy patterns emerged in the qualitative data collected, such as consistent misidentification of a color by one group but not another.

3.3 Image Evaluation

Fourth, the same questions were asked about a short series of images, each with a dominant color, in case the effect of the blue light filter was heavily dependent on context. The full set of images used can be found in Appendix C, and a sample question page can be seen in Figure 3.4.

The images were selected to represent different hues, and 8 were evaluated.

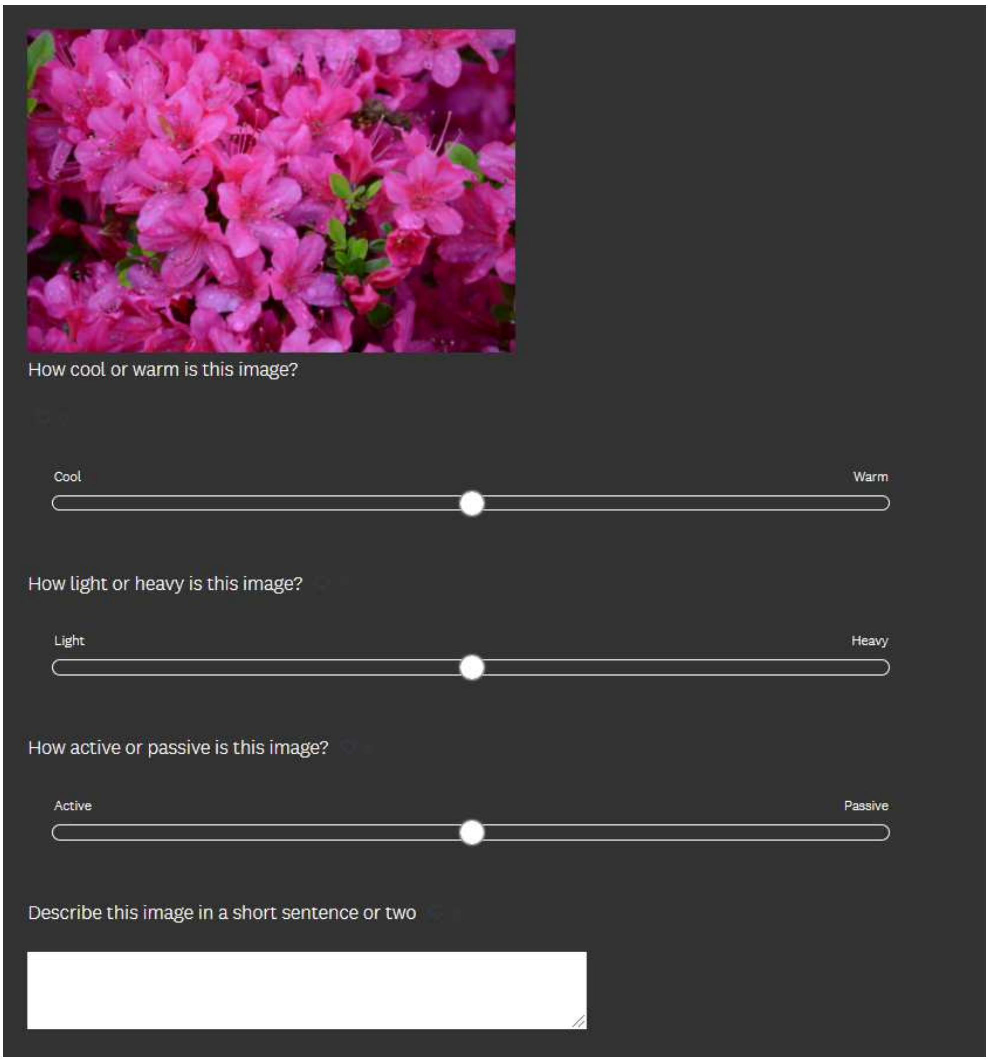

Figure 3.4: A sample image question.

Chapter 4

Results and Analysis

4.1 Demographics

Of the 49 total participants who completed the study, 12 were female and 33 were male, while 5 identified as Other. 15 participants were ages 18-24, 31 were 25-34, 2 were between 35 and 44, and 1 was between 55 and 64. 10 participants began the study, but elected not to finish. Their data has been discarded. 38 participants indicated that they had no colorblindness, while 7 indicated they did. They were mostly Deuteranopic (Red-Green colorblind), though two did not know what type of colorblindness they had, and one indicated both deuteranomaly and protanomaly. It is possible that some participants who indicated deuteranopia meant deuteranomaly, as the two are not always clearly differentiated. Deuteranopia is complete red-green color blindness, while deuteranomaly is partial color blindness, and is somewhat more common. Collectively, all the forms are called color vision deficiency, or CVD. Additionally, four participants were unsure if they had color vision deficiency. While these demographics may not necessarily be a very good representative sample of a population, the correlations between the demographics and the responses were minor and uncertain, and the demographics were divided evenly across the testing conditions. Therefore the impact of the demographic is judged to be minimal.

4.2 Statistics

The responses had an average standard deviation of 18.4 on a 100 point scale, with some varying to a maximum of 35.0 and a minimum of 5.1. Mean responses for each color can be found in Appendix A.

4.2.1 Qualitative Data

The qualitative data was not homogeneous enough for common data analysis techniques, but some patterns did emerge under a subjective overview of the data. Notably, participants rarely misidentified colors, even ones significantly affected by the filtering. White was still called white or off white, blue was still called blue, even if the colors on the participants' screens were closer to yellow and black than the typical shades. The only colors that had significant instances of misidentification were the darker tones. Dark purple was occasionally misidentified as dark red, and vice versa, slightly more frequently in the case of the blue light filter being active. The word "dark" occurred slightly more often in the description of a low-luminosity blue with the filter than without. These differences were slight though and could easily be produced by coincidence or bias.

4.2.2 Data Processing

After collecting and arranging the responses, filtering out incomplete responses, and coding the results, a two-way Analysis of Variance (ANOVA) was performed on the results. Each of the emotional metrics used (Temperature, Weight, and Activity) were individually used as the dependent variable. For each, the independent variables were the two experimental conditions: whether the room was brightly or dimly lit, and whether the blue light filter was enabled or disabled. The demographic information was included as a potential factor as well, including the participants' age, gender, and color vision deficiency or lack thereof. The RGB components (The red, green, and blue values used to define the colors) of each color were also included as independent variables. Additionally, interaction effects were checked for between the RGB components, and between the room lighting and the blue light filter status.

4.3 Results

4.3.1 Testing Conditions

Neither of the two testing conditions (Presence or absence of a blue light filter, and light level of the room) were individually shown to have a significant effect on any of the emotional response metrics measured ($p > 0.05$). There was also no significant interaction effect detected between the test condition variables ($p > 0.05$). It is worth noting that the relationship between the testing conditions and warmth were all $p < 0.15$, suggesting that more data may be needed to clarify the connection or lack thereof, whereas the other metrics were more definitively unrelated. Additionally, when excluding data from all respondents who indicated any form of color vision deficiency, there was a statistically significant interaction between the testing conditions with regards to perceived warmth.

