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Effects of Screen Light Filtering Software on Sleep and Morning Alertness

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EFFECTS OF SCREEN LIGHT FILTERING SOFTWARE ON

SLEEP AND MORNING ALERTNESS

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A Thesis

Presented to

The Graduate Faculty

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In Partial Fulfillment

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Master of Science

Mental Health Counseling

_____

by

Heng-Yu Jonathan Chi

November 2017

CENTRAL WASHINGTON UNIVERSITY

Graduate Studies

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ABSTRACT

EFFECTS OF SCREEN LIGHT FILTERING SOFTWARE ON

SLEEP AND MORNING ALERTNESS

by

Heng-Yu Jonathan Chi

November 2017

Research has shown that blue light can impact the circadian rhythm. Research has

also suggested that use of electronic devices, such as computers and televisions that emit

blue light before sleep, can negatively impact sleep quality. This research has led to the

creation of computer software which lowers the levels of blue light in the evening to help

with sleep. This study looked at the impact of wavelength filtering software on sleep

onset, sleep duration and subjective alertness after morning waking of four college

students. The college students were randomized into two groups and had the wavelength

filtering software f.lux installed on their computer. Participants in the intervention group

had their computer set to display 1900 K light 2 hours before bedtime for 7 days straight

while the control group had their computer set to display 5000 K light. All participants

were asked to complete the Pittsburgh Sleep Diary for 7 days straight. Participants in the

1900 K light condition on average had a longer sleep onset latency, shorter sleep duration

and were subjectively less alert in the morning compared to the 5000 K light condition.

However, the variability within groups made any differences in the means statistically

insignificant. The majority of participants in both groups wanted to continue the software

after the study. The low sample size prevented significant results from being formed. The

study served as a pilot study to help direct future research on wavelength filtering

software.

ACKNOWLEDGMENTS

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CHAPTER I

INTRODUCTION

There has been an increase in the use of personal electronics by the general American population within the past 20 years. Tablets have come from being almost nonexistent in 2009 to being used by an estimated 45% of the population in 2015 and an estimated 92% of Americans own a cellphone and 72% own a computer (Anderson, 2015). Many of these electronic devices, aiming to simulate daylight, emit relatively high levels of blue light (Cajochen et al., 2011; Chang, Aeschbach, Duffy, & Czeisler, 2015).

The prevalence of the use of personal electronics with LED screens has resulted in concerns from researchers over its potential effects on sleep (Holzman, 2010). This concern comes from previous research on the role of light acting as a resetting mechanism for the body's internal cycle of day and night (Vitaterna, Takahashi, & Turek, n.d.). The link between blue light and the body's internal day night cycle has been shown through behavioral research and through the presence of neuronal pathways (Holzman, 2010).

A survey in 2011 estimated that roughly 87% of individuals in the US have had sleep difficulties for at least a few nights each week (National Sleep Foundation, n.d.). A further 38% of responders said that they had at least a few nights each week where they could not fall asleep easily and 61% felt "un-refreshed" the next day. Overall 63% of individuals responded saying that they did not get enough sleep on weekdays. Lack of sleep has also been linked with obesity, heart problems, diabetes, anxiety, depression and a higher mortality rate (Colten & Altevogt, 2006). With the high prevalence of poor sleep

and the consequences of sleep deficiency, there is a need to find interventions that are easily implemented and disseminated.

The effort to search for ways to help people sleep better as well as past research on blue light has led to the creation of software such as f.lux (Hernendez, 2016). F.lux, and software like it, adjusts the color of the screen to display less blue light and lowers the brightness during the evening with the intention of helping individuals fall sleep (Hernendez, 2016). This software and software like it, has little research on its direct effects (Heath et al., 2014). This study was designed to study the effects of the use of wavelength filtering and brightness lowering software on the time it takes to fall asleep, the amount of sleep, and the alertness of college students when waking up.

CHAPTER II

LITERATURE REVIEW

Circadian Rhythm Biology

The circadian rhythm is our body's internal cycle as evidenced by physical and behavioral changes that coincide with night and day (Vitaterna et al., n.d.). Changes in the circadian rhythm are often referred to as a phase shift, which can either be a phase advance or a phase delay (Vitaterna et al., n.d.). A phase advance is when the biological daytime moves forward in time, while a phase delay is when the biological nighttime is delayed (Lewy, 2010). While the propensity to sleep is impacted by the circadian rhythm, sleep can happen at any point during the circadian rhythm (Cajochen, Kräuchi, & Wirz-Justice, 2003). Research has shown that the circadian rhythm is primarily controlled by the suprachiasmatic nucleus (SCN) located in the hypothalamus (Holzman, 2010; Vitaterna et al., n.d.). Evidence for the role of the SCN comes from lesion studies in animal models where parts of the entire SCN are damaged or removed (Silver & Schwartz, 2005). In one study, rats with damaged SCNs started drinking at random points in a room with a 12-hour light and dark cycle, compared to rats with an unaffected SCN who drank primarily when the room was dark (Stephan & Zucker, 1972).

Further support of the role of the SCN in the circadian rhythm was demonstrated by transplanting SCN cells into brain tissue with a damaged SCN (Tousson & Meissl, 2004). In one set of experiments, the authors took coronal slices from mice with a section of the hypothalamus that had the SCN in order to examine whether the SCN was affecting the neuroendocrine as well as the autonomic system. Microelectrodes were used to record the hypothalamus activity. During the initial recordings, the researchers found

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that there was a pattern of about 24 hours in the firing. Next, the researchers removed a part of the SCN or the entire SCN and found that the pattern of firing became incoherent even when a part of the SCN was removed. Finally, the researchers grafted cultured SCN cells which restored a regular pattern in the hypothalamus. The regular pattern was also restored by the use of the chemical arginine–vasopressin. Ultimately, the researchers found that the SCN sends its patterns though neurons as well as chemical diffusion. In addition to finding a general source for the circadian rhythm and the SCN, other researchers have also found links between melatonin and the SCN (Gillette & McArthur, 1995).

      Melatonin and the Circadian Rhythm. During the night phase of the circadian rhythm, the SCN causes a chain reaction leading to the creation of melatonin in the pineal gland (Gillette & McArthur, 1995). Because of the link between the circadian rhythm and melatonin, studies on the circadian rhythm often measure the levels of melatonin in participants to chart participant's circadian rhythm (Cajochen, Zeitzer, Czeisler, & Dijk, 2000). Research has found that the SCN's body clock influences the production of melatonin which in turn influences the SCN's body clock (Gillette & McArthur, 1995). While melatonin is oftentimes used as a measurement of the circadian rhythm it does not directly impact sleep itself and cannot be used as an indicator of sleep quality (Cajochen et al., 2003). Melatonin can indirectly impact sleep by phase shifting the circadian rhythm, decrease sleep onset latency and inhibit excitatory signals from the SCN (Cajochen et al., 2003).

      Cues and the Circadian Rhythm. While the SCN keeps an internal body clock to regulate the circadian rhythm, this body clock is not perfectly accurate (Vitaterna et al.,

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n.d.). The circadian rhythm, regulated by the SCN, is roughly a little over 25 hours long (Holzman, 2010). To maintain accuracy, the body uses external cues to help regulate the circadian rhythm (Vitaterna et al., n.d.). The external cues can cause phase shifts in the individual's circadian rhythms. According to these authors these external cues are called zeitgebers and include temperature, physical activity, social interaction. Some zeitgebers such as social interaction have a relatively small effect (Beattie, Kyle, Espie, & Biello, 2015). Light however is by far the most influential zeitgeber in animals (Vitaterna et al., n.d.).

Properties of Light

Being a wave, the characteristics of light are determined by the amplitude and wavelength of the wave. Higher energy levels within the light wave are associated with shorter wavelengths and higher amplitudes. Amplitude and wavelength are physical dimensions of light while brightness and hue are the respective psychological dimensions of light. While different units of measurements can be used for wavelengths and amplitudes, within the research literature that this proposal covers, nanometer (nm) is most commonly used for wavelength and lux is most commonly used for light intensity. Light that only emits one wavelength is referred to as monochromatic light. Most of the light we see is polychromatic light which consists of a range of light at different wavelengths. This is why when light is shown though a prism it gets divided. When describing polychromatic light, the term peak wavelength refers to the wavelength where there is the largest output of light. Light that has a narrower range of wavelengths is considered more saturated than light that has a wider range of wavelengths.

For reference, 380 nm to 700 nm is generally the extent of the human ability to perceive light and it is known as the visible spectrum ("Visible light," n.d.). The longest wavelengths within the visible spectrum are perceived as red, while the shortest wavelengths are perceived as violet ("Visible light," n.d.). White light does not have a single wavelength but rather is composed of multiple separate wavelengths. Full daylight is around 10,752 lux, overcast daylight is around 1,075 lux and indoor recommended light levels are around 500 lux ("Recommended light levels," n.d.). Additionally, within the context of lighting, color temperature is also used to describe light color. The unit for color temperature is kelvin (K) (Thomas & Matthews, n.d.). According to the authors, lower kelvins are perceived as red and orange while higher kelvins are perceived as blue and color temperatures in the middle of the scale (5,500 K) are perceived as white. In general, daylight is on the higher end of the scale (Thomas & Matthews, n.d.).

Effect of Light on Sleep

One must first look at the underlying biology to understand the role of light on the circadian rhythm. The optic tract can be divided into the primary optic tract and the retinohypothalamic tract (Holzman, 2010). The primary optic tract goes towards the occipital lobe and is associated with vision while the retinohypothalamic tract goes to the suprachiasmatic nucleus. Rather than receiving input from rods or cones the suprachiasmatic nucleus receives input from intrinsically photosensitive retinal ganglion cells (Zaidi et al., 2007). The intrinsically photosensitive retinal ganglion cells were discovered in late 1990s using animal models (Holzman, 2010).

Mice were genetically engineered to not have rods or cones yet light still affected their behavior (Holzman, 2010). Later research was done on two human participants to

support the existence of the cells in humans (Zaidi et al., 2007). According to the authors, participants did not have functional cones due to disease yet they were still able to sense the presence of light at some wavelengths. The investigators were able to cause changes in sleep patterns and alertness by exposing the participants to 6.5 hours of light at a specific wavelength. The participants went to sleep later than usual and had a lower subjective sleepiness when they woke up. The retinohypothalamic tract gives a biological explanation of how light can affect the circadian rhythm.

Research has shown that exposure to light during the beginning of the animal's subjective night causes the individual to delay the circadian rhythm and go to sleep later (Vitaterna et al., n.d.). In several studies, the presence of light during the rest of the animal's subjective night caused the circadian rhythm to advance and the subject to be more alert earlier than the subject otherwise would be (Vitaterna et al., n.d.). This advance and delay of the circadian rhythm led the researchers to theorize that light acts to reset the circadian rhythm. Other research has shown that it is not only presence of light that affects sleep and the circadian rhythm but the properties of light as well (Cajochen et al., 2000; Lockley, Brainard, & Czeisler, 2003).

Effect of brightness on sleep. In one study, participants were subjected to an absolute light-dark cycle to see how the circadian rhythm of participants can be altered under different lighting conditions (Wever, Polášek, & Wildgruber, 1983). During the experiment, length of light-dark cycles in the room were gradually increased. The light level of the light portion of the light-dark cycles was experimentally manipulated at 1000 lux and 4000 lux. Participants in the brighter light condition had longer circadian cycles as measured by sleep, body temperature and urine. Although the study demonstrated that

brightness affects the length of the circadian rhythm it did not give information on how brightness affects the ability to get to sleep or the quality of sleep.

A later experimental study was done to look at brightness and alertness (Cajochen et al., 2000). Participants were 23 adults who kept a regular sleep pattern for 2 weeks. Participants were exposed to 6.5 hours of light that was between 3 lux to 9100 lux depending on the condition to which they were randomly assigned. The light was close to the subjects' bed time and before and after the intervention the light level was around 3 lux. Objective alertness was assessed though the Karolinska Drowsiness Test where electroencephalogram (EEG) recordings were measured while the participant focused on a spot for 4 minutes (Putilov & Donskaya, 2013). Subjective alertness was assessed though a self-report test called the Karolinska Sleepiness Scale (Gillberg, Kecklund, & Akerstedt, 1994). Melatonin levels, EEG recordings and body temperature were also collected to assess where the participant was in their circadian rhythm. Overall the researchers confirmed their hypothesis that there was a dose response relationship and found that as light level increased, alertness (subjective and objective) increased and melatonin decreased. The study result indicated that as little as 50-130 lux of light can reset the circadian rhythm. The researchers note how brightness can be used to combat sleepiness for those who need to stay up late. Research has also examined the role of wavelength on sleep as well.

Effect of wavelength on sleep. Unlike the rods and cones which have multiple types of photopigments optimized to different bands of wavelengths of light, the intrinsically photosensitive retinal ganglion cell has only one type of photopigment called melanopsin (Bailes & Lucas, 2013). Taking human cell cultures with melanopsin and

exposing them to different wavelengths of light, the authors found that the photopigment was most sensitive to light at the wavelength of 479 nm. Perceptually this wavelength is seen as blue light ("Visible light," n.d.).

The Bailes and Lucas (2013) findings are further supported by behavioral experiments on humans (Lockley et al., 2003). Subjects without rods and cones were found to have a later sleep onset time when exposed to 6.5 hours of 460 nm light than when exposed to 6.5 hours of 555 nm light (Zaidi et al., 2007). The difference in exposure to 460 nm light and 555 nm light has also been looked at in individuals with sight (Lockley et al., 2003). Lockley et al. (2003) investigated how 6.5 hours of 555 nm light versus 460 nm light affected the circadian rhythm and melatonin levels of 16 participants ages 19 to 27. Lockley et al. (2003) found that individuals exposed to the 460 nm light had less melatonin and a larger change in the circadian rhythm as seen by a larger phase delay. Melatonin level in both studies was assessed through saliva samples which were also used to help assess the phase delay. This was calculated by the difference in the two circadian rhythms, the one before the intervention and the one after the intervention (Lockley et al., 2003; Zaidi et al., 2007). Overall the results point to a potential impact of blue light on sleep, light that many electronics emit (Holzman, 2010).

Chellappa et al. (2013) examined the impact of different wavelengths of levels of light on the sleep cycles of 30 participants ages 20 to 31. The researchers had the participants sleep at a regular time and length for 1 week before the intervention. Six hours before the participants' bedtimes the subjects were exposed to 90 minutes in dim light and then 120 minutes in darkness. After that, depending on the group they were in, the participants were exposed under 2500 K, 3000 K or 6500 K light for 120 minutes.

The dim light was less than 8 lux and the manipulated lights were between 25 to 32 lux. The participants were then shown dim light for 45 minutes before going to bed. The researchers measured EEG readings to get the participants' sleep cycles. Subjects exposed to 6500 K blue enriched light had less frontal slow wave activity in the first sleep cycle. Chellappa et al. (2013) indicated that exposure of blue light before bed may affect sleep structure but further research needs to be done on long term and functional effects. The current study will exend Chaellappa's (2013) study by looking at the use of blue light over a 2 week period and look at waketime alertness.