Excluding the participants in a dark room led to a significant difference in the perceived warmth ($p < 0.05$) but no difference in the perceived weight or activity. Examining only the participants in a dark room showed no significant difference on any of the scales ($p > 0.05$).

In short, it appears that using a digital blue light filter in a well lit room affects the perception of a color's warmth, whereas using one without outside light sources does not significantly alter the emotional response to colors.

4.3.2 RGB Components

The RGB components and the interactions between them were all responsible for a large proportion of the variance ($p < 0.05$), with a few notable exceptions. The green component had a less pronounced effect on a color's warmth though just shy of significance ($p > 0.05$), there was no interaction between blue and green ($p > 0.05$), but still an interaction effect between red and green ($p < 0.05$). Similarly, there was no interaction effect between red and blue when determining a color's weight, and less interaction between blue and green when determining activity ($p > 0.05$). Apart from these exceptions, all of the RGB components and interactions between them were statistically significant determiners of the emotional response metrics.

4.3.3 Demographics

The demographics did seem to have some effect on the overall emotional response to colors. None of the demographics has a significant effect on warmth ($p > 0.05$). Age and color vision deficiency had some effect on the perception of both weight and activity ($p < 0.05$) but not warmth, while gender only affected activity ($p < 0.05$). However, due to the relatively low certainty values (Most p values were between 0.05 and 0.01), and the fact that the demographics were randomly divided among the conditions, this should not affect the validity of the rest of the data.

Chapter 5

Discussion

5.1 Quantitative Data

In general, the results show that blue light filters do not significantly affect the emotional perception of colors regardless of environment, with the exception of a color's warmth in a well-lit environment. This makes sense, as the filtering effect is best described as altering the color temperature. If anything, it is surprising that there was not a statistically significant effect for the other dimensions of color emotion, and that the difference disappeared without environmental light.

The warmth dimension of color emotion paints a fairly clear picture of color constancy at play, but color weight and activity are slightly less certain. It is well documented that the mind will adapt to a new baseline, but the specific extent to which this occurs in a given instance is difficult to predict or assess. It seems most likely that the difference caused by blue light filters is simply not large enough to produce a significant difference in perception of these aspects. However in this case it would be expected that there would have been no difference between the responses to the white color with the filter and the responses to the light yellow which was chosen to emulate what white becomes with the filter. However, though there was not quite a significant difference between these responses in color weight, there was a significant difference in color activity, suggesting that lack of difference in colors is not the only reason. It is also likely that even with a bright room providing a reference color, participants still adapted to or compensated for the colors on their screen surrounding the color squares. Most likely some combination of these two effects is responsible for the lack of significant difference in these other color emotion dimensions.

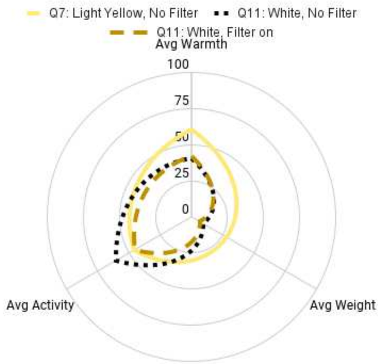

Figure 5.1: Comparison of white with no filter, white with a blue light filter active, and the light yellow color that white becomes under the blue light filter, viewed with no filter

Figure 5.2: Average results for 3 different colors to illustrate typical differences between responses to colors.

5.2 Qualitative Data

The qualitative data is similarly interesting in its lack of a clear difference. Participants clearly knew what each color was, regardless of the blue light filter's interference. The descriptions for each color are largely uniform with no clear delineation between the conditions, and agree almost wholly. The case of the 'Full White' color (#ffffff) is probably the most indicative of this uniformity. Under the settings used in this study, it changes from paper white to a color that would be clearly identified as yellow in isolation. The color which it changes into was included in the study as well, and was consistently identified as yellow with various descriptors. However not a single participant used the word yellow to describe the white color swatch, regardless of the test condition. This is most likely because color constancy applies to electronically displayed colors, and blue light filters alter our perceptions in the same way as a change in lighting.

In combination with the lack of a relation between the presence of the blue light filter and emotional perception, this suggests that the emotional reaction to a color is based more on the color that is identified than on the color which is seen.

5.3 Color Component Relationships

Among the components of the colors, a few interesting effects emerge.

Green being less involved in the perception of warmth suggests that the primary factor in color warmth is the balance between blue and red. The interaction between green and red implies that yellow (Green+Red) is perceived differently than red, while the lack of interaction between green and blue implies that cyan and blue are largely interchangeable in terms of color temperature. When drawing comparisons to physical phenomena this makes sense. Fire is composed of red and yellow for the most part, and heating metal generally goes from red to yellow and then to white, with blue not making an appearance. On the opposite end of the spectrum, blue and cyan represent things like ice, water, oceans, and so on, but there is no consistent progression of color with coldness.

The other two missing interaction effects are a bit more difficult to identify a cause for. The lack of interaction between blue and green in relation to a color's activity could be attributed to a similar idea as with temperature, where cyan is rarely distinguished from blue. The lack of interaction between red and blue with regards to weight is hardest to parse. Perhaps the spectrum between red and blue is perceived as more a combination of the two colors than its own color in the middle.

However, the specifics of which colors invoke which emotional responses were not the primary aim of this study, and any findings or extrapolation in this vein should be taken with a grain of salt. The primary results are quite clear in showing that there is not a significant effect of blue light filters on the emotional response to colors.

Chapter 6

Conclusions and Future work

6.1 Context

Light from electronics can have some negative effects on our health. Blue light filters are a promising way to mitigate these risks, and widely used. The precise effects these filters have on our perceptions have not been thoroughly researched. However, according to the results of this study, these effects, at least with regards to the emotions inspired by colors, are minimal or nonexistent.

6.2 Limitations

This was a relatively small study, and was hampered by the inability to perform in-person testing in an environment with controlled lighting and display conditions. Due to these limitations, it leaves some doubt whether the lack of change was due to an effect along the lines of color constancy, or the magnitude of changes induced by the filter simply being too small to overcome the uncontrolled variables.

6.3 Future Work

A future study replicating this experiment with a larger sample size, more questions, more tightly controlled testing conditions, or all three may reveal more. This study also did not look at different types of blue light filters or different strengths of filtering, both of which may be worth future investigation.

Additionally, studies examining the same subject with different emotional response scales or a greater focus on individual colors may prove enlightening.

6.4 Takeaways

Blue light filters do have an effect on the emotional perception of colors. However this effect is only significant when there is significant light from a source other than the computer screen, and only appears to affect the perception of color temperature in that case. As this effect only appeared when participants were able to reference against environmental light, it appears that the adaptation and inference effects that produce color constancy do extend to emotional perceptions of color. The hypothesis is therefore upheld, with the caveat that if there is significant environmental light, blue light filters can affect the perception of a color's temperature.

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Appendix A

Tables of color codes and results

Table A.1 below lists the RGB color components, as well as the average result among all participants in each emotional metric, and the standard deviation of that average. The following table A.2-5 show the same information for each of the four individual conditions. Table A.6 shows the same information organized by question.

Question Number	Red	Green	Blue	Avg Warmth	Warmth StDev	Avg Weight	Weight StDev	Avg Activity	Activity StDev
1	0	0	68	45	27.7	51	36.7	59.5	26.8
2	0	68	0	54.1	21	40.9	29	52.8	24.3
3	187	187	255	42.4	19.8	43.7	26.7	57.5	23.9
4	0	68	68	39.2	20.4	43.6	26.6	57.4	22.9
5	255	0	0	62.9	31.1	57	26.7	35.6	29.4
6	255	233	119	76.2	21.8	37.7	26.6	24.8	23.3
7	0	0	0	43.1	32	61.6	37.1	57.8	34.6
8	255	255	0	46.7	35	66.8	37.7	51.1	39.1
9	51	51	85	50.7	30.2	51.3	30.5	50	32.6
10	255	255	255	39.2	30.8	39	34.6	60.1	32.3
11	51	85	51	44.9	28.6	36.3	31.2	53.7	30.1
12	0	255	0	46.1	27.4	44.4	30.2	39.3	30.6
13	51	85	85	42.1	28.8	44.9	30.8	41.8	32.1
14	0	255	255	33.6	24.2	39	28.4	43.9	29.5
15	64	64	64	35.9	25.9	44.3	33.2	49.8	35.8
16	255	187	255	52.4	28.1	47.2	30.8	53.2	32.9
17	68	0	0	66.1	23.5	50.7	31.9	41.7	26.9
18	0	0	255	45.1	29.7	69.9	24.5	48.9	28.3
19	68	0	68	37	25.1	66.1	24.4	49.3	25.7
20	255	187	187	55.8	24.4	45.8	29.1	49.9	23.6
21	68	68	0	53.8	23.8	48.7	31.5	56.1	25.6
22	0	255	255	56.8	27.2	59.2	33.6	41.1	34.4
23	187	255	187	53.3	29.8	30.1	30.5	25.2	25.1
24	85	51	51	45.8	24.5	43.8	30.2	52.6	26.1
25	187	255	255	38.9	25.2	43	31.8	58.3	23.4
26	85	51	85	39.8	24.7	41.8	30.5	57.1	23.2
27	192	192	192	47.4	23.2	48.3	26.4	64.7	23.3
28	85	85	51	44.2	22.3	47.9	25.4	68.2	22.6
29	128	128	128	46.6	21.2	56.8	19.6	72.6	18.1
30	128	128	128	45.4	21.7	47.7	19.8	74.4	17.5

Table A.1: Averages and standard deviations among all participants.

Question Number	Red	Green	Blue	Avg Warmth	Warmth StDev	Avg Weight	Weight StDev	Avg Activity	Activity StDev
1	0	0	68	22.7	16.9	88.8	9	76.5	21.3
2	255	255	187	63.8	17.8	7.6	8.1	59.7	29.5
3	0	68	0	42	16.6	63.1	16.8	52.8	14.7
4	187	187	255	47.3	22.6	20	15.3	61	22.6
5	0	68	68	41.4	18.1	58.2	16.6	55.2	17.6
6	255	0	0	90.5	11	49.1	37.3	13	16.7
7	255	233	119	60.3	18.1	27.9	13.8	45.7	18.3
8	0	0	0	24.7	22.1	98.2	3	83.6	33.5
9	255	255	0	70.4	20	36.6	32.2	33.7	29.8
10	51	51	85	31.5	17	60.7	29.5	77.5	15.7
11	255	255	255	40.7	32.5	9.2	15.1	60.4	38.7
12	51	85	51	39.3	14.8	62.7	14	64.4	18.1
13	0	255	0	64.5	27.3	37.8	39	16.8	17.4
14	51	85	85	30.8	11.3	58.2	18.9	58.8	14.1
15	0	255	255	44	31.9	22.1	21.1	19.8	15.3
16	64	64	64	30.5	15.7	59.5	25.7	79.5	24.1
17	255	187	255	71.8	25.4	25.5	16.3	25.6	16.7
18	68	0	0	59.9	24.6	78.8	13.8	55.1	29.1
19	0	0	255	20	14.3	74.2	27.9	42.1	28.5
20	68	0	68	39.2	25.4	67.5	17.7	51.7	17.3
21	255	187	187	66.5	23.3	17.3	12.5	29.1	21.1
22	68	68	0	31.7	18.1	78.2	16.9	70.7	22.8
23	0	255	255	76.5	23.6	48.7	41.1	7.4	8.7
24	187	255	187	38.2	23.2	20.5	18.5	34.6	23.8
25	85	51	51	49.5	27.9	65	23.2	60.7	27.6
26	187	255	255	23.6	15.2	14	11.2	55.5	25.6
27	85	51	85	46.8	22.3	66.6	18.7	59.8	24.7
28	192	192	192	31.7	22.4	28.3	19.6	57.8	28.4
29	85	85	51	42.4	19.5	68.9	11.4	74.4	13.7
30	128	128	128	42.1	22.6	51.5	16.9	74.7	11.2

Table A.2: Averages and standard deviations among participants in the dark room and 6500K filter condition.

Question Number	Red	Green	Blue	Avg Warmth	Warmth StDev	Avg Weight	Weight StDev	Avg Activity	Activity StDev
1	0	0	68	38.4	32.6	90.6	10	71.1	20.5
2	255	255	187	53.3	23.9	15.9	10.9	42.4	25.3
3	0	68	0	57.4	23	75.6	14.2	62.6	22.9
4	187	187	255	33.6	23.3	17.6	12.1	35	30
5	0	68	68	51.3	28.2	70.7	18.4	60.4	24.7
6	255	0	0	86	13.3	42	25	6.6	11.8
7	255	233	119	57.1	30.5	25.4	16.6	25.9	20.1
8	0	0	0	30.3	38.3	92.3	17	66.1	45.1
9	255	255	0	55.7	33	34	31.9	14	13
10	51	51	85	42.6	27.8	63.1	22.5	69.3	14
11	255	255	255	42.3	43.2	6.6	10.5	45.4	42.8
12	51	85	51	52.9	25.6	56.9	25.3	50	25.8
13	0	255	0	32.4	36.5	24.7	29.8	20.1	36.4
14	51	85	85	43.7	25.7	62.9	26.3	65.4	15.8
15	0	255	255	24.6	26.8	11	9.2	18.3	24.6
16	64	64	64	51.6	33.7	77	10.8	78.4	11.4
17	255	187	255	57.1	27.8	17	15	23.6	14.8
18	68	0	0	68.7	18.6	79.4	12.9	41	23
19	0	0	255	33	32.2	51.6	39.6	54.7	36.9
20	68	0	68	53	27.6	75.7	22.2	55.6	31.2
21	255	187	187	38.7	24.3	19	8	47.6	30.5
22	68	68	0	59.6	19	74.6	16.8	70.7	14.3
23	0	255	255	45.9	37	40.6	45.2	21.9	35.5
24	187	255	187	33.6	22.6	10.4	8.9	40.1	25.3
25	85	51	51	48.4	23.4	69	19.2	63.6	18.5
26	187	255	255	29.4	26.3	6.9	6.9	49.3	25.2
27	85	51	85	64.3	20.4	60.1	24.9	63.3	20.2
28	192	192	192	52	24.5	35.1	29	68.1	26.4
29	85	85	51	60.6	19.5	68.9	13.8	72.7	16.7
30	128	128	128	41.7	29.5	50	26.2	72.1	23.4

Table A.3: Averages and standard deviations among participants in the dark room and 2700K filter condition.