The Effect of Electronic Use on Sleep

Concerns about the use of electronics during the evening altering the circadian rhythm have come from the light level given off and wavelength of LCD screens (Holzman, 2010). As earlier research noted, lux as low as 50 lux can affect the circadian rhythm; light levels that are well within the reach of phones and tablets (Cajochen et al., 2000; Krahn & Gordon, 2013).

Computer monitors cannot display all the wavelengths but rather use red, green and blue pixels to create the perception of different colors. Researchers measured a light spectrum profile from an Apple tablet displaying an e-book (Chang, Aeschbach, Duffy, & Czeisler, 2015; Zaidi et al., 2007). The spectral profile is a viewing of complex wavelength patterns of light as constituent bands of light. The study found that the largest peak in wavelength was at 450 nm which is perceived as blue (Chang et al., 2015; Heath et al., 2014). Further research on a computer monitor has shown a similar peak of light at around 460 nm (Cajochen et al., 2011). This is close to the wave length of 460 nm – 479 nm that past research suggested as the maximum sensitivity for the intrinsically

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photosensitive retinal ganglion cells (Bailes & Lucas, 2013; Zaidi et al., 2007). With electronics emitting light that matches the criteria to stimulate the intrinsically photosensitive retinal ganglion cells, investigators have looked at electronic use and sleep within different populations (Holzman, 2010).

   Correlational data on electronic use and sleep. Numerous correlational studies have been performed investigating the relationship between sleep and electronic use by children and adolescents (Hale & Guan, 2015). Hale and Guan (2015) systematically reviewed 67 studies on the subject. The results are difficult to compare since sleep can and was measured though several ways in the different studies. Common dependent variables were the time that participants headed to bed, time they took to fall asleep, duration of sleep, subjective view of daytime sleepiness, subjective view of daytime tiredness, number of times they woke up at night and several more (Hale & Guan, 2015).

   Computer use was investigated in 31 of the 67 studies, and 94% of them found a link between sleep and computer use (Hale & Guan, 2015). The review showed that those who used computers longer tended to stay up later and have more sleep problems. There were mixed results between studies on the amount of time it took to fall asleep. Mobile device use was monitored in 18 of the 67 studies and 83% of them found a link between sleep and mobile device use for either daytime tiredness, presence of a delayed bedtime or sleep onset latency.

   Correlations between sleep and electronic use have been found in young adults as well. For example, Mesquita and Reimão (2010) used a questionnaire on 710 college students to get information about electronic use and the Pittsburgh Sleep Quality Index to get information on sleep quality (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989).

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The Pittsburgh Sleep Quality Index uses subjective sleep quality, sleep latency, disturbances during sleep, daytime functioning, sleep medication usage, and sleep duration to give a global score for subjects' sleep quality (Buysse et al., 1989). In the study, individuals with poorer sleep were more likely to use computers in the evening. As with all correlational studies, causality cannot be linked so it may be possible that individuals who sleep worse are more inclined to use electronics (Hale & Guan, 2015). Experimental research is needed for inferences of causation.

Experimental data on electronic use and sleep. One study compared the use of an LED screen versus a cold cathode fluorescent lamp (CCFL) (Cajochen et al., 2011). The CCFL screen displays a different spectrum profile and has 30% of the amount of blue light (440 nm to 470 nm) compared to an LED screen (Cajochen et al., 2011). The authors took 13 participants, ages 19 to 34, and exposed them to the CCFL screen or to the LED screen for 5 hours before the participants went to bed. The exposure started 6 hours before the subjects went to bed. The screens were blank but participants did watch a movie on the screen for 20 minutes after 2 of the 5 hours. After 1 week they switched conditions. Participants in the study first needed to establish a regular wake and sleep schedule for 2 weeks. The authors then measured melatonin, memory performance using a word pair learning task, EEG readings, alertness, and subjective sleepiness using the Karolinska Sleepiness Scale and the Karolinska Drowsiness Test. Users viewing the LED screen had less melatonin compared to those that did not. Those who viewed the LED screen also had higher cognitive performance and alertness after the exposure and less sleepiness during the movie. The enhanced alertness and cognition are thought to be a

potential detriment if the user wants to sleep and may lead to a longer sleep onset (Cajochen et al., 2011).

Further research looked at the impact of time and brightness of LEDs on melatonin (Wood, Rea, Plitnick, & Figueiro, 2013). The study was a 2x3 factor within subject study with 13 participants. The conditions of the first factor were with a tablet (40 lux of light), with a orange tinted goggles that blocked short wavelengths combined with using a tablet, and with goggles that had blue LEDs combined with using a tablet. It is notable that the authors also compared a 1-hour exposure against a 2-hour exposure for the second factor when past studies have used exposure times of over 4 hours. Like most other sleep studies, participants needed to establish a regular pattern of sleep for 1 week. The researchers found that for the tablet condition 1 hour of exposure to the light did not produce a decrease in melatonin levels as opposed to 2 hours where it did. The condition with the tablet and blue light showed effects on the melatonin level after only 1 hour. The study shown that while tablets can affect melatonin levels a duration of over an hour is needed. A weakness of the study is that it did not measure the functional impact of the conditions on sleep.

Chang et al. (2015) wanted to compare reading off a tablet versus reading off a physical book on sleep and alertness. The independent variable was whether participants got 5 hours of reading on the tablet before their bedtime or 5 hours of reading a paper book before their bedtime. The ebook emitted roughly 31 lux while the print book reflected less than 1 lux. Participants needed to establish a regular pattern of sleep for 3 weeks before the intervention. Unlike previous studies, where the intervention only took place over one evening, this study had the intervention for 5 days. The authors used the

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Karolinska Sleepiness Scale to get a subjective look on sleepiness through a 9-point self-reported Likert scale, and the Karolinska Drowsiness Test for a more objective look on sleepiness through EEG reading. Polysomnographic recordings were used to get the amount of time slept and melatonin data were also recorded for the study. Like previous studies, results indicate that reading the tablet substantially decreased melatonin and subjective sleepiness in participants right before they went to bed. Participants in the tablet condition were also more likely to be sleepier in the morning when they filled out the Karolinska Sleepiness Scale after waking up. The Karolinska Sleepiness Scale was repeatedly filled out over the course of an hour in roughly 6 minute intervals. What was new to this study is that they found that participants reading the tablet took longer to fall asleep and had lower levels of alertness during the morning. However, the difference in sleep onset latency was only roughly 10 minutes indicating that the effects of blue light on alertness may be a result of a change in the sleep structure than a decreased sleep latency. The study shows that electronic use before bedtime can potentially impact sleep, melatonin and the circadian rhythyn. This is concerning given that electronics are widely used before bedtime (National Sleep Foundation, n.d.).

One survey of United States residents, performed in 2011on 1,508 participants ages 13-64, looked at sleep habits as well as electronic use (National Sleep Foundation, n.d.). In the survey 61% of respondents were on their computer before attempting to get to bed. The results indicated that 58% of respondents used cellphones during the time. Younger age groups were substantially more likely to use electronics an hour before attempting to go to bed. Overall the survey points to a high prevalence of portable

electronic use before bed suggesting that interventions targeted towards the effects of

electronics on sleep can impact a large percentage of individuals.

Interventions that Filter Light for Sleep

      Tinted glasses for sleep. Orange tinted glasses known as blue blockers have been

developed as a way to block blue light (Lely et al., 2015; Sasseville, Paquet, Sévigny, &

Hébert, 2006). The glasses are designed to block wavelengths smaller than 540 nm as

well as minimize wavelengths around 550 nm (Sasseville et al., 2006). One study using

14 participants was designed to investigate melatonin levels of those that used blue

blockers versus those that used placebo glasses which were tinted gray when they were

exposed to 1 hour of bright light (Sasseville et al., 2006). The investigators controlled for

light intensity by increasing the light level for the participants using the blue blockers.

This made it so that brightness was not a confounding variable. They found that

participants using the placebo had a significant drop in their melatonin levels while the

melatonin levels for the blue blocker group were not affected when compared to the

baseline. A weakness of the study was that the light used was around 2200 to 4000 lux.

Consequently, the light levels were higher than what most people will encounter before

bed ("Recommended light levels," n.d.). It is normally recommended that 150 lux be set

for light at home ("Recommended light levels," n.d.). The study showed the potential of

the goggles as being a simple way to possibly prevent light from affecting the circadian

rhythm.

      A more recent study looked at the effects of using blue blockers under a LED

screen for teen males (Lely et al., 2015). The exposure lasted 5.5 hours each day for a

week, 3 hours before bed. In addition to measuring melatonin, the researchers also looked

at cognitive performance using a psychomotor vigilance test, wakefulness, and subjective sleep quality as measured by the Leeds Sleep Evaluation Questionnaire. Participants in the blue blocker group again had higher levels of melatonin. The blue blocker group was more subjectively tired before going to bed. There were no significant differences in tiredness in the morning or in sleep quality. The study suggests that blocking blue wavelengths may not be enough to substantially affect sleep quality but it can potentially affect the time it takes to get to sleep. While potentially useful, blue blocker glasses require the participant to remember to put on the glasses each evening.

Wavelength filtering room lights for sleep. Recently research is looking at room lights that change in kelvin during the day eliminating the need for a behavioral change (M Giménez et al., 2011). Giménez et al. (2011) examined color changing lights at a hospital setting on 171 patients. The patients were diagnosed with heart problems and their average age was 65.9 ($SD = 14.9$). The light shifted from 6500K to 2700K. The researchers used actiwatchs that monitored body movement to measure sleep onset duration, sleep latency and sleep latency. Because the participants were hospital clients the length of the intervention depended on how many nights an individual stayed at the hospital. On average participants were in the hospital for 7 nights and the maximum time a subject was at the hospital was 19 nights. The researchers found a significant interaction between the number of days spent in the hospital and the condition. Participants who were in the hospital longer and were in the intervention group had a shorter sleep onset delay, longer sleep duration and better sleep efficiency. While the kelvin changing lights can affect the light given off by the room it does not address the light given off by electronics such as televisions, computer screens, tablets and phones.

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Wavelength filtering software for sleep. A recent approach has come to alter the displays of electronics rather than have subjects adopt a new behavior or purchase new light sources (Hernendez, 2016). Informed by the research on electronics and blue light, application developers have come out with different applications for various platforms that shift displays towards a lower color temperature by decreasing the levels of blue light emitted (Hernendez, 2016). This has an effect of filtering low wavelengths of light and decreasing the overall brightness of electronic screens (Heath et al., 2014).

One of the more predominantly featured wavelength blocking software is f.lux (Beres, 2015). The application, currently available on Windows and macOS, alters the screen color depending on the time of day, location and wake time of the user ("f.lux," 2009). Outside research using a USB2000 + RAD spectroradiometer has shown that, when it is set to a color temperature of 2700 K, the levels of color around 450 nm go down significantly and that most of the emitted light is 588 nm (Heath et al., 2014). The software has been featured in news sources such as the *Wall Street Journal* and *Huffington Post* as an evidence-based application that may help with sleep (Beres, 2015; Hernendez, 2016).

This trend in the software and the research background behind it has been noticed by large companies such as Amazon, Apple and Microsoft (Hernendez, 2016; Pidgeon, 2017). Amazon added a feature to their tablets in 2015 called Blue Shade that lowers the levels of blue light (Hernendez, 2016). In March of 2016, Apple released an update to their mobile devices adding a similar feature called Night Shift ("iOS 9.3 updates," 2016). Later in September of 2016, Apple embedded the Night Shift mode within the quick access setting menu of their phones increasing the accessibility of the feature

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(Hardawar, 2016). The Android operating system for phones does not have a blue light filter setting but applications are available in the Google Play app store (Hernendez, 2016). The most prominent wavelength managing application in the Google Play app store with over a million downloads is the Twilight app. The app has 154,153 reviews giving it an overall rating of 4.5 out of 5 stars (Urbandroid, n.d.). In late summer of 2016 the Canadian eBook company Kobo released an eBook that changes color depending on the time of day ("Kobo Aura ONE," 2016). In the late spring to early summer of 2017 both Microsoft and Apple released updates to their operating systems for their computers to have this feature significantly increasing awareness and accessibility of wavelength blocking software ("How to use Night Shift," 2017; Pidgeon, 2017).

Microsoft, Apple and Kobo all make claims on their websites that the feature can allow users to sleep better ("How to use Night Shift," 2017; "Kobo Aura ONE," 2016; Pidgeon, 2017). Research however is needed to evaluate the claims of the companies to see whether the effect of filtering blue light on electronics in environments outside of the lab is even effective. The present study looked at the effect of blue light for college students in a field environment.

While wavelength blocking software has a theoretical basis as shown by the existence of the retinohypothalamic tract and past studies on blue light and sleep, little research has been done directly on it (Heath et al., 2014). Difficulties with performing research on wavelength blocking software arise due to how computer monitors can vary in their accuracy of displaying the correct hue and differences in the lux that they emit ("The best notebook displays" 2016). Wavelength blocking software can also differ in the amount of blue light that they emit ("f.luxometer," n.d.).

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One study on wavelength blocking software only showed small to insignificant effects of the software (Heath et al., 2014). Heath et al. (2014) looked at how the use of f.lux over 1 hour affected sleep compared to dim light and a control. The investigators used a sample of 16 adolescents who were in a within-subject experiment that lasted 3 days. For each night, the participants read a book on an iPad, an iPad with f.lux or a book with dim lighting. Next, they measured cognitive alertness using the GO/NOGO task, subjective sleepiness, sleep pattern and time to fall sleep using an EEG. The researchers also looked at the participants' propensity to sleep earlier or later as a mediating factor measured by the Munich Chrono Type Questionnaire. In the end only cognitive alertness scores right after the light exposure had a significant difference, with the users of f.lux being more cognitively alert. This study is important in that it shows that wavelength affecting software may not significantly affect the time to fall asleep nor the sleep itself. However, more research needs to be done to confirm this and whether the results are generalizable to adults. One of the things that the researchers noted was that the length of exposure was significantly smaller compared to the exposure time in previous studies (Heath et al., 2014). This research is consistent with that of Wood et al.'s (2013) study showing that more than 1 hour of exposure from a tablet is needed to affect melatonin levels.

The lack of effect in Heath et al.'s (2014) study may also be shown by preliminary results of a study from Krahn and Gordon (2013). The preliminary results show that holding the iPad 3 14 inches away decreases the lux level for the viewer to 32 lux at maximum brightness vs 248 lux when the tablet is right next to the user's face. Hue and saturation values were not noted in the paper. The authors suggested that using

tablets at 14 inches may be effective in preventing adverse effects of the light. In contrast, the study on f.lux had the subjects use the iPads 15.75 inches away (Heath et al., 2014). However, in one survey, on high school students in Shanghai, researchers found that, in a sample of 1,067 students, only 22.9% of students looked at their screen further than 9.84 inches away (Shan et al., 2013).