Question Number	Red	Green	Blue	Avg Warmth	Warmth StDev	Avg Weight	Weight StDev	Avg Activity	Activity StDev
1	0	0	68	22.3	20.1	85.1	8.5	77.4	14.6
2	255	255	187	72.1	14.8	23.8	15.5	34.2	25.5
3	0	68	0	37.1	13.2	55.9	22.1	64.5	24.1
4	187	187	255	52.1	18.1	26	13	54.4	29.5
5	0	68	68	28.8	12	66.1	22.3	60.5	15.7
6	255	0	0	87.6	21.3	55.3	31	16.5	27.2
7	255	233	119	69.2	20.2	28.3	13.4	34.4	25.7
8	0	0	0	18.7	31.2	96.3	6.9	91.7	13.5
9	255	255	0	74	20.9	30.2	21.8	27.5	18.7
10	51	51	85	25.7	25	74.9	8.2	78.2	18.7
11	255	255	255	44.9	35.8	19.3	22.7	30.8	29.2
12	51	85	51	42.5	18.1	64.7	15.2	69.5	12.7
13	0	255	0	44.6	38.3	25.7	31.8	10.5	12.3
14	51	85	85	43.1	24.7	59.9	18.9	73.7	17.6
15	0	255	255	33.2	23.9	15.8	17.5	19	18
16	64	64	64	45.3	25.4	79.8	18.8	78.8	28.7
17	255	187	255	70.9	24.2	23.2	21.8	18	9
18	68	0	0	71.9	19.6	77.7	15.4	66.5	27.7
19	0	0	255	25.9	10.9	67.7	20.4	35.1	23.9
20	68	0	68	60.9	17.9	69.6	17.9	61.2	18.2
21	255	187	187	69.3	20.4	26.7	11.7	38.1	16.5
22	68	68	0	51.6	20.8	79	14	72.9	15.3
23	0	255	255	67.8	30.8	39.1	37.5	12.3	13.2
24	187	255	187	49.2	30.4	25.6	12	38.5	26.1
25	85	51	51	57.4	18.5	74.5	14.7	72.5	16.2
26	187	255	255	32.5	21.4	24.5	20.9	44.8	24.9
27	85	51	85	61.9	18.6	71.7	11.8	67.6	22.4
28	192	192	192	45.9	24.4	32.3	20.7	64	30.2
29	85	85	51	50	19.6	69.5	6.4	71.7	21.9
30	128	128	128	53.7	18.5	48.7	19.8	68.1	16.6

Table A.4: Averages and standard deviations among participants in the bright room and 6500K filter condition.

Question Number	Red	Green	Blue	Avg Warmth	Warmth StDev	Avg Weight	Weight StDev	Avg Activity	Activity StDev
1	0	0	68	22.1	12.8	77.8	12.6	62.7	22.2
2	255	255	187	65.3	15.6	18.8	11.1	48.9	21.9
3	0	68	0	42.3	18.7	71.3	9.6	57.6	18.8
4	187	187	255	27	13.9	23.2	10.8	67.8	22.1
5	0	68	68	31	13.7	67.9	12.3	60.6	16.2
6	255	0	0	89.8	13.9	46.3	32.9	10.7	8.9
7	255	233	119	66.3	14.4	23	12	39.8	17.7
8	0	0	0	18.1	23.9	99	2.3	64.6	37
9	255	255	0	79.6	10.8	47.7	40.4	15.2	14.5
10	51	51	85	26	22.2	62.2	23.9	77.3	17.9
11	255	255	255	64.4	32.1	12.7	32.9	39.2	34
12	51	85	51	36.2	21.9	53.7	20.3	64.9	14.3
13	0	255	0	53	26.6	24.3	26.4	15.4	13.1
14	51	85	85	19.6	15.4	64.7	15.8	75.4	12.8
15	0	255	255	26.1	23.8	16.7	13.6	20.3	11.5
16	64	64	64	30.8	22	72.7	16.9	83.8	10.4
17	255	187	255	60.3	22.4	23.1	9.1	39.2	20.1
18	68	0	0	64.6	27.8	79.4	13.2	60.4	21.7
19	0	0	255	20.3	20.2	44.6	26.7	34.9	25.3
20	68	0	68	46.7	23.1	73.2	9.9	63.4	14.5
21	255	187	187	64.6	18.8	18.6	11.9	57.3	25.2
22	68	68	0	45.7	20.4	73.8	18.7	67.1	17.7
23	0	255	255	73.4	15.5	37.1	31.8	8.1	7.4
24	187	255	187	31.9	15.8	13.7	10.9	43.1	24.9
25	85	51	51	53.9	24.9	67.7	15.6	67.8	15.1
26	187	255	255	15.2	9.1	19	23.7	51.7	22.8
27	85	51	85	46.2	19.6	65.7	14.1	64.2	15
28	192	192	192	35.8	20.5	25.3	17.3	75.3	15.9
29	85	85	51	41.9	23.2	55.3	22.1	63.8	22.2
30	128	128	128	42.1	18.1	40	19	83.7	18.7

Table A.5: Averages and standard deviations among participants in the bright room and 2700K filter condition.