Ultimately, current research on wavelength affecting software is minimal compared to the widespread use of the software (Shan et al., 2013). While indirect research on blue light has shown an impact of light on melatonin levels and sleep cycles, there is little support of functional outcomes as a result of blocking blue light before sleep (Heath et al., 2014). There is no study on f.lux that exposes the participants for more than an hour and there is also no study on f.lux use in a computer which has a greater surface area to emit light. Studies have generally been performed in highly controlled laboratory environments that are not necessarily present in the outside environment causing them to have questionable ecological validity. Longer term experimental research going past 2 weeks on the impact of electronics on sleep has not been looked at as well (Cajochen et al., 2011).

The current study was designed to partially bridge the gap in research and practice by comparing individuals who use wavelength blocking software at recommended settings (1900 K) for at least 2 hours before bed on their computers for 1 week versus those who use the software at a control setting (5000 K). It was predicted that participants using a wavelength blocking application at recommended settings for 2 hours before their normal bedtime would overall report shorter sleep onset latency, longer sleep duration

and higher alertness on final wakening over participants who use the software at a control

setting.

CHAPTER III

METHODS

Design

The study was a 7-day randomized longitudinal study with an attention (placebo) control comparison group and experimental group as shown by Figure 1. A longitudinal design format was selected because of the measure used for the dependent variables. Since sleep can vary day by day, the sleep diary measure used for the dependent variables needs to go on for multiple days in a row to get a more valid measurement. A single pretest and posttest is not enough. While the measure used was normed using 14 days of measurements, in order to attract more participants the study was shortened to 7 days of measurements (Monk et al., 1994).

Point	A	B	C							D
Day			1	2	3	4	5	6	7	
Control			Screen set to 5000 k before sleeping							
Intervention			Screen set to 1900 K before sleeping							

Figure 1. Study Design. Chart of the design and flow of the study. At point A participants had their first meeting with the PI where they were given information of the study, signed the informed consent, given the Ishihara colorblind test and asked to backup their computers. At point B participants were asked to meet with the PI again to review the requirements of the study and install f.lux. At point C the participants filled out surveys that were given with f.lux. active. At point D the participants were given the exit survey.

The dependent variables were sleep duration, sleep onset latency and wake time alertness which was measured by an online sleep diary. Individuals in the attention (placebo) control group had their screen light set to 5000 K (white light) for at least 2 hours before they intend to sleep while individuals in the intervention group had their

screen light set to 1900 K (candle light) for at least 2 hours before they intend to sleep. Participants were guided in person and given an instruction sheet to using f.lux to set their computer to the correct settings. The 5000 K interval for the control group was selected because at that color temperature the computer display still had 450 nm as the peak wavelength yet the display will noticeably change ("f.luxometer," n.d.). The 1900 K interval for the intervention group was selected for two reasons; the narrowband wave lengths are significantly diminished and it is the recommended/default setting for the program ("f.luxometer," n.d.). Sleep onset latency was operationally defined as the number of minutes that it took for the participant to fall asleep. Sleep duration was operationally defined as the number of minutes from when the person fell asleep to when they finally woke up. Morning alertness on final wakening was measured using a self-report 10-point Likert scale (from 1 = "very sleepy" to 10 "very alert") The dependent variables were measured though the Pittsburgh Sleep Diary (PghSD) (Appendix A) that was administered for 7 consecutive days though an online survey (Monk et al., 1994). The participants were asked to complete the survey within 2 hours of waking.

Participants

The study recruited a total of eight participants with the mean age of 19.9 (*SD* = 2.0) and an equal number of females and males. All participants were undergraduate students taking a psychology course. Due to attrition, only four participants stayed in the study. The four participants who left the study left before data collection began due to various reasons. Half of the people that left (*n* = 2) the study was due to them not wanting or able to back up their computer. Of the four participants who stayed in the study, the mean age was 21 (*SD* = 2.1) with three male participants and one female participant.

Three of the participants used Mac OS as their operating system while one participant used Windows. There were two participants in each group.

The study received the Institutional Review Board approval to recruit participants. Participants were recruited using the psychology department's Sona system that provided the study description (Appendix B) A research assistant went to research methods psychology classes, and put up posters in the psychology building. To be included in the study, participants needed to normally use their computers within 2 hours before trying to sleep for at least an average of 4 days a week. The participants needed to be ages 18 and over. Participants must also have been able and willing to install software on their computer and know how to backup their computer onto an external hard drive. It was important for participants to know how to backup their computer because the steps and the software to backup a computer can vary between computers manufacturers. Participants must also have had an external hard drive where they can backup their data. Colorblind individuals were excluded from the study; this matches with some of the exclusion criteria that the previous study on f.lux used (Heath et al., 2014). Participants who have been diagnosed with a sleep disorder by a professional were excluded from the study. These criteria were selected since the variables can significantly affect sleep (Heath et al., 2014). Participants who use or have used screen color altering software on their computers were excluded to prevent potential confounds. There were no exclusion criteria based on gender, race or ethnicity.

The 1900 K group participants watched TV on average 6.5 times ($SD = 2.12$) during the study 2 hours before heading to bed which is higher than the 5000 K group which used the TV on average 1.0 times ($SD = 1.41$) during the study. When the 1900 K

group watched TV, the participants watched TV for a longer duration ($M = 57.5$, $SD = 24.75$) each time than the 5000 K group ($M = 15.0$, $SD = 21.21$). The 1900 K group used their cell phone more often 2 hours before bed ($M = 7.5$, $SD = 0.71$) during the week than the 5000 K group ($M = 5.5$, $SD = 4.95$). The 1900 K group used their cell phone longer each time ($M = 35$, $SD = 7.07$) than the 5000 K group ($M = 20$, $SD = 14.14$). The 1900 K reported 4 total naps in the study while the 5000 K group reported 0 naps during the study. Alcohol and caffeine use before bedtime was reported to be only used once by one member of the 1900 K group. The 5000 K group reported exercising 5 hours before bed a total of two times during the study while the 1900 K did not report doing any exercise.

Measures

      Sleep diary. A daily sleep diary that each participant filled out each day for 7 consecutive days was used to measure the dependent variables (Appendix A). The sleep diary is considered a subjective measure since it relies on the user's self-report. A widely used standardized sleep diary does not exist despite sleep diaries being commonly used in research (Carney et al., 2012). Sleep diaries are created specifically for the individual study for most research using sleep diaries (Carney et al., 2012). Research has compared sleep diaries to more accurate objective methods such as ambulatory polysomnographic monitoring and actigraphy (Rogers, Caruso, & Aldrich, 1993; Usui et al., 1999). Ambulatory polysomnographic monitoring generally looks at electrical activity in the brain, eyes and heart, oxygen saturation, and breathing to determine when a subject is asleep and gather data on the sleep cycle (Marcus et al., 2014). Actigraphy uses a device placed on the wrist to monitor body movement to help determine if a client is asleep.

Using 50 adult participants, Usui et al. (1999) compared sleep diaries with actigraphy on 35 adult individuals with and without sleep disorders. The researchers also found that sleep diaries on healthy young adults had a sensitivity of around 87.9% (SD = 6.49) meaning that when participants reported that they were asleep, 87.9% of the time they were asleep as recorded by the actigraphs. The specificity of the sleep diary for young healthy adults was around 96.5% (SD = 2.37) meaning that when participants reported that they were awake, 96.5% of the time they were awake as recorded by the actigraphs. The sensitivity and specificity for elderly healthy adults around 74.3 years old was lower around 80.6% (SD = 2.37) and 91.6% (SD = 2.37). The sensitivity and specificity for individuals with sleeping disorders is 70.9% (SD = 22.3) and 94.0% (SD = 4.59). Later research, on 16 adults, using ambulatory polysomnographic monitoring found that that sleep diaries overestimated the time to fall asleep by an average of 16.97 minutes (Vallières & Morin, 2003). Vallières and Morin (2013) also found that sleep diaries tended to underestimate the amount of time that the participants slept by an average of 56.21 minutes.

The Pittsburgh Sleep Diary (PghSD) (Appendix A) was used to measure sleep onset latency, sleep duration, sleep quality and morning alertness (Monk et al., 1994). In the initial validation studies by Monk et al. (1994) on 96 individuals over 14 days, the PghSD was able to detect sleep differences in the week and circadian timing. The researchers also found that there was a significant correlation (r =.430, p < .0001) for time sleeping when the measure was compared to actigraphy. Monk et al. (1994) also looked at test-retest reliability over an average interval of 22 months. They found a significant correlation with the Pearson's correlation coefficient ranging from .561 to .664

($p < .001$) between the test and retest. Because the validation studies occurred over a 14-day time period and because of the unreliability of sleep, the authors strongly urge users of the instrument to collect data for at least 14 days.

The daily sleep diary was administered through a daily online survey rather than though a journal log for validity and convenience. One research study on 80 adults, using a daily diary over 21 days, for chronic pain found that paper diaries had more non-compliance compared to electronic diaries (Stone, Shiffman, Schwartz, Broderick, & Hufford, 2002). In the study, 90% of participants using the paper diary reported compliance of completing the diary within the requested 30-minute interval. Stone et al. (2002) found that actual compliance to the paper diary was 11% while actual compliance with the electronic diary was 94%.

The PghSD for this study consists of 14 questions and is expected to take less than 5 minutes to complete. The sleep diary questions consist of nominal, ordinal, interval and ratio variables. The first four questions in the sleep diary gathered information on time spent sleeping and the amount of time it took to fall asleep. The next six questions assessed the number of awakenings and how the participant awakened. The final three questions assessed sleep quality, mood on final awakening and alertness on final awakening using a 10-point Likert scale.

Daily questionnaire. A 7 to 11 question daily questionnaire (Appendix C) was given along with the PghSD to check for possible confounds. The number of questions asked depended on some of the answers that the participant chose for some of the questions. The questionnaire was expected to take 5 minutes to complete. The first question assesses for alcohol use on the previous night. This is done because alcohol can

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be an significant extraneous variable that affects sleep and is relatively common in college students (Heath et al., 2014). The next questions assessed whether the participant took a nap, ingested caffeine the evening before, used marijuana the evening before, used any drugs, medication or herbal substances the day before, exercised the evening before or engaged in moderate to strenuous physical activity during the evening. The questions assessed potential variables that may impact the sleep of the participants (Heath et al., 2014). The final three questions were to check whether the participant used their computer and whether f.lux was in effect. If the participant either said yes to any of the confound questions, did not use the computer, did not have f.lux activated, did not submit the survey within 2 hours of their wake time or did not submit the survey at all the data for the day were removed from the statistical analysis. An exception was given if the participant gave notice of why their data would be late and recorded the data each day. This exception happened with two participants who did not have internet access during the weekend. If the participant were to have more than 2 days where their data were removed, the participant was dropped from the study. This did not happen in the study.

Exit survey. There was also a 14 to 22 question exit survey (Appendix D) given at the end of the study. The survey included quantitative and qualitative questions. The survey includes questions in a yes/no, fill in the blank and short answer format. The exit survey was expected to take about 20 minutes to complete. The exit survey's primary purpose was to find potential confounds that may have happened in the study. The confounds assessed were the use of other electronics and the time spent on the computer each night. These confounds were assessed in the exit survey rather than in the daily survey to keep the daily survey brief and increase adherence. The exit survey questions

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include nominal and interval variables as well as short answer responses. The exit survey was also used to inform potential future studies.

      Ishihara colorblind test. During the beginning of the study, the participants were screened for color deficiencies using the Ishihara colorblind test (Appendix E). The test consists of images with different colored dots that will be seen differently by people who are fully colorblind or have red and green color deficiencies (Dain, 2004). Individuals with colorblindness will see different patterns than individuals without colorblindness when they look at the images (Dain, 2004). Each image is only shown to the client for 3 seconds before the next image is shown (Dain, 2004). The specificity and sensitivity of individual images is around 85 to 95 percent while the specificity and sensitivity of the overall test is close to 1 (Dain, 2004). While the test comes in 24 and 38 image versions, the study only used four plates due to the high specificity and sensitivity of the individual plates. The purpose of the test was to do a quick screen for colorblindness and not to make any formal diagnosis. All participants passed the screen ($n = 8$).

Procedure

      The Mac version and Windows version of the f.lux software was downloaded from the f.lux website onto a Kingston Digital DataTraveler 8 GB flash drive. The thumb drive was used to install the software onto the participants' computers when they met with the investigator. Participants were not given the thumb drive but rather they installed the file when they met individually with the principal investigator (PI). The file on the thumb drive was an executable file. The software was scanned by Sophos antiviruses. Before the files were scanned, the antivirus software was updated to the most recent

version. Finally, write protection was enabled onto the flash drive to prevent the files from alteration.

After participants were recruited, the PI or the research assistant and individual participants set up a time to meet. During this meeting, as set by the first meeting outline (Appendix F), the PI met with participants one-on-one. The PI went over the eligibility criteria, the informed consent form, study procedure and answered any questions or concerns. The PI also showed the participant the PI's computer at 1900 K (the setting of the experimental condition) and asked the participant if it was acceptable for their own computer to look like that for at least 2 hours before they wish to sleep for 2 weeks. This was done to diminish differential attrition from the intervention light group. After obtaining the participant's informed consent, the researcher performed the Ishihara colorblind test with each participant individually. Each participant was informed about the limitations of the Ishihara colorblind test. The other participants were asked to wait outside the room while the test proceeded. Participants who failed to give the correct numbers on the test were dropped out of the study and referred to a medical clinic for further testing. After the first meeting, participants were randomly assigned, using Microsoft Excel, to either the control or intervention group before they met the experimenter again. The random assignment helped to distribute the differences among the different screens used by participants. Participants were required to backup their computer to their personal external hard drive before the next meeting to prevent a loss of data if something went wrong with the installation of the f.lux software. Participants were directed to a link to their email to the backup instructions from Microsoft and Apple.

The participants individually met with the PI again. During the second meeting, as set by the second meeting outline (Appendix G), the PI installed the software f.lux onto their primary computer. The primary computer was operationally defined as the computer that the participant uses before going to bed. If the participant uses a desktop, they were asked to bring a flash drive to the meeting, otherwise they were asked to bring their laptop. Participants were guided by the PI step by step on installing f.lux and managing the f.lux settings. Participants with desktops were guided on how to do this on the PI's computer.

Participants assigned to the control screen light group set the f.lux program settings to 5000 K while the participants assigned the intervention screen light group set the f.lux program settings to 1900 K. Participants set f.lux to change the screen color 2 hours before the participant's earliest bedtime. Participants received a sheet on the f.lux settings (Appendix H-K) which showed how to check the f.lux settings for their operating system and condition. Participants were asked to not change the settings of f.lux to anything other than what they were instructed. Participants also received a sheet on how to uninstall f.lux on Mac and Windows operating systems (Appendixes L and M respectively), how to troubleshoot common problems that occur with f.lux labeled "Troubleshooting f.lux" (Appendix N) and information about the medical clinic (Appendix O). Finally, participants received a sheet on recommended behaviors labeled "Suggested Guidelines to Follow" (Appendix P). The sheet strongly suggested that participants not take naps during the day, not drink alcohol before going to bed, not ingest caffeine before going to bed, and not exercise or engage in moderate to strenuous

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physical activity before going to bed. The suggestions were added to decrease the presence of potential confounds in the study.