Table A.6: Results Grouped by Question/Color Part 1

Condition	Avg Warmth	Warmth StDev	Avg Weight	Weight StDev	Avg Activity	Activity StDev
Question 1				R:0	G:0	B:68
Average	45	28	51	37	60	27
Dark 2700	38.4	32.6	90.6	10.0	71.1	20.5
Dark 6500	22.7	16.9	88.8	9.0	76.5	21.3
Bright 2700	22.1	12.8	77.8	12.6	62.7	22.2
Bright 6500	22.3	20.1	85.1	8.5	77.4	14.6
Question 2				R:255	G:255	B:187
Average	54.1	21.0	40.9	29.0	52.8	24.3
Dark 2700	53.3	23.9	15.9	10.9	42.4	25.3
Dark 6500	63.8	17.8	7.6	8.1	59.7	29.5
Bright 2700	65.3	15.6	18.8	11.1	48.9	21.9
Bright 6500	72.1	14.8	23.8	15.5	34.2	25.5
Question 3				R:0	G:68	B:0
Average	42.4	19.8	43.7	26.7	57.5	23.9
Dark 2700	57.4	23.0	75.6	14.2	62.6	22.9
Dark 6500	42	17	63	17	53	15
Bright 2700	42.3	18.7	71.3	9.6	57.6	18.8
Bright 6500	37.1	13.2	55.9	22.1	64.5	24.1
Question 4				R:187	G:187	B:255
Average	39.2	20.4	43.6	26.6	57.4	22.9
Dark 2700	33.6	23.3	17.6	12.1	35.0	30.0
Dark 6500	47.3	22.6	20.0	15.3	61.0	22.6
Bright 2700	27	14	23	11	68	22
Bright 6500	52.1	18.1	26.0	13.0	54.4	29.5
Question 5				R:0	G:68	B:68
Average	63	31	57	27	36	29
Dark 2700	51.3	28.2	70.7	18.4	60.4	24.7
Dark 6500	41.4	18.1	58.2	16.6	55.2	17.6
Bright 2700	31.0	13.7	67.9	12.3	60.6	16.2
Bright 6500	28.8	12.0	66.1	22.3	60.5	15.7
Question 6				R:255	G:0	B:0
Average	76.2	21.8	37.7	26.6	24.8	23.3
Dark 2700	86.0	13.3	42.0	25.0	6.6	11.8
Dark 6500	90.5	11.0	49.1	37.3	13.0	16.7
Bright 2700	89.8	13.9	46.3	32.9	10.7	8.9
Bright 6500	87.6	21.3	55.3	31.0	16.5	27.2
Question 7				R:255	G:233	B:119
Average	43	32	62	37	58	35
Dark 2700	57.1	30.5	25.4	16.6	25.9	20.1
Dark 6500	60.3	18.1	27.9	13.8	45.7	18.3
Bright 2700	66.3	14.4	23.0	12.0	39.8	17.7
Bright 6500	69.2	20.2	28.3	13.4	34.4	25.7
Question 8				R:0	G:0	B:0
Average	46.7	35.0	66.8	37.7	51.1	39.1
Dark 2700	30.3	38.3	92.3	17.0	66.1	45.1
Dark 6500	24.7	22.1	98.2	3.0	83.6	33.5
Bright 2700	18.1	23.9	99.0	2.3	64.6	37.0
Bright 6500	18.7	31.2	96.3	6.9	91.7	13.5
Question 9				R:255	G:255	B:0
Average	51	30	51	31	50	33
Dark 2700	55.7	33.0	34.0	31.9	14.0	13.0
Dark 6500	70.4	20.0	36.6	32.2	33.7	29.8
Bright 2700	79.6	10.8	47.7	40.4	15.2	14.5
Bright 6500	74.0	20.9	30.2	21.8	27.5	18.7
Question 10				R:51	G:51	B:85
Average	39.2	30.8	39.0	34.6	60.1	32.3
Dark 2700	42.6	27.8	63.1	22.5	69.3	14.0
Dark 6500	31.5	17.0	60.7	29.5	77.5	15.7
Bright 2700	26.0	22.2	62.2	23.9	77.3	17.9
Bright 6500	25.7	25.0	74.9	8.2	78.2	18.7
Question 11				R:255	G:255	B:255
Average	45	29	36	31	54	30
Dark 2700	42.3	43.2	6.6	10.5	45.4	42.8
Dark 6500	40.7	32.5	9.2	15.1	60.4	38.7
Bright 2700	64.4	32.1	12.7	32.9	39.2	34.0
Bright 6500	44.9	35.8	19.3	22.7	30.8	29.2

Table A.7: Results Grouped by Question/Color Part 2

Condition	Avg Warmth	Warmth StDev	Avg Weight	Weight StDev	Avg Activity	Activity StDev
Question 12				R:51	G:85	B:51
Average	46.1	27.4	44.4	30.2	39.3	30.6
Dark 2700	52.9	25.6	56.9	25.3	50.0	25.8
Dark 6500	39.3	14.8	62.7	14.0	64.4	18.1
Bright 2700	36.2	21.9	53.7	20.3	64.9	14.3
Bright 6500	42.5	18.1	64.7	15.2	69.5	12.7
Question 13				R:0	G:255	B:0
Average	42	29	45	31	42	32
Dark 2700	32.4	36.5	24.7	29.8	20.1	36.4
Dark 6500	64.5	27.3	37.8	39.0	16.8	17.4
Bright 2700	53.0	26.6	24.3	26.4	15.4	13.1
Bright 6500	44.6	38.3	25.7	31.8	10.5	12.3
Question 14				R:51	G:85	B:85
Average	33.6	24.2	39.0	28.4	43.9	29.5
Dark 2700	43.7	25.7	62.9	26.3	65.4	15.8
Dark 6500	30.8	11.3	58.2	18.9	58.8	14.1
Bright 2700	19.6	15.4	64.7	15.8	75.4	12.8
Bright 6500	43.1	24.7	59.9	18.9	73.7	17.6
Question 15				R:0	G:255	B:255
Average	36	26	44	33	50	36
Dark 2700	24.6	26.8	11.0	9.2	18.3	24.6
Dark 6500	44.0	31.9	22.1	21.1	19.8	15.3
Bright 2700	26.1	23.8	16.7	13.6	20.3	11.5
Bright 6500	33.2	23.9	15.8	17.5	19.0	18.0
Question 16				R:64	G:64	B:64
Average	52	28	47	31	53	33
Dark 2700	51.6	33.7	77.0	10.8	78.4	11.4
Dark 6500	30.5	15.7	59.5	25.7	79.5	24.1
Bright 2700	30.8	22.0	72.7	16.9	83.8	10.4
Bright 6500	45.3	25.4	79.8	18.8	78.8	28.7
Question 17				R:255	G:187	B:255
Average	66.1	23.5	50.7	31.9	41.7	26.9
Dark 2700	57.1	27.8	17.0	15.0	23.6	14.8
Dark 6500	71.8	25.4	25.5	16.3	25.6	16.7
Bright 2700	60.3	22.4	23.1	9.1	39.2	20.1
Bright 6500	70.9	24.2	23.2	21.8	18.0	9.0
Question 18				R:68	G:0	B:0
Average	45.1	29.7	69.9	24.5	48.9	28.3
Dark 2700	68.7	18.6	79.4	12.9	41.0	23.0
Dark 6500	60	25	79	14	55	29
Bright 2700	64.6	27.8	79.4	13.2	60.4	21.7
Bright 6500	71.9	19.6	77.7	15.4	66.5	27.7
Question 19				R:0	G:0	B:255
Average	37.0	25.1	66.1	24.4	49.3	25.7
Dark 2700	33.0	32.2	51.6	39.6	54.7	36.9
Dark 6500	20.0	14.3	74.2	27.9	42.1	28.5
Bright 2700	20	20	45	27	35	25
Bright 6500	25.9	10.9	67.7	20.4	35.1	23.9
Question 20				R:68	G:0	B:68
Average	56	24	46	29	50	24
Dark 2700	53.0	27.6	75.7	22.2	55.6	31.2
Dark 6500	39.2	25.4	67.5	17.7	51.7	17.3
Bright 2700	46.7	23.1	73.2	9.9	63.4	14.5
Bright 6500	60.9	17.9	69.6	17.9	61.2	18.2
Question 21				R:255	G:187	B:187
Average	53.8	23.8	48.7	31.5	56.1	25.6
Dark 2700	38.7	24.3	19.0	8.0	47.6	30.5
Dark 6500	66.5	23.3	17.3	12.5	29.1	21.1
Bright 2700	64.6	18.8	18.6	11.9	57.3	25.2
Bright 6500	69.3	20.4	26.7	11.7	38.1	16.5
Question 22				R:68	G:68	B:0
Average	57	27	59	34	41	34
Dark 2700	59.6	19.0	74.6	16.8	70.7	14.3
Dark 6500	31.7	18.1	78.2	16.9	70.7	22.8
Bright 2700	45.7	20.4	73.8	18.7	67.1	17.7
Bright 6500	51.6	20.8	79.0	14.0	72.9	15.3