Data collection for the participant began the next day. The PghSD survey was sent out at 4 AM each day though Qualtrics. The daily questionnaire was sent with the same email and method. The survey was sent out for 7 continuous days. The participant was instructed to complete the survey within 2 hours of their final wake time. Survey responses submitted after 2 hours of waking were considered invalid and not included in the data analysis unless the participant informed the PI of the reason for the delay. If a participant had more than two invalid or missing responses within a one-week time frame, they were asked to leave the study and the participant's data were excluded in the data analysis. This did not happen in the study.

The extended daily questionnaire (Appendix Q), at the end of the study asked participants to re-check the f.lux settings to see that they had not changed. The daily questionnaire also included two additional questions to find out if and how the f.lux settings had changed. If the f.lux color temperature and time settings changed from the required settings then the participant's data for that week was removed from the data analysis. After day 7, participants were given the online exit survey and debriefed (Appendix R) through an email. The participant's personally identifiable information was deleted from the Excel file a week later. Overall participants were in the study for a total of 1 to 2 weeks depending on their ability to meet with the PI during the first two meetings.

Statistical Tests

The independent variable was the light condition. The dependent variables were number of minutes to fall asleep, number of minutes asleep and the subjective alertness score. Due to the small sample size, only descriptive statistics were calculated for these data. Descriptive statistics on each question in the exit interview were used to help inform the presence of potential confounds as well as future research directions.

Hypothesis

It was hypothesized that users who set the temperature shifting software f.lux to display a color temperature of 1900 K for at least 2 hours before going to bed would report an overall shorter sleep onset, longer sleep duration, and higher subjective alertness after waking up compared to users who set the temperature shifting software f.lux to display a color temperature of 5000 K.

CHAPTER IV

RESULTS

Data were collected from May 16, 2017 to June 1, 2017. All participants started using f.lux within 48 hours of each other. Sleep onset latency of the 1900 K group in minutes each day was, on average, higher compared to the 5000 K group as shown in Table 1 and Figure 2.

Table 1

Mean and Standard Deviations Between the Conditions on Different Measures of Sleep

	1900 K		5000 K	
Variable	*M*	*SD*	*M*	*SD*
Sleep Onset Latency (min)	33.57	39.05	10.43	8.07
Sleep Duration (hr)	6.42	2.23	8.71	2.11
Subjective Alertness (1-10)	6.29	2.84	6.57	1.50
Sleep Quality (1-10)	6.14	2.21	7.14	1.51
Morning Mood (1-10)	6.00	2.25	6.93	1.59
Time Awake (min)	9.64	17.37	7.57	9.48

Note. Data obtained from The Pittsburgh Sleep Diary (Appendix A)
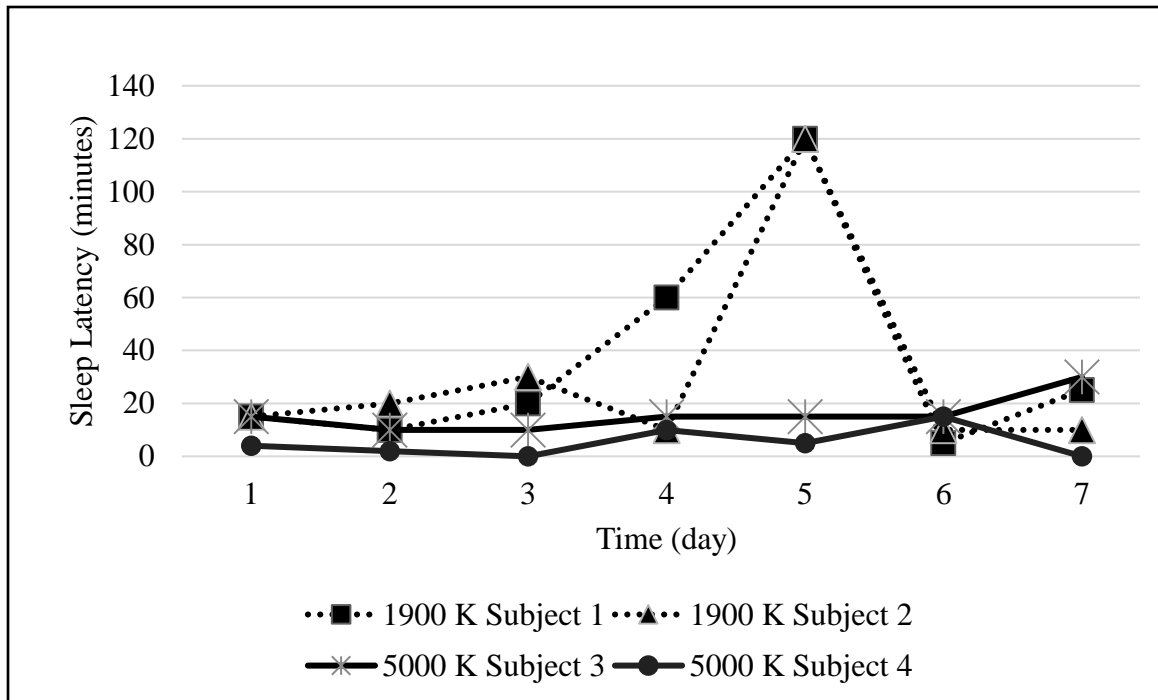
Figure 2. Sleep Latency of Subjects Sleep latency in minutes for each subject over 7 days.

Sleep duration of the 1900 K group in hours each day was, on average, lower compared

to the 5000 K group (Figure 3.).
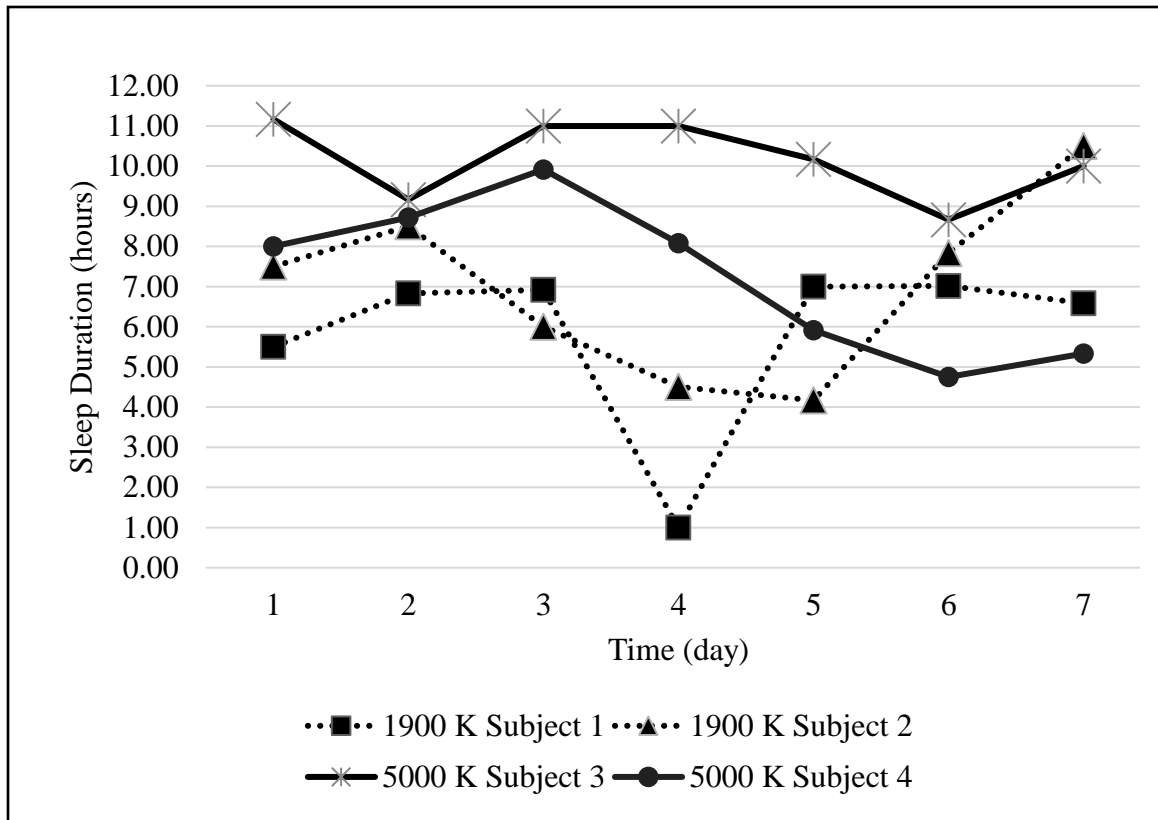
Figure 3. Sleep Duration of Subjects. Sleep duration in hours for each subject over 7 days.

Subjective alertness after waking up on the scale of 1-10 of the 1900 K group was, on

average, lower compared to the 5000 K group (Figure 4.).
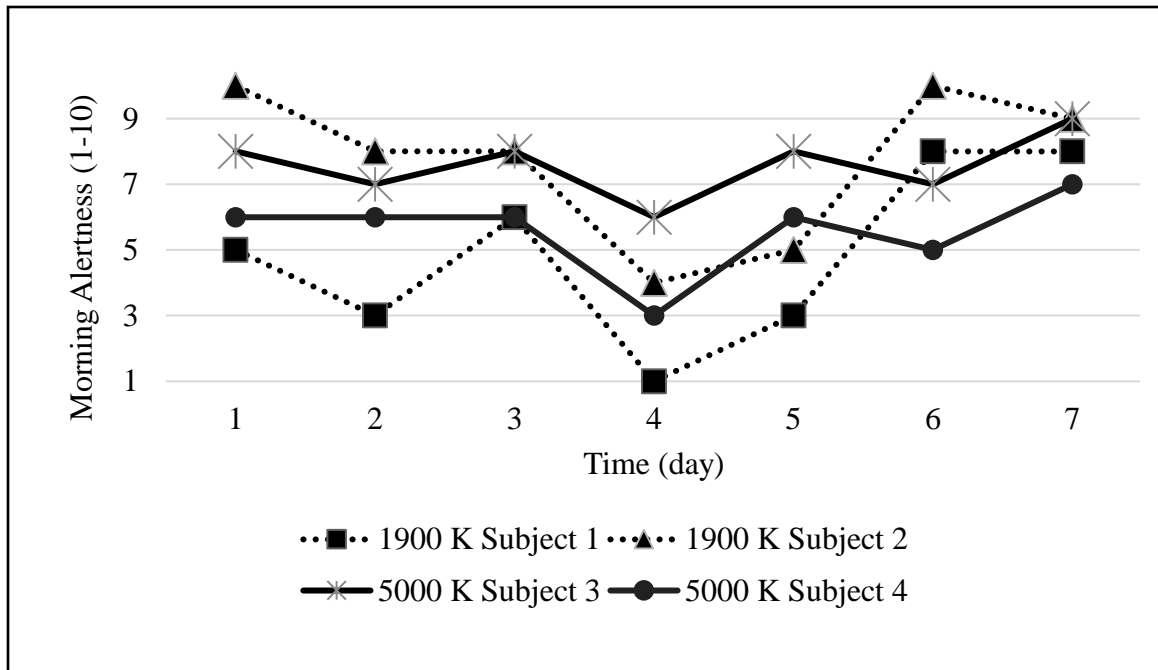
Figure 4. Morning Alertness of Subjects. Morning alertness from a scale of 1 to 10 (with 1 being "vary sleepy" and 10 being "very alert") for each subject over 7 days.

The variability for all the dependent variables was high enough that any differences in the mean are insignificant. On average, f.lux was reported by the participants to be activated 68.5 minutes ($SD = 60.4$) each day.

Sleep quality on the scale 1-10 of the 1900 K group was on average lower compared to the 5000 K group. Mood in the morning on the scale 1-10 of the 1900 K group was on average lower compared to the 5000 K group. Total number of minutes awake each evening during interruptions while sleeping in the 1900 K group was on average higher compared to the 5000 K group. Again, it is important to note that variability for all the dependent variables was high enough that any differences are insignificant. Most of the participants ($n = 3$) said that they would continue to use the software. Half of the participants ($n = 2$) said that they would continue to use the software because they believed that it can work.

CHAPTER V

DISCUSSION

The 1900 K group had overall poorer sleep quality as measured by sleep onset latency, sleep duration, and subjective alertness after waking. This contradicted the hypothesis that individuals in the 1900 K group would report better sleep outcomes for those independent variables. Data from the other questions in the diary on subjective sleep quality, mood in the morning, and the total number of minutes awake all point to the 1900 K group having poorer sleep during the study. However, it is important to note that the variability within the groups causes any differences to be insignificant.

It is, however, unlikely that f.lux causes poorer sleep. The results go against the study by Heath et al. (2014) of f.lux where there were no statistically significant differences or a small effect of f.lux on cognitive alertness while the tablet was on. Inferential conclusions to the general population cannot be made from the present study due to the small sample size. Originally a MANOVA was proposed on the three dependent variables. However, the small sample size would have violated many of the assumptions necessary for a MANOVA.

One of the most basic assumptions that was likely violated was the assumption that participants were randomly distributed to create close to equal conditions in mean and variance starting out. Smaller sample sizes are more likely to have unequal conditions that are randomly distributed than larger sample sizes. With a sample size of four, it is likely that the two conditions of sleep quality were not equal from the start and that there was sampling error. This is indicated potentially by the noticeably lower levels of television use by the 5000 K group participants 2 hours before bedtime compared to

the normal American population where proximity 60% watch television (National Sleep Foundation, n.d.) . With electronic use before bedtime linked to poorer sleep outcomes, it is not surprising that the 1900 K group which had higher television use had poorer sleep outcomes (Mesquita & Reimão, 2010). The 1900 K group also had more naps compared to the 5000 K group which is also linked to poorer nighttime sleep (Heath et al., 2014). This points to the 190 0K group likely having participants with poorer sleep compared to the 5000 K group before the intervention began giving a potential explanation for why the results contradicted the hypothesis.

Another assumption needed by the MANOVA that would not have been possible to check was whether there were any univariate or multivariate outliers in the data. The small sample prevented any determination of whether there were any outliers in each group because of the need for a minimum of three data points in each group to determine if there is an outlier. The inability to detect an outlier does not mean that there were no outliers in the sample.

Finally, the last indication that the sample size was too small to use an MANOVA was shown when the needed sample size was calculated for the experiment. A global effects MANOVA was done to find the required sample size using an effect size of .25 and a power of .8 in G.Power. The effect size was obtained from Heath's et al. (2014) study using f.lux where they got an eta-squared of .25 for the effect of cognitive alterness while the screen was on. The sample size needed was 30 which is larger than the sample size obtained.