Table A.8: Results Grouped by Question/Color Part 3

Condition	Avg Warmth	Warmth StDev	Avg Weight	Weight StDev	Avg Activity	Activity StDev
Question 23				R:0	G:255	B:255
Average	53.3	29.8	30.1	30.5	25.2	25.1
Dark 2700	45.9	37.0	40.6	45.2	21.9	35.5
Dark 6500	76.5	23.6	48.7	41.1	7.4	8.7
Bright 2700	73.4	15.5	37.1	31.8	8.1	7.4
Bright 6500	67.8	30.8	39.1	37.5	12.3	13.2
Question 24				R:187	G:255	B:187
Average	46	25	44	30	53	26
Dark 2700	33.6	22.6	10.4	8.9	40.1	25.3
Dark 6500	38.2	23.2	20.5	18.5	34.6	23.8
Bright 2700	31.9	15.8	13.7	10.9	43.1	24.9
Bright 6500	49.2	30.4	25.6	12.0	38.5	26.1
Question 25				R:85	G:51	B:51
Average	38.9	25.2	43.0	31.8	58.3	23.4
Dark 2700	48.4	23.4	69.0	19.2	63.6	18.5
Dark 6500	49.5	27.9	65.0	23.2	60.7	27.6
Bright 2700	53.9	24.9	67.7	15.6	67.8	15.1
Bright 6500	57.4	18.5	74.5	14.7	72.5	16.2
Question 26				R:187	G:255	B:255
Average	40	25	42	31	57	23
Dark 2700	29.4	26.3	6.9	6.9	49.3	25.2
Dark 6500	23.6	15.2	14.0	11.2	55.5	25.6
Bright 2700	15.2	9.1	19.0	23.7	51.7	22.8
Bright 6500	32.5	21.4	24.5	20.9	44.8	24.9
Question 27				R:85	G:51	B:85
Average	47.4	23.2	48.3	26.4	64.7	23.3
Dark 2700	64.3	20.4	60.1	24.9	63.3	20.2
Dark 6500	46.8	22.3	66.6	18.7	59.8	24.7
Bright 2700	46.2	19.6	65.7	14.1	64.2	15.0
Bright 6500	61.9	18.6	71.7	11.8	67.6	22.4
Question 28				R:192	G:192	B:192
Average	44	22	48	25	68	23
Dark 2700	52.0	24.5	35.1	29.0	68.1	26.4
Dark 6500	31.7	22.4	28.3	19.6	57.8	28.4
Bright 2700	35.8	20.5	25.3	17.3	75.3	15.9
Bright 6500	45.9	24.4	32.3	20.7	64.0	30.2
Question 29				R:85	G:85	B:51
Average	46.6	21.2	56.8	19.6	72.6	18.1
Dark 2700	60.6	19.5	68.9	13.8	72.7	16.7
Dark 6500	42.4	19.5	68.9	11.4	74.4	13.7
Bright 2700	41.9	23.2	55.3	22.1	63.8	22.2
Bright 6500	50.0	19.6	69.5	6.4	71.7	21.9
Question 30				R:128	G:128	B:128
Average	45	22	48	20	74	18
Dark 2700	41.7	29.5	50.0	26.2	72.1	23.4
Dark 6500	42.1	22.6	51.5	16.9	74.7	11.2
Bright 2700	42.1	18.1	40.0	19.0	83.7	18.7
Bright 6500	53.7	18.5	48.7	19.8	68.1	16.6

Appendix B

Images of the Survey

Screenshots of the various pages of the survey for context.

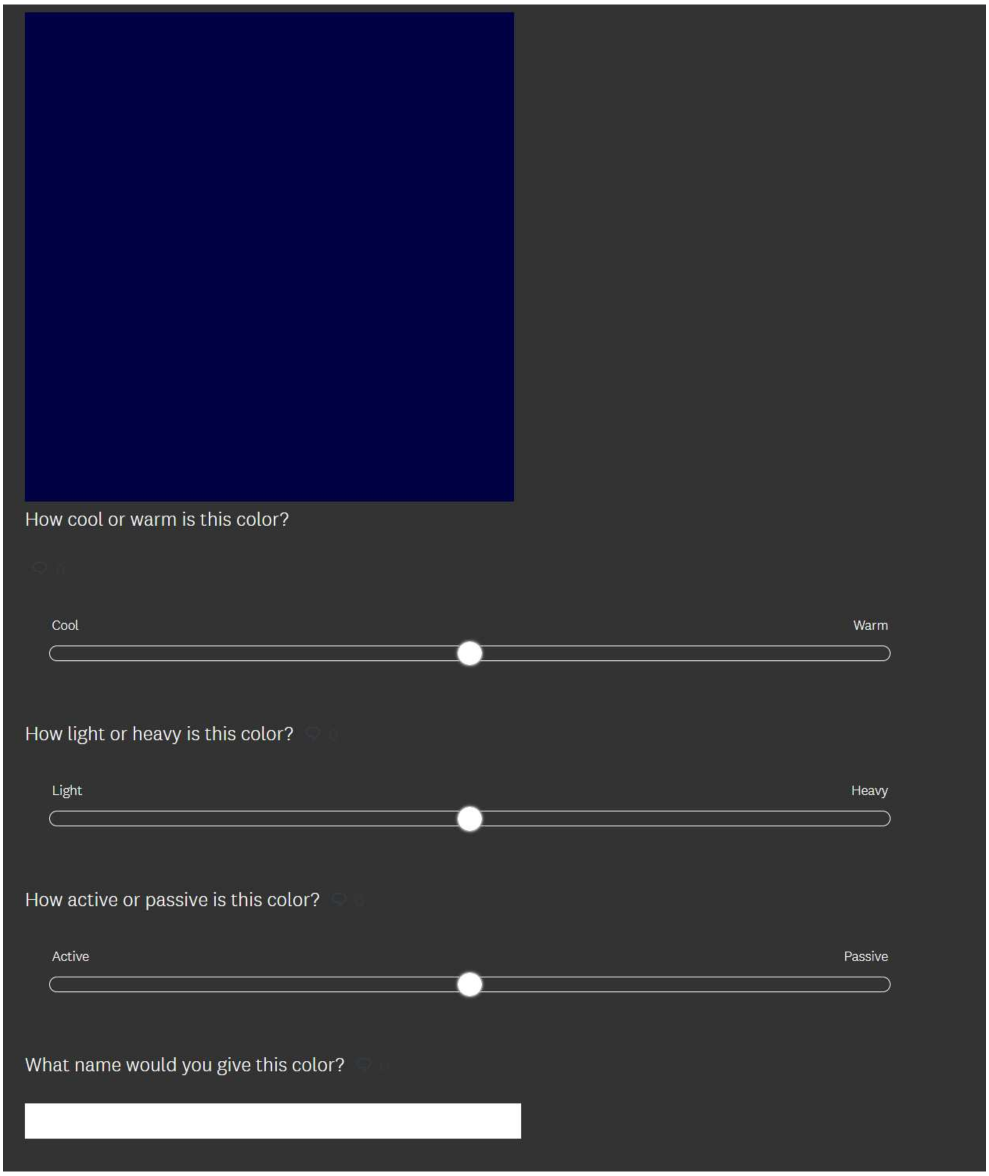


Figure B.1: A sample color question.

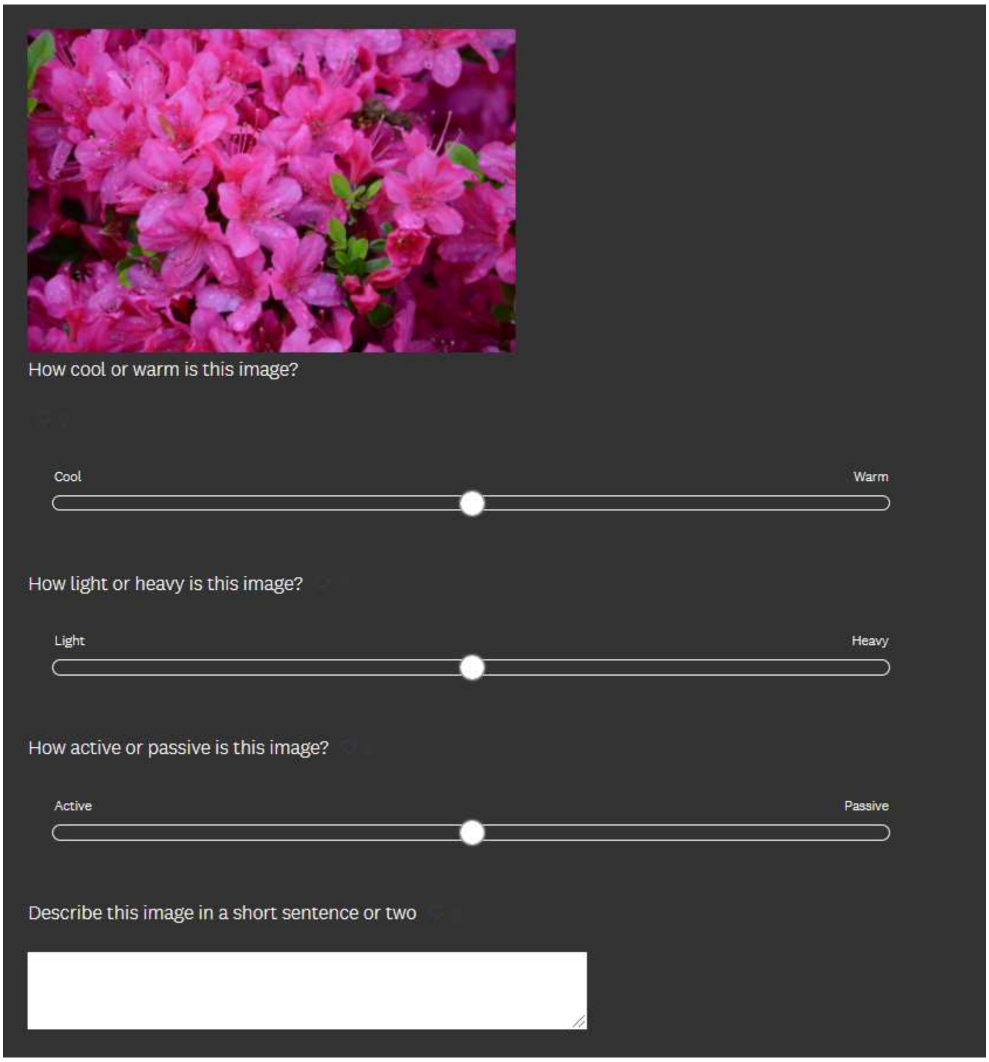


Figure B.2: A sample image question.

Welcome to this study on the effects of blue light filters on the emotions associated with colors.

This study essentially consists of four parts.
First, you will be asked to install f.lux, a program which alters the colors on your screen. Blue light filters like f.lux are used to reduce the amount of blue and green light emitted from devices at night, as these have been shown to have an impact on sleep. Most modern operating systems have a setting to do this already, but to ensure consistency, if you have turned this on, I ask that you temporarily disable the built in version and use f.lux.

Second, you will be asked to find a well-lit room for the remainder of the study, and asked to spend at least 15 minutes adjusting to the light from your computer. There, with f.lux enabled, you will be asked a few questions about demographics and the circumstances in the room. After that you can do whatever you like using your computer for the rest of the adjustment time.

Third, you will be shown a color, and be asked to decide where it belongs on three scales: Warm or Cool, Heavy or Light, and Active or Passive. You will then be asked what name you would give the color. There are no wrong answers for any of these, just go with your gut reaction. This will repeat for a few dozen different colors.

Fourth, you will be shown some pictures, and be asked to evaluate them on the same scales as in the third part, as well as give a short sentence describing them.

After that, you'll be done with the study and will have helped extend our understanding of blue light filters.