Limitations

Throughout the study, there had been a series of decisions balancing internal validity, external validity, and feasibility. This study was designed to maximize external validity and feasibility at the cost of internal validity. Previous experimental research on light and sleep had primarily used sleep labs where participants would spend one to several nights. The sleep labs allowed the experimenters to strongly control extraneous variables and the intervention. A highly controlled sleep lab while having a large amount of internal validity would not have much external validly. The study was designed so that the intervention mimicked real life conditions to increase the ecological validity.

Not using a sleep lab added numerous extraneous variables that were not controlled. When the f.lux software was activated participants may not have been on their computers for the entire time. Individuals as a result may have received different amounts of exposure to the intervention. Overall, the mean for the exposure time to f.lux at night in the study was about half of the 2 hours targeted exposure time for the study. The exposure time received was shown by Wood et al.'s (2013) study to not be effective in impacting sleep. Additionally, fidelity to the treatment may not have been accurately reported by the participants and the exposure time might have been even lower than reported. This is due to the inability of the software to directly report use to the researcher. The naturalistic setting of the study also prevented the researcher from directly checking that the software was on and used. The setting impacted the fidelity to the treatment since the accuracy of the self-report cannot be verified.

Other sources of narrowband light outside the participants' computer were also uncontrolled. As discussed earlier, the participants in the study used other electronic

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sources such as televisions and smart phones. It is also possible that participants' home lighting may emit a large amount of blue light. While participants were asked to note the lighting in their room, it was not feasible to compare the different lights. For example, one participant just wrote down "white Christmas lights" while another participant wrote down "one light". Any of these additional sources was a potential confound that could have prevented the software from having any effect.

The extraneous variables could have potentially been controlled through instructions requiring that individuals abstain from using other devices and to use their computer for a prescribed amount of time. However, it was decided not to use this route for several reasons. Adding behavioral constraints would have introduced a high likelihood of a disruption effect. The constraints would also likely significantly lower the number of participants willing to enter the study and increase the attrition rate. This would have lowered the power and statistical validity of the experiment which was already facing issues with recruitment without more restrictive instructions. Having college students not use their cellphones, tablets or television for 2 hours each day for 7 straight days was not realistic. Finally, adding behavioral constraints would have lowered the ecological validity of the study. Rather, the study included a list of behaviors that were recommended to help control for the constraints.

The lack of a sleep lab also meant that the possibility of using an EEG to monitor sleep was absent. It was infeasible to have each participant take a EEG home due to the complexity of operation and the cost of an EEG. This is unfortunate, because out of the common methods to measure the duration slept by participants, the EEG is the most

accurate method (Usui et al., 1999). As a result, the choices left were to use sleep actinography or a subjective self-reported measure on sleep.

If finances where not a constraint, the study would have used sleep actigraphy to get an objective look at sleep. Research has shown that actigraphy is much more reliable and valid than self-report measures. However, the cost of actigraphy ($100+ per each one) is not financially feasible with the study budget ("Prices," n.d.). A no-cost option to get actinography data was to restrict participants to individuals who already owned a device like a Fitbit. However, this would have significantly constrained the number of potential participants that could be recruited. While melatonin was measured in most other experiments mentioned in the literature review, it was not considered for this proposal due to the added complexity and cost. Additionally, melatonin levels, while related to the circadian rhythm and sleep, are not a direct measure of the construct of sleep.

This left the remaining option of a self-report measure which raises the question of measurement errors, accuracy of report and treatment fidelity. This concern is particularly heightened when examining the dependent variable of sleep latency where subjective self-report has been shown to be unreliable (Vallières & Morin, 2003). To get a more valid measurement, the Pittsburg Sleep Diary recommends a measurement interval of at least 14 days (Monk et al., 1994). However, due to recruitment issues where no participants were entering the study, the measurement interval was significantly shortened to 7 days adding further questions to reliability and validity of the measurement data. There was also no way to check if participants faithfully reported the data to the best of their abilities.

The advantage of the 7-day measurement time was the reduced chance that the novelty effect significantly affected the final results. If the intervention had occurred for 3 days, then the novelty effect would have been a larger concern. Both groups also did not have any pretests done to see whether both groups were equal at the beginning of the study which added another confound to the study. While the original design for the study did have 14 days of observation before the intervention began as the pretest before f.lux was activated, it was removed to increase participant recruitment.

While the use of the attention (placebo) group helps to control for a placebo effect, since it is was not a true placebo group, the placebo effect was not perfectly controlled. Individuals were still likely to figure out whether they were in the placebo or intervention group due to the large visual differences between the interventions of the two groups. One of the participants in the placebo group noted in their exit survey that they believed that f.lux was not set at the correct level for it to work. The lack of a true placebo added the potential of compensatory rivalry to become an issue in the study where the placebo group worked more than the intervention group on improving their sleep quality. For example, someone knowing that they were in the control group might follow the suggested guidelines for sleep more closely than someone in the experimental group who might believe that using f.lux is enough to improve sleep. Expectancy effects were also a potential issue where members of the experimental group may have reported better sleep outcomes than what they experienced.

The study with a high attrition rate of 50% was also a threat to internal validity due to its impact on the sample size. However, all the attrition was before the individuals

were assigned to groups and there was no differential attrition between the groups. The sample size did remain a problem which impacted the generalizability of the study.

The use of only college students in the study brings up the issue of population validity and the intervention's generalizability to other populations; however, this was not a large concern given that college students match the population that would likely use the intervention. College students are in the age range where they are more likely to use electronics at night (National Sleep Foundation, n.d.). Additionally, college students are more likely to report sleep issues (Hershner & Chervin, 2014).

Future Directions

One of the most significant lessons from the study that can be applied to future studies is on how to increase recruitment. The most effective way the study got participants was to send someone to research method psychology classes and give a short talk (less than 5 minutes) to the class about the study. It is recommended that future in-person studies include a similar recruitment method and increase the number of classes where talks are given.

The study also only had extra credit as compensation and required longer and more effort compared to other psychology studies. A potential award that may be considered in the future instead of extra credit is to offer a different compensation such as using a raffle system with a monetary reward to motivate students to enter. This would have given other students who were not taking psychology courses an incentive to participate. The value of the reward would have to be low enough that participants would not give false responses just to get the reward.

To better control for other sources of light on phones and tablets, future research should also evaluate the use of wavelength filtering software on phones and tablets in conjunction with wavelength filtering software on computers. With television, this is not possible to implement due to the lack of wavelength filtering software. Given how much television is used by Americans, it should be monitored as a potential confound. This can be done with a MANCOVA which can control for continuous covariates such as minutes watching the TV. The original proposed MANOVA for the study would not have done that.

Both Microsoft and Apple released updates to their operating systems for their computers which mimic the functionality of f.lux at a time when this study had already been designed ("How to Use Night Shift," 2017; Pidgeon, 2017). Given the ubiquity of wavelength filtering software on computers in the future, it is suggested that future studies on wavelength filtering software use Night Light and Night Shift, the Microsoft and Apple equivalence of f.lux.

Computer users that are seeking to improve their sleep or reduce eye strain will likely just use the built-in features rather than go the extra trouble to install f.lux. The fact that the features are native to the operating system also likely mean that they are more stable and reliable which is also a motivating factor for users. It is likely that studies using Night Light and Night Shift would be more reflective of the average user's experience with wavelength filtering software than using f.lux in the near future. The likely stability of Night Light and Night Shift would also mean that study participants would not need to backup their computers due to the decreased chance of negative results by the native software on the computer. This is important as the requirement for

participants to backup their computer in the study made 25% ($n = 2$) of participants to drop out of the study. Ultimately, while the study was unable to create any inferential data on the effectiveness of f.lux to the outside population it served as a useful pilot study to help inform future field research on this topic.

REFERENCES

Anderson, M. (2015, October 29). Technology device ownership: 2015. Retrieved from http://www.pewinternet.org/2015/10/29/technology-device-ownership-2015/

Bailes, H. J., & Lucas, R. J. (2013). Human melanopsin forms a pigment maximally sensitive to blue light (λmax ≈ 479 nm) supporting activation of Gq/11 and Gi/o signalling cascades. *Proceedings of the Royal Society B: Biological Sciences*, *280*(1759). https://doi.org/10.1098/rspb.2012.2987

Beattie, L., Kyle, S. D., Espie, C. A., & Biello, S. M. (2015). Social interactions, emotion and sleep: A systematic review and research agenda. *Sleep Medicine Reviews*, *24*, 83–100. https://doi.org/10.1016/j.smrv.2014.12.005

Beres, D. (2015, August 26). F.lux's new "Backwards alarm clock" is the sleep angel on your shoulder. Retrieved from http://www.huffingtonpost.com/entry/flux-backwards-alarm-clock_us_55dde705e4b04ae497054a79

Buysse, D. J., Reynolds, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh sleep quality index: A new instrument for psychiatric practice and research. *Psychiatry Research*, *28*(2), 193–213. https://doi.org/10.1016/0165-1781(89)90047-4

Cajochen, C., Frey, S., Anders, D., Späti, J., Bues, M., Pross, A., … Stefani, O. (2011). Evening exposure to a light-emitting diodes (LED)-backlit computer screen affects circadian physiology and cognitive performance. *Journal of Applied Physiology*, *110*(5), 1432–1438. https://doi.org/10.1152/japplphysiol.00165.2011

Cajochen, C., Kräuchi, K., & Wirz-Justice, A. (2003). Role of melatonin in the regulation of human circadian rhythms and sleep. *Journal of Neuroendocrinology*, *15*(4), 432–437. https://doi.org/10.1046/j.1365-2826.2003.00989.x

Cajochen, C., Zeitzer, J. M., Czeisler, C. A., & Dijk, D. (2000). Dose-response relationship for light intensity and ocular and electroencephalographic correlates of human alertness. *Behavioural Brain Research*, *115*(1), 75–83. https://doi.org/10.1016/S0166-4328(00)00236-9

Carney, C. E., Buysse, D. J., Ancoli-Israel, S., Edinger, J. D., Krystal, A. D., Lichstein, K. L., & Morin, C. M. (2012). The Consensus Sleep Diary: Standardizing prospective sleep self-monitoring. *Sleep*, *35*(2), 287–302. https://doi.org/10.5665/sleep.1642

Chang, A., Aeschbach, D., Duffy, J. F., & Czeisler, C. A. (2015). Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning alertness. *Proceedings of the National Academy of Sciences*, *112*(4), 1232–1237. https://doi.org/10.1073/pnas.1418490112

Chellappa, S. L., Steiner, R., Oelhafen, P., Lang, D., Götz, T., Krebs, J., & Cajochen, C. (2013). Acute exposure to evening blue-enriched light impacts on human sleep. *Journal of Sleep Research*, *22*(5), 573–580. https://doi.org/10.1111/jsr.12050

Colten, H. R., & Altevogt, B. M. (2006). Extent and health consequences of chronic sleep loss and sleep disorders. In *Sleep Disorders and Sleep Deprivation: An Unmet Public Health Problem.* National Academies Press. Retrieved from http://www.ncbi.nlm.nih.gov/books/NBK19961/

Dain, S. J. (2004). Clinical colour vision tests. *Clinical and Experimental Optometry*, *87*(4–5), 276–293. https://doi.org/10.1111/j.1444-0938.2004.tb05057.x

f.lux. (2009). Retrieved from http://justgetflux.com/

f.luxometer. (n.d.). Retrieved from https://fluxometer.com/rainbow/

Gillberg, M., Kecklund, G., & Akerstedt, T. (1994). Relations between performance and subjective ratings of sleepiness during a night awake. *Sleep*, *17*(3), 236–241.

Gillette, M. U., & McArthur, A. J. (1995). Circadian actions of melatonin at the suprachiasmatic nucleus. *Behavioural Brain Research*, *73*(1–2), 135–139. https://doi.org/10.1016/0166-4328(96)00085-X

Hale, L., & Guan, S. (2015). Screen time and sleep among school-aged children and adolescents: a systematic literature review. *Sleep Medicine Reviews*, *21*, 50–58. https://doi.org/10.1016/j.smrv.2014.07.007

Hardawar, D. (2016, September 16). iOS 10 review: Apple evolves. Retrieved from https://www.engadget.com/2016/09/16/ios-10-review/

Heath, M., Sutherland, C., Bartel, K., Gradisar, M., Williamson, P., Lovato, N., & Micic, G. (2014). Does one hour of bright or short-wavelength filtered tablet screenlight have a meaningful effect on adolescents' pre-bedtime alertness, sleep, and daytime functioning? *Chronobiology International*, *31*(4), 496–505. https://doi.org/10.3109/07420528.2013.872121

Hernendez, D. (2016, April 4). Apps aim to keep devices from disrupting sleep. Retrieved from http://www.wsj.com/articles/do-apps-aimed-at-making-gadgets-less-disruptive-to-sleep-work-1459782897?tesla=y

Hershner, S. D., & Chervin, R. D. (2014). Causes and consequences of sleepiness among

        college students. *Nature and Science of Sleep*, *6*, 73–84.

        https://doi.org/10.2147/NSS.S62907

Holzman, D. C. (2010). What's in a color? The unique human health effects of blue light.

        Environmental Health Perspectives, *118*(1), A22–A27.

How to use Night Shift on your Mac. (2017, July 27). Retrieved October 2, 2017, from

        https://support.apple.com/en-us/HT207513

iOS 9.3 updates. (2016, March). Retrieved from http://www.apple.com/ios/updates/

Kobo Aura ONE. (2016). Retrieved from https://us.kobobooks.com/products/kobo-aura-

        one

Krahn, L., & Gordon, I. (2013). In bed with a mobile device: Are the light levels

        necessarily too bright for sleep initiation? *Journal Sleep and Sleep Disorders*

        Research, *36*, 184.

Lely, S. van der, Frey, S., Garbazza, C., Wirz-Justice, A., Jenni, O. G., Steiner, R., …

        Schmidt, C. (2015). Blue blocker glasses as a countermeasure for alerting effects

        of evening light-emitting diode screen exposure in male teenagers. *Journal of*

        Adolescent Health, *56*(1), 113–119.

        https://doi.org/10.1016/j.jadohealth.2014.08.002

Lewy, A. (2010). Clinical implications of the melatonin phase response curve. *The*

        Journal of Clinical Endocrinology and Metabolism, *95*(7), 3158–3160.

        https://doi.org/10.1210/jc.2010-1031

Lockley, S. W., Brainard, G. C., & Czeisler, C. A. (2003). High sensitivity of the human

        circadian melatonin rhythm to resetting by short wavelength light. *The Journal of*

Clinical Endocrinology & Metabolism, *88*(9), 4502–4502.

https://doi.org/10.1210/jc.2003-030570

M Giménez, Geerdincka, L., Versteylen, M., Leffers, P., Herremansa, H., Ruyterd, B., …

Meekesa, G. (2011). Light and sleep within hospital settings. *Sleep-Wake*

Research In The Netherlands, *22*, 56–59.

Marcus, C. L., Traylor, J., Biggs, S. N., Roberts, R. S., Nixon, G. M., Narang, I., …

Schmidt, B. (2014). Feasibility of comprehensive, unattended ambulatory

polysomnography in school-aged children. *Journal of Clinical Sleep Medicine*.

https://doi.org/10.5664/jcsm.3970

Mesquita, G., & Reimão, R. (2010). Quality of sleep among university students: effects

of nighttime computer and television use. *Arquivos de Neuro-Psiquiatria*, *68*(5),

720–725. https://doi.org/10.1590/S0004-282X2010000500009

Monk, T. H., Reynolds, C. F., Kupfer, D. J., Buysse, D. J., Coble, P. A., Hayes, A. J., …

Ritenour, A. M. (1994). The Pittsburgh Sleep Diary. *Journal of Sleep Research*,

3(2), 111–120. https://doi.org/10.1111/j.1365-2869.1994.tb00114.x

National Sleep Foundation. (n.d.). 2011 Sleep in America poll. Retrieved from

https://sleepfoundation.org/sites/default/files/sleepinamericapoll/SIAP_2011_Sum

mary_of_Findings.pdf

Pidgeon, E. (2017, May 8). Windows 10 tip: Lower the blue light emitted from your PC

with Night light. Retrieved from

https://blogs.windows.com/windowsexperience/2017/05/08/windows-10-tip-

lower-blue-light-emitted-pc-night-light/

Prices. (n.d.). Retrieved from http://www.geneactiv.org/products/pricing/

51

Putilov, A. A., & Donskaya, O. G. (2013). Construction and validation of the EEG

    analogues of the Karolinska sleepiness scale based on the Karolinska drowsiness

    test. *Clinical Neurophysiology*, *124*(7), 1346–1352.

    https://doi.org/10.1016/j.clinph.2013.01.018

Recommended light levels. (n.d.). Retrieved from

    http://www.noao.edu/education/QLTkit/%20ACTIVITY_Documents/Safety/Ligh

    tLevels_outdoor+indoor.pdf

Rogers, E., Caruso, C., & Aldrich, S. (1993). Reliability of sleep diaries for assessment of

    sleep/wake patterns. *Nursing Research*, *42*(6), 368–372.

Sasseville, A., Paquet, N., Sévigny, J., & Hébert, M. (2006). Blue blocker glasses impede

    the capacity of bright light to suppress melatonin production. *Journal of Pineal

    Research*, *41*(1), 73–78. https://doi.org/10.1111/j.1600-079X.2006.00332.x

Shan, Z., Deng, G., Li, J., Li, Y., Zhang, Y., & Zhao, Q. (2013). Correlational analysis of

    neck/shoulder pain and low back pain with the use of digital products, physical

    activity and psychological status among adolescents in Shanghai. *PLOS ONE*,

    8(10), e78109. https://doi.org/10.1371/journal.pone.0078109

Silver, R., & Schwartz, W. J. (2005). The suprachiasmatic nucleus is a functionally

    heterogeneous timekeeping organ. *Methods in Enzymology*, *393*, 451–465.

    https://doi.org/10.1016/S0076-6879(05)93022-X

Stephan, F. K., & Zucker, I. (1972). Circadian rhythms in drinking behavior and

    locomotor activity of rats are eliminated by hypothalamic lesions. *Proceedings of

    the National Academy of Sciences of the United States of America*, *69*(6), 1583–

    1586.

Stone, A. A., Shiffman, S., Schwartz, J. E., Broderick, J. E., & Hufford, M. R. (2002).

    Patient non-compliance with paper diaries. *BMJ : British Medical Journal*,

    324(7347), 1193–1194.

Sunrise/Sunset calculator. (2017). Retrieved from

    https://www.esrl.noaa.gov/gmd/grad/solcalc/sunrise.html

The best notebook displays as reviewed by Notebookcheck. (2016, October 3). Retrieved

    from http://www.notebookcheck.net/The-Best-Notebook-Displays-As-Reviewed-

    By-Notebookcheck.120541.0.html

Thomas, M., & Matthews, C. (n.d.). LED lighting selecting guide. Retrieved from

    https://www.michigan.gov/documents/mdcd/%20Energy_Observer_-

    _Selecting_LED_Lighting_422716_7.pdf

Tousson, E., & Meissl, H. (2004). Suprachiasmatic nuclei grafts restore the circadian

    rhythm in the paraventricular nucleus of the hypothalamus. *The Journal of

    Neuroscience*, *24*(12), 2983–2988. https://doi.org/10.1523/JNEUROSCI.5044-

    03.2004

Urbandroid. (n.d.). Twilight. Retrieved from

    https://play.google.com/store/apps/details?id=com.urbandroid.lux&hl=en

Usui, A., Ishizuka, Y., Obinata, I., Okado, T., Fukuzawa, H., & Kanba, S. (1999).

    Validity of sleep log compared with actigraphic sleep-wake state II. *Psychiatry

    and Clinical Neurosciences*, *53*(2), 183–184. https://doi.org/10.1046/j.1440-

    1819.1999.00529.x

Vallières, A., & Morin, C. M. (2003). Actigraphy in the assessment of insomnia. *Sleep*,

    26(7), 902–906.

Visible light. (n.d.). Retrieved from

    http://missionscience.nasa.gov/ems/09_visiblelight.html

Vitaterna, M. H., Takahashi, J. S., & Turek, F. W. (n.d.). Overview of circadian rhythms.

    Retrieved from http://pubs.niaaa.nih.gov/publications/arh25-2/85-93.htm

Wever, R. A., Polášek, J., & Wildgruber, C. M. (1983). Bright light affects human

    circadian rhythms. *Pflügers Archiv*, *396*(1), 85–87.

    https://doi.org/10.1007/BF00584704

Wood, B., Rea, M. S., Plitnick, B., & Figueiro, M. G. (2013). Light level and duration of

    exposure determine the impact of self-luminous tablets on melatonin suppression.

    Applied Ergonomics, *44*(2), 237–240.

    https://doi.org/10.1016/j.apergo.2012.07.008

Zaidi, F. H., Hull, J. T., Peirson, S. N., Wulff, K., Aeschbach, D., Gooley, J. J., …

    Lockley, S. W. (2007). Short-wavelength light sensitivity of circadian, rupillary,

    and visual awareness in humans lacking an outer retina. *Current Biology*, *17*(24),

    2122–2128. https://doi.org/10.1016/j.cub.2007.11.034

Appendix A

The Pittsburgh Sleep Diary

The Pittsburgh Sleep Diary copyright is owned by the University of Pittsburgh. The University of Pittsburgh allows the use of the Pittsburgh Sleep Diary for non-commercial or educational purposes.

SLEEP DIARY   **WAKETIME**   **KEEP BY BED**

Please fill out this part of the diary first thing in the morning.

day .... date ....

went to bed last night at ....

attempted to fall asleep at ....

minutes until fell asleep ....

finally woke at ....

Awakened by *(check one)*:

- alarm clock/radio ☐
- someone whom I asked to wake me ☐
- noises ☐
- just woke ☐

After falling asleep, woke up this many times during the night (circle)

0   1   2   3   4   5 or more

total number of minutes awake ....

- woke to use bathroom (circle # times)
  0   1   2   3   4   5 or more

- awakened by noises/child/bedpartner (circle # times)
  0   1   2   3   4   5 or more

- awakened due to discomfort or physical complaint (circle # times)
  0   1   2   3   4   5 or more

- just woke (circle # times)
  0   1   2   3   4   5 or more

Ratings (place a mark somewhere along the line):

Sleep Quality:
very bad _____ very good

Mood on Final Wakening:
very tense _____ very calm

Alertness on Final Wakening:
very sleepy _____ very alert

(Monk et al., 1994)

Sona Study Description
Title: " Computer Monitor Light and Biological Rhythms"

Description of study: Can software that changes the color of your computer screen before bedtime affect human biological rhythms?

This is a 2-3-week multi-part study. If you choose to be a participant:
1. We will ask you to meet with the researcher in a group for 15 mins to go over the informed consent form. We will ask you to backup your computer onto an **external** hard drive each week.
2. You will meet the researcher again individually for 20 mins to install (or learn to install) a software that changes the color of your computer screen during the evening.
3. We will then ask you to fill out daily 10 min survey on your sleep for 14 consecutive days. We will ask you to fill out the survey within 2 hours after you wake up.
4. We will finally ask that you please fill out a 15-min survey after the 14ᵗʰ day.

Eligibility requirements:

You can take part in this study if
- Are 18 years or older
- You use a personal computer 2 hours before bed for at least 4 days a week
  - That operating system of that personal computer is either Windows or MacOS.
- You can install software onto the computer you use before sleeping.
- You own a personal external hard drive that has enough space to backup your computer
- You know how to backup your computer to an external hard drive

You cannot take part in this study if
- You are colorblind
- Have used or currently use software that changes the color of your screen
- Have been diagnosed with a sleep disorder (Sleep disorders include, but are not limited to, Insomnia, Hypersomnolence Disorder, Narcolepsy, Sleep Apnea and Restless Legs Syndrome)

Appendix C

Daily Questionnaire

Please fill this out to the best of your abilities within 2 hours of waking up.

Due to the sensitive nature of some of the questions we ask that you fill out the survey in a private location.

1. Did you take any naps yesterday?

Yes/No

a. (If the participant answered no the question skip logic will skip this question) How many naps did you take and for how long did you take the nap(s).

(Short Answer)

2. Did you drink alcohol 5 hours before going to bed?

Yes/No

3. Did you drink any caffeine drinks 5 hours before going to bed?

Yes/No

4. Did you use any marijuana 5 hours before going to bed?

Yes/No

5. Did you use any other drugs, medication or herbal supplements the day before?

a. (If the participant answered no the question skip logic will skip this question) Please list the drugs, medication or herbal supplements that you used.

(Short Answer)

6. Did you exercise or engage in moderate to high physical activity 5 hours before going to bed?

Yes/No

7. Did you use your computer at any time two hours before you tried to go to sleep?

Yes/No

  a. (If the participant answered no the question skip logic will skip this question) Was F.lux in effect when you used your computer during the two hours before you tried to go to sleep?

Yes/No/Don't Know

(the "Don't know" option only appears to participants in the control group)

  b. (If the client answered yes) Roughly, how many minutes did you use the computer while F.lux was in effect?

____Hr____Min

Appendix D

Exit Survey

Thank you for participating in this study. We ask that you please fill out this final survey to the best of your abilities.

1. Do you plan on continuing using f.lux or similar software after this study?

    Yes/No

    a. Please explain your reasoning in the box below.

    (Short Answer)

2. Would you consider using software similar to f.lux on a phone or tablet?

    Yes/No

    a. Please explain your reasoning in the box below.

    (Short Answer)

3. Roughly how much time each night was f.lux activated for?

    _____min

4. On average how long did you use your computer during the two-hour timeframe before you went to bed during the course of this study?

    _____min

5. Do you work a night shift?

    Yes/No

6. Did you use a television screen within the two hours of going to bed during the course of this study?

    Yes/No

    a. On average, how many times a week did you use a television screen within two hours of going to bed during the course of this study?

                                       _____Times

    b. On average how long did you use a television screen during the two-hour timeframe before you went to bed during the course of this study?

                                       _____Min

7. Did you use a tablet within the two-hours of going to bed during the course of this study?

                                       Yes/No

    a. On average how many times a week did you use a tablet within two hours of going to bed during the course of this study?

                                       _____Times

    b. On average how long did you use a tablet during the two-hour timeframe before you went to bed during the course of this study?

                                       _____Min

8. Did you use a phone within the two-hours of going to bed during the course of this study?

                                       Yes/No

    a. On average how many times a week did you use a phone within two hours of going to bed during the course of this study?

              _____Times

    b. On average how long did you use a phone during the two-hour timeframe before you went to bed during the course of this study?

              _____Min

9. Did you normally engage in social activity during the 2 hours before going to bed?

              Yes/No

    a. On average, how many times a week did you engage in social activity within two hours of going to bed during the course of this study?

              _____Times

    b. Please describe what type of social activity you engaged in.

              (Short Answer)

10. Please describe the number, type and wattages of the lightbulbs that are normally on in the room you are in two hours before bedtime.

              (Short Answer)

11. What model and brand of laptop or computer monitor did use during this study that was affected by f.lux?

12. Please leave any additional comments that you would like to say in the box

below.