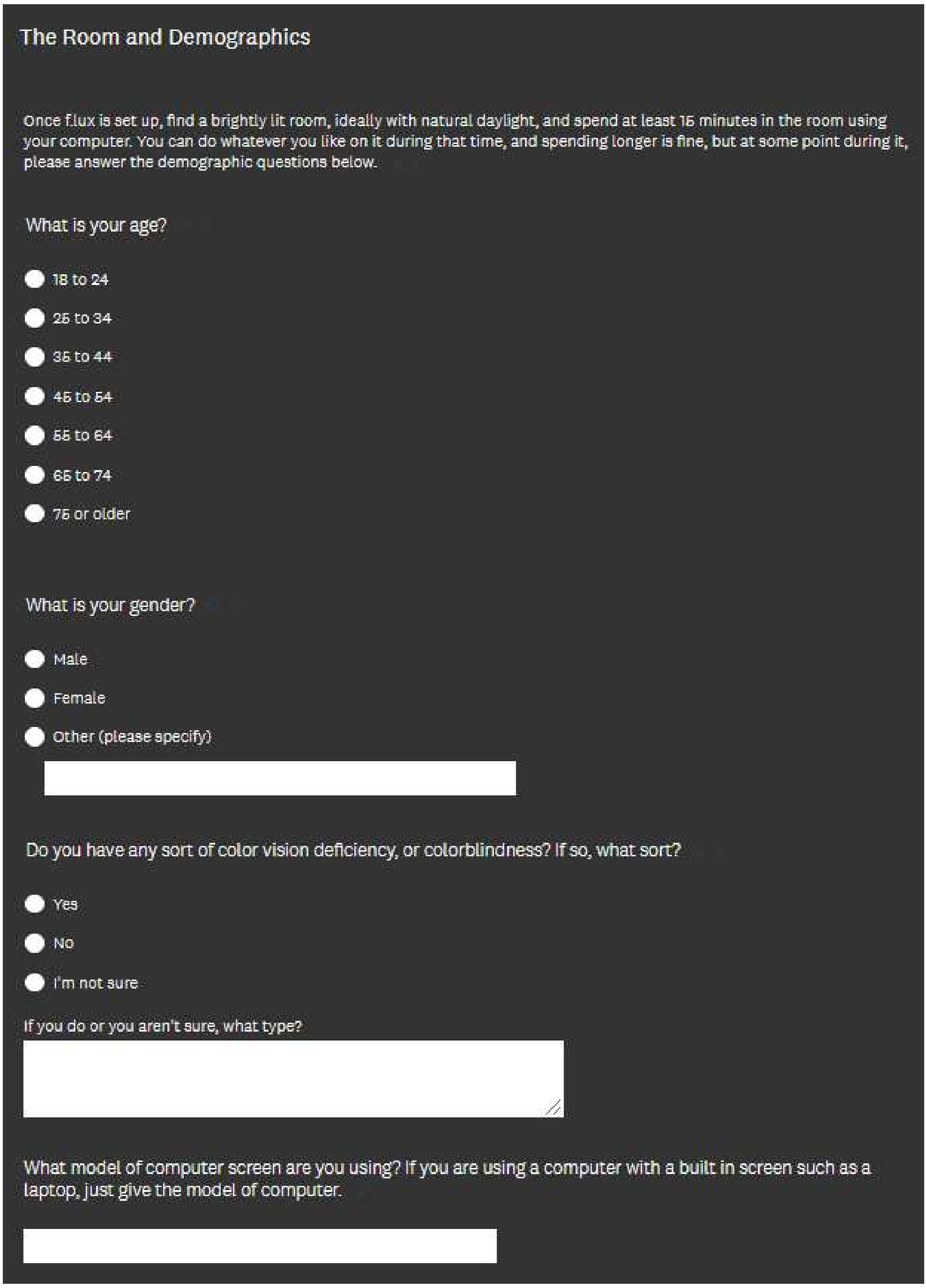
The information you provide in this survey will be used for academic research and the writing of a thesis paper. If you want to stop at any point you can, and if you want to have your results removed for any reason, email bluelightcolorstudy@gmail.com with your participant number.

Using a computer for an extended period, especially in an otherwise dark room, may cause eye strain. It is recommended that you reduce the brightness of your screen, and look away from your screen or close your eyes occasionally to combat this. Using screens shortly before sleeping can cause difficulties in getting proper sleep, so it is recommended that you complete this exercise shortly after sundown to minimize the impact on your sleep.

Do you agree to participate in this study?

- [ ] I agree that the information I provide here can be used as described above.
- [ ] I understand the risks associated with using a computer under these circumstances.
- [ ] The study has been explained to me and I agree to participate.
- [ ] I understand that I can withdraw from the study at any time for any reasons.

Figure B.3: The informed consent page of the survey.



The Room and Demographics

Once f.lux is set up, find a brightly lit room, ideally with natural daylight, and spend at least 15 minutes in the room using your computer. You can do whatever you like on it during that time, and spending longer is fine, but at some point during it, please answer the demographic questions below.

What is your age?

- 18 to 24
- 25 to 34
- 35 to 44
- 45 to 54
- 55 to 64
- 65 to 74
- 75 or older

What is your gender?

- Male
- Female
- Other (please specify)

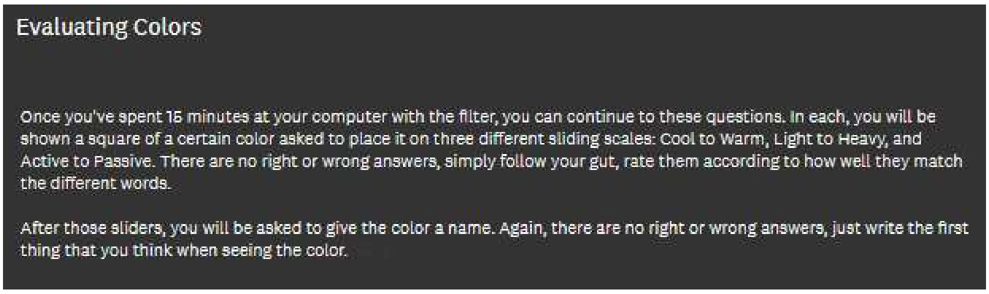
Do you have any sort of color vision deficiency, or colorblindness? If so, what sort?

- Yes
- No
- I'm not sure

If you do or you aren't sure, what type?

What model of computer screen are you using? If you are using a computer with a built in screen such as a laptop, just give the model of computer.

Figure B.4: The demographics collection page of the survey.



Evaluating Colors

Once you've spent 15 minutes at your computer with the filter, you can continue to these questions. In each, you will be shown a square of a certain color asked to place it on three different sliding scales: Cool to Warm, Light to Heavy, and Active to Passive. There are no right or wrong answers, simply follow your gut, rate them according to how well they match the different words.

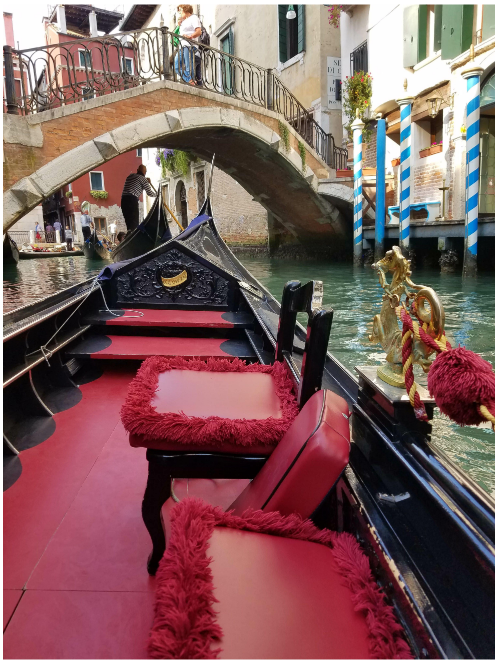
After those sliders, you will be asked to give the color a name. Again, there are no right or wrong answers, just write the first thing that you think when seeing the color.

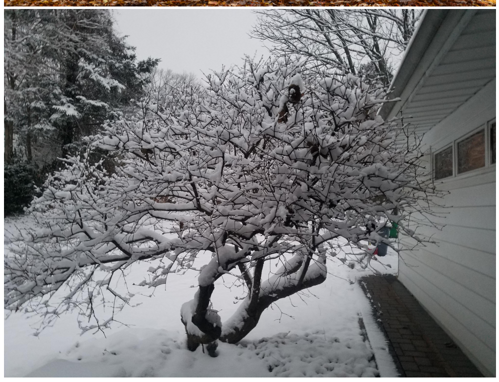
Figure B.5: Instructions given in the survey.

Appendix C

Images used in Survey

The 8 images used in the last portion of the survey. All images are by kconners on MorgueFile.





For DIVA

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