Ishihara Colorblind Test

The images below will be printed on paper. Each image will be shown for 3 seconds to the participants (Dain, 2004). The "answers" are 29,7,6,73.
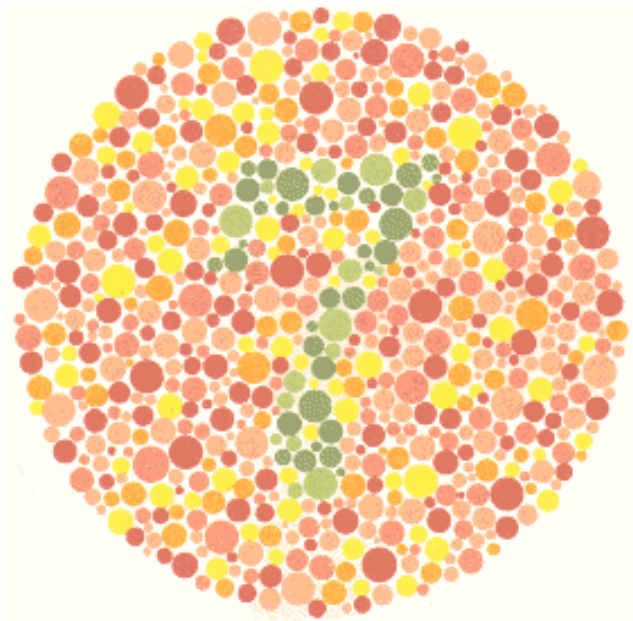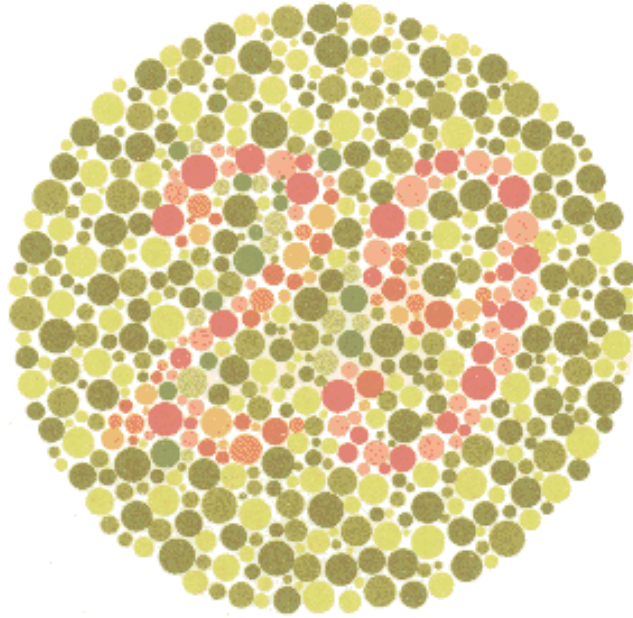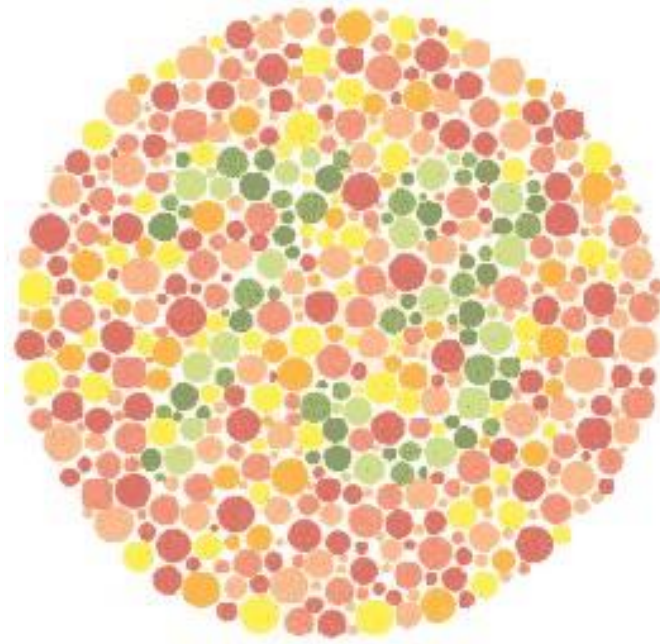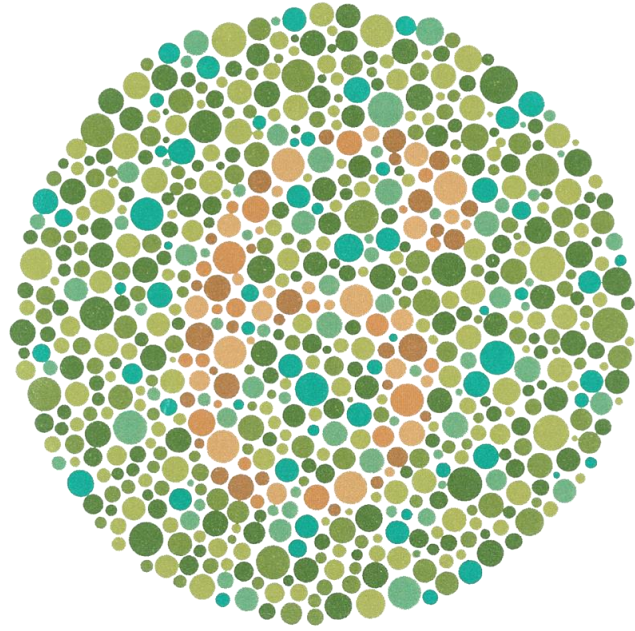
<div align="center">**Appendix F**</div>

First Meeting Outline

In the first meeting the PI will meet with the participants in groups of up to 10 people for roughly 15 mins. The PI will…

1. Talk about the study procedures
2. Go through the informed consent form with the participant.
   a. The PI will vocally confirm with each client whether they understand each section of the PI
3. Have the participants fill out the informed consent form.
4. The PI will hand everyone information about the SMCC and the services they offer.
5. Administer the Ishihara colorblind test
   a. The PI will emphasize that the test is not perfect and may misclassify people
   b. The test will be administered individually. Other participants will be asked to wait outside the room while the test is administered.
   c. The test will be administered by paper. With the subject having 3 seconds to make out the symbol.
   d. Subjects that may be colorblind will be referred to the SMCC.
6. Obtain the participants phone number, email, age and if their computer uses Windows or MacOS
7. Ask the participants to backup their computer by the next meeting onto an external hard drive.
8. Ask the participants if they have any final questions.

Appendix G

Second Meeting Outline

In the second meeting the PI will meet with the participants one on one for roughly 20 min. The Pi will

1. Check if the participant backed up their computer
    a. If the participant said that they did not backup their computer the PI will ask that the participant reschedule the second meeting.
2. Briefly review the study procedures again.
3. Recheck the participant's consent of being in the study
4. Ask the client "how often has your computer crashed in the past month"
5. Install the software onto the participant's computer using a USB drive
    a. If the participant has a desktop the PI will load the executable file onto the participates USB drive and show the participant how to install the software
6. Set the software settings to the condition that the participant was randomly assigned to.
7. Ask if the participant want to have daily text reminders that say "Please fill out the daily survey within 2 hours of waking up"
8. Give the participant information on
    a. how to check the software settings
    b. how to trouble shoot the software
    c. how to uninstall the software
    d. a list of things that the PI encourages the subject to do
9. Ask if the client has any final questions.

Appendix H

Windows F.lux Settings (for attention (placebo) control group)

Below are the instructions for checking the F.lux settings on your computer. Please check the F.lux settings when you receive the email informing you to do so. If you have any questions or concerns, please email the investigator though the Sona System.

1. Click on your start menu. Click on "All apps" Open F.lux on your start menu.
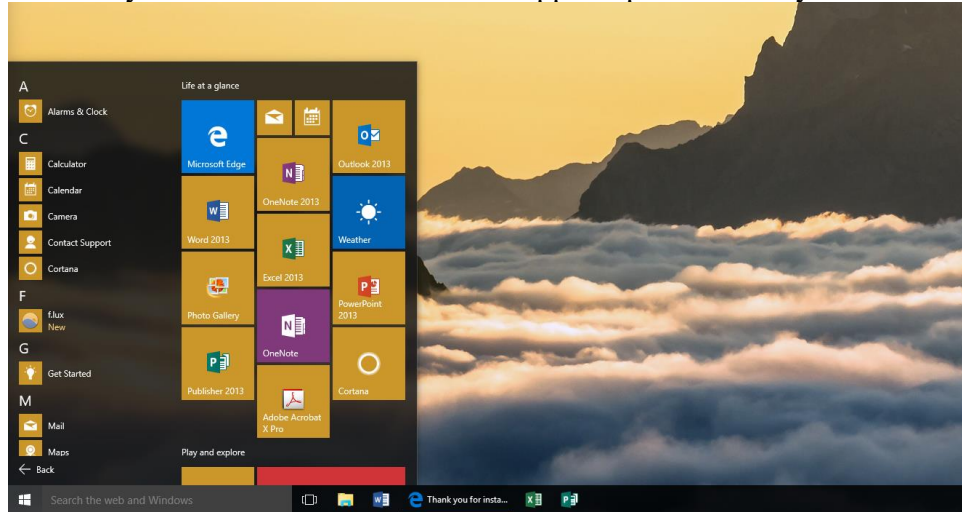


2. You should see this window.

3. Click on the box with three horizontal lines.

4. Please check that none of the options have a check mark on the left.
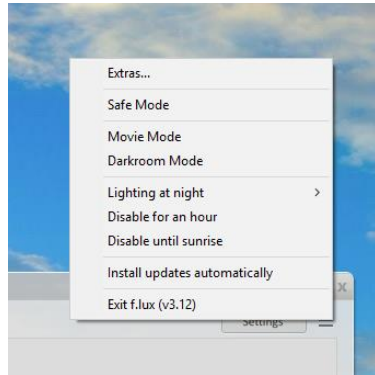
5. Go to "Lighting at night". Check that the "5000k:Sunlight" is selected
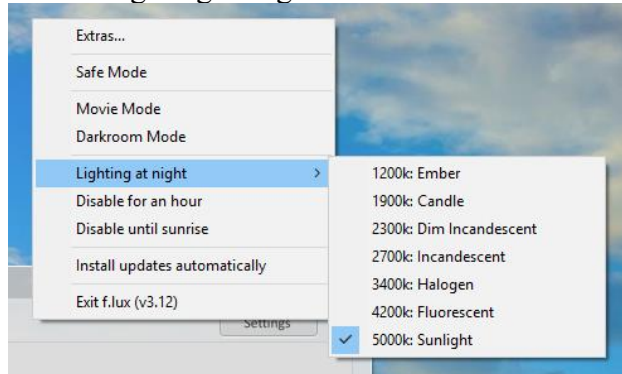
6. Click on "Extras".
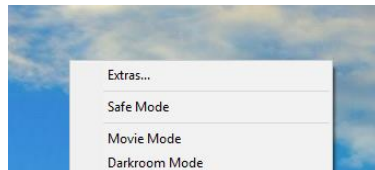
7. Please check that none of the options are checked of. Click "done".
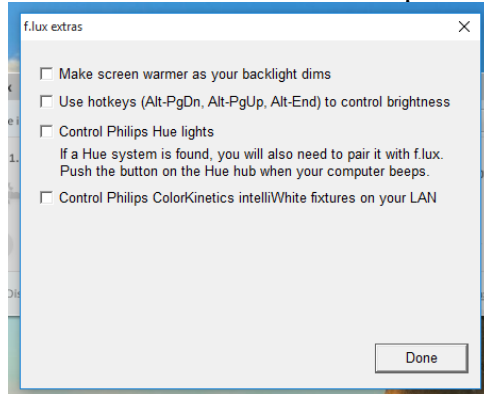
8. Please click on "Settings".
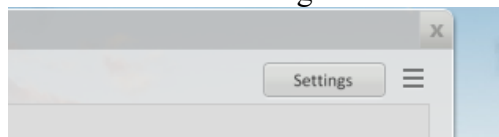
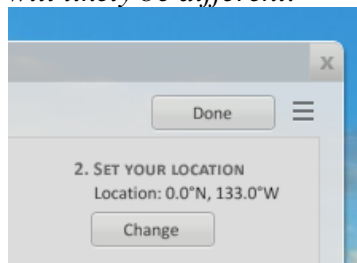9. Check that the "Daytime" slider is set to "6500K" and that the "At night" slider is set to "5000K".

10. Check that the "Transition Speed" is set to "Fast (20s)"

11. Check that the "Disable for one hour (for doing color-sensitive work)" is unchecked.

12. Please check that the location corresponds to the longitude and latitude of your earliest bedtime of the week as seen in the chart below. *For this example the longitude and latitude are set at 0.01 N, 133.0W but your longitude and latitude will likely be different.*

Your Earliest Bedtime of the Week	Longitude and Latitude
12:00 Noon	0.01 N, 24.5 W
12:30 PM	0.01 N, 17 W
1:00 PM	0.01 N, 9.5 W
1:30 PM	0.01 N, 2 W
2:00 PM	0.01 N, 5.5 E
2:30 PM	0.01 N, 13 E
3:00 PM	0.01 N, 20.5 E
3:30 PM	0.01 N, 28 E

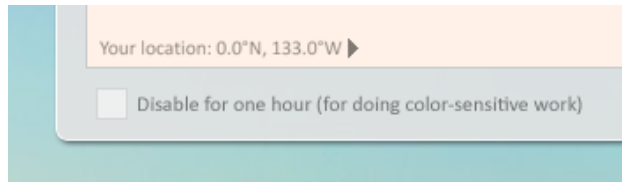|		
4:00 PM	0.01 N,	35.5 E
4:30 PM	0.01 N,	43 E
5:00 PM	0.01 N,	50.5 E
5:30 PM	0.01 N,	58 E
6:00 PM	0.01 N,	65.5 E
6:30 PM	0.01 N,	73 E
7:00 PM	0.01 N,	80.5 E
7:30 PM	0.01 N,	88 E
8:00 PM	0.01 N,	95.5 E
8:30 PM	0.01 N,	103 E
9:00 PM	0.01 N,	110.5 E
9:30 PM	0.01 N,	118 E
10:00 PM	0.01 N,	125.5 E
10:30 PM	0.01 N,	133 E
11:00 PM	0.01 N,	140.5 E
11:30 PM	0.01 N,	148 E
12:00 Midnight	0.01 N,	155.5 E
12:30 AM	0.01 N,	163 E
1:00 AM	0.01 N,	170.5 E
1:30 AM	0.01 N,	178 E
2:00 AM	0.01 N,	174.5 W
2:30 AM	0.01 N,	167 W
3:00 AM	0.01 N,	159.5 W
3:30 AM	0.01 N,	152 W
4:00 AM	0.01 N,	144.5 W
4:30 AM	0.01 N,	137 W
5:00 AM	0.01 N,	129.5 W
5:30 AM	0.01 N,	122 W
6:00 AM	0.01 N,	114.5 W
6:30 AM	0.01 N,	107 W
7:00 AM	0.01 N,	99.5 W
7:30 AM	0.01 N,	92 W
8:00 AM	0.01 N,	84.5 W
8:30 AM	0.01 N,	77 W
9:00 AM	0.01 N,	69.5 W
9:30 AM	0.01 N,	62 W
10:00 AM	0.01 N,	54.5 W
10:30 AM	0.01 N,	47 W
11:00 AM	0.01 N,	39.5 W
11:30 AM	0.01 N,	32 W

("Sunrise/Sunset calculator," 2017)

13. If the longitude and latitude are different please click "Change" and enter the correct longitude and latitude. Click "OK" once you are done.
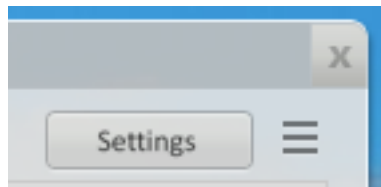

14. Click "Done".

15. Please look at "Your location" and check again that the longitude and latitude are correct.
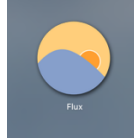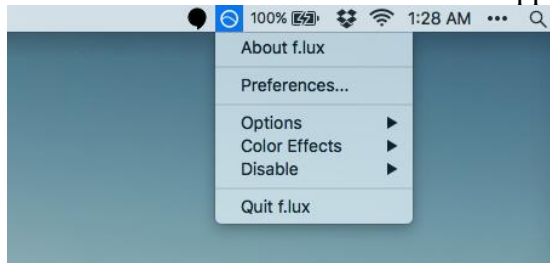

16. Click the "X"

Appendix I

Windows F.lux Settings (for the intervention group)

Below are the instructions for checking the F.lux settings on your computer. Please check the F.lux settings when you receive the email informing you to do so. If you have any questions or concerns, please email the investigator though the Sona System.
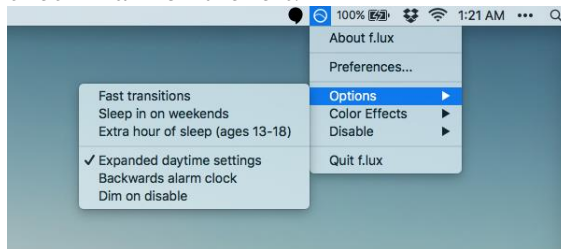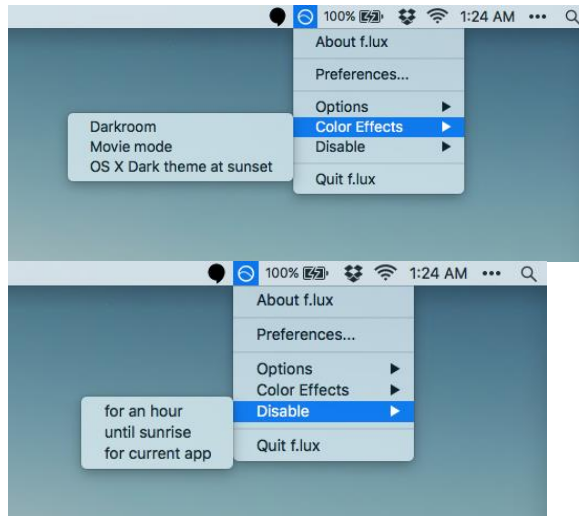
1. Click on your start menu. Click on "All apps" Open F.lux on your start menu.
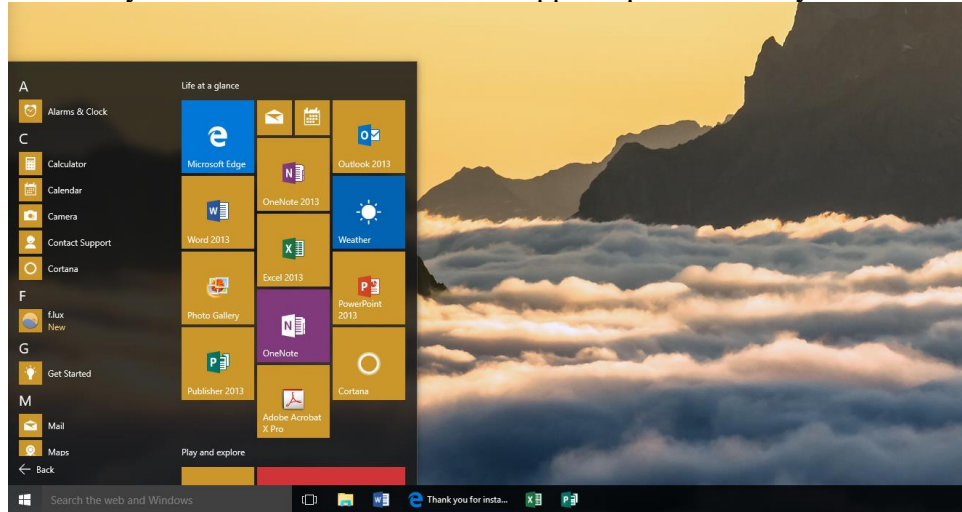
2. You should see this window.
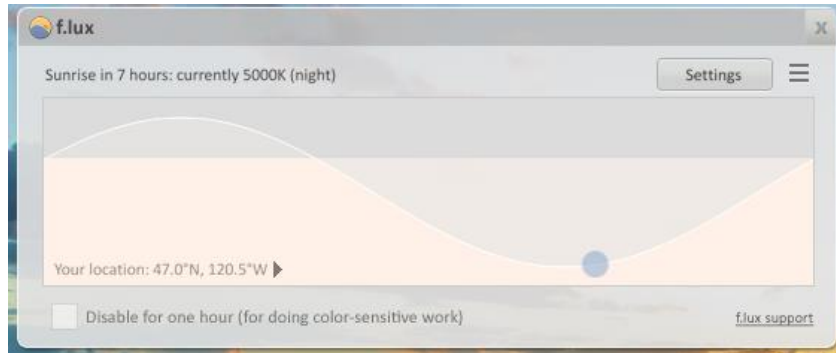
3. Click on the box with three horizontal lines.

4. Please check that none of the options have a check mark on the left.
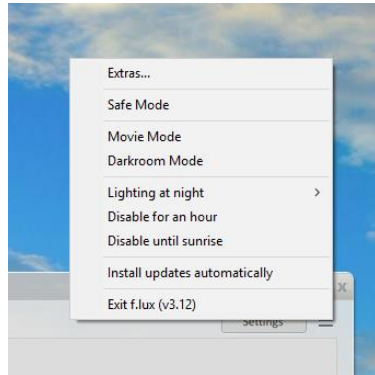
5. Go to "Lighting at night". Check that the "1900k: Candle" is selected
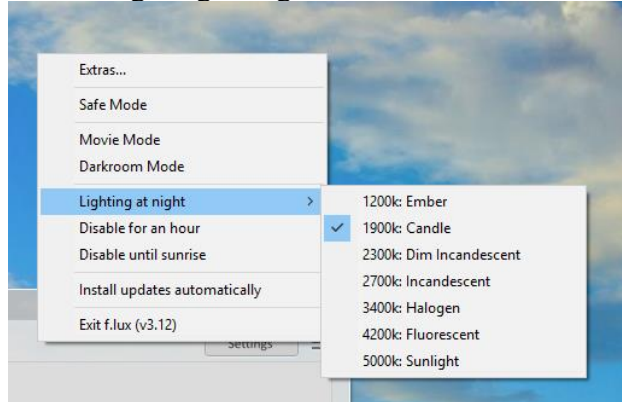
6. Click on "Extras".
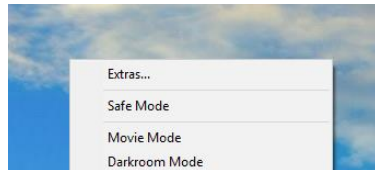
7. Please check that none of the options are checked of. Click "done".
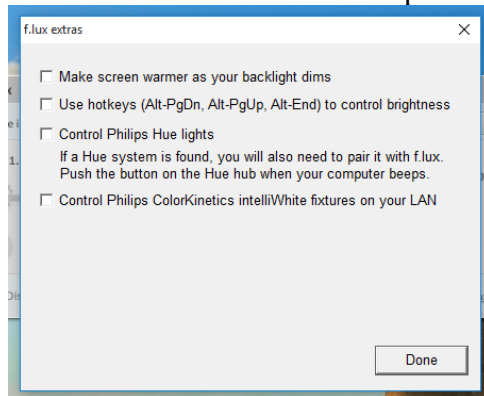
8. Please click on "Settings".
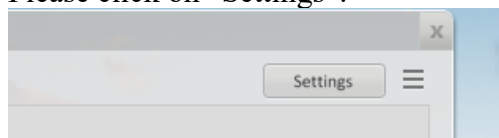
9. Check that the "Daytime" slider is set to "6500K" and that the "At night" slider is set to "1900K".

10. Check that the "Transition Speed" is set to "Fast (20s)"

11. Check that the "Disable for one hour (for doing color-sensitive work)" is unchecked.

12. Please check that the location corresponds to the longitude and latitude of your earliest bedtime of the week as seen in the chart below. *For this example the longitude and latitude are set at 0.01 N, 133.0W but your longitude and latitude will likely be different.*

Your Earliest Bedtime of the Week	Longitude and Latitude
12:00 Noon	0.01 N, 24.5 W
12:30 PM	0.01 N, 17 W
1:00 PM	0.01 N, 9.5 W
1:30 PM	0.01 N, 2 W
2:00 PM	0.01 N, 5.5 E
2:30 PM	0.01 N, 13 E
3:00 PM	0.01 N, 20.5 E
3:30 PM	0.01 N, 28 E

4:00 PM	0.01 N,	35.5 E
4:30 PM	0.01 N,	43 E
5:00 PM	0.01 N,	50.5 E
5:30 PM	0.01 N,	58 E
6:00 PM	0.01 N,	65.5 E
6:30 PM	0.01 N,	73 E
7:00 PM	0.01 N,	80.5 E
7:30 PM	0.01 N,	88 E
8:00 PM	0.01 N,	95.5 E
8:30 PM	0.01 N,	103 E
9:00 PM	0.01 N,	110.5 E
9:30 PM	0.01 N,	118 E
10:00 PM	0.01 N,	125.5 E
10:30 PM	0.01 N,	133 E
11:00 PM	0.01 N,	140.5 E
11:30 PM	0.01 N,	148 E
12:00 Midnight	0.01 N,	155.5 E
12:30 AM	0.01 N,	163 E
1:00 AM	0.01 N,	170.5 E
1:30 AM	0.01 N,	178 E
2:00 AM	0.01 N,	174.5 W
2:30 AM	0.01 N,	167 W
3:00 AM	0.01 N,	159.5 W
3:30 AM	0.01 N,	152 W
4:00 AM	0.01 N,	144.5 W
4:30 AM	0.01 N,	137 W
5:00 AM	0.01 N,	129.5 W
5:30 AM	0.01 N,	122 W
6:00 AM	0.01 N,	114.5 W
6:30 AM	0.01 N,	107 W
7:00 AM	0.01 N,	99.5 W
7:30 AM	0.01 N,	92 W
8:00 AM	0.01 N,	84.5 W
8:30 AM	0.01 N,	77 W
9:00 AM	0.01 N,	69.5 W
9:30 AM	0.01 N,	62 W
10:00 AM	0.01 N,	54.5 W
10:30 AM	0.01 N,	47 W
11:00 AM	0.01 N,	39.5 W
11:30 AM	0.01 N,	32 W

("Sunrise/Sunset calculator," 2017)

13. If the longitude and latitude are different please click "Change" and enter the correct longitude and latitude. Click "OK" once you are done.

14. Click "Done".

15. Please look at "Your location" and check again that the longitude and latitude are correct.

16. Click the "X"

MacOS f.lux Settings (for attention (placebo) control group)
Below are the instructions for checking the F.lux settings on your computer. Please check the F.lux settings when you receive the email informing you to do so. If you have any questions or concerns, please email the investigator though the Sona System.
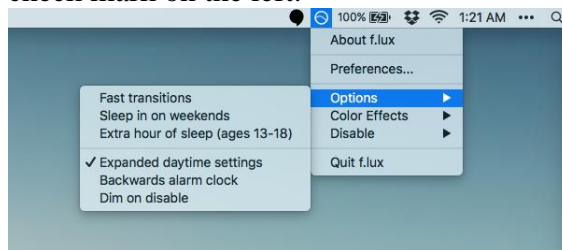
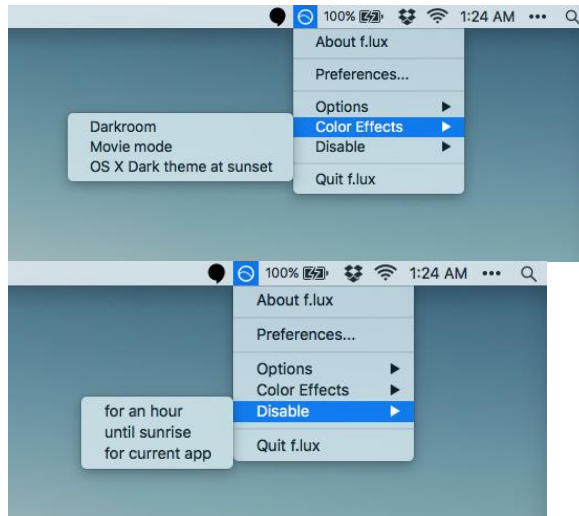1. Open F.lux on your application drawer.

2. Click on the icon in the toolbar on the upper right hand corner of your screen.

3. Under "Options" please check that only the "Expanded daytime settings" has a check mark on the left.

4. Under "Color Effects" and "Disable" please check that none of the options have a check mark on the left.

5. Click on "Preferences" and the "f.lux preference" window should appear.

6. The "f.lux preference" window

7. On the "f.lux preference" window, please check that the location is set to "47.0071,   -120.54".

8. Please think of the earliest time each week that you would prefer to go to bed at.

Earliest time each week that I would prefer to go to bed _____

9. Subtract 2 hours from the time. For example, if you had 11PM as your previous answer subtracting 2 hours you would get 9 PM

Earliest time each week that I would go to bed minus 2 hours _____

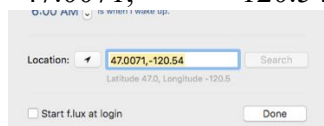10. Add 8 hours to the amount you got in the previous step. For example, if you had 9 PM as your previous answer, adding 8 hours, you would get 5 AM.

Previous time adding 8 hours_____

11. Please set the time in "is when I wake up" to the time that you got in the previous answer.

12. Please check that the option box on the right hand corner is selected to custom colors.
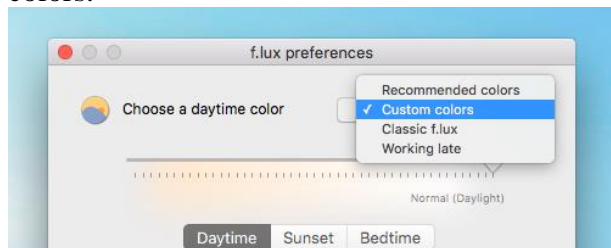
13. Click the "Daytime" tab and please check that the slider is selected to "Normal (Daylight)".
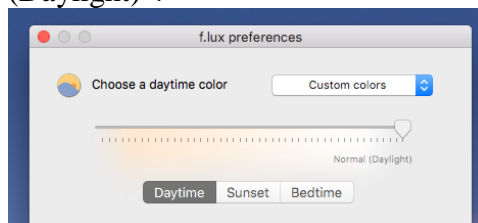
14. Click the "Sunset" tab and please check that the slider is selected to "5000K".
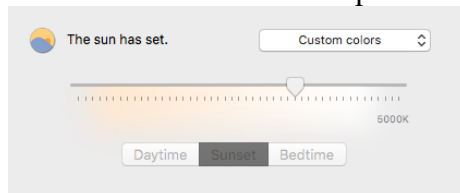
15. Click the "Bedtime" tab and please check that the slider is selected to "Sunset only".
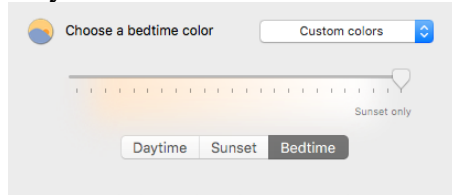
16. Please check mark the "Start f.lux at login" option at the bottom left hand corner of the window and click "Done".
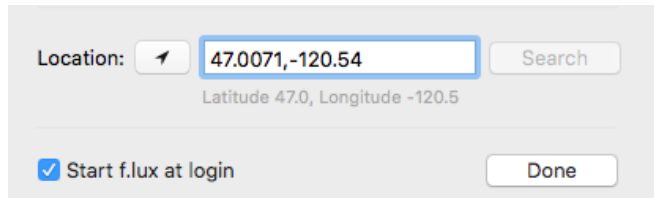
Appendix K

MacOS f.lux Settings **(for the intervention group, the difference is present after step 11)**

Below are the instructions for activating F.lux on your computer. Please activate the program when you receive the email informing you to do so. If you have any questions or concerns, please email the investigator though the Sona System.

1. Open F.lux on your application drawer.

2. Click on the icon in the toolbar on the upper right hand corner of your screen.

3. Under "Options" please check that only the "Expanded daytime settings" has a check mark on the left.

4. Under "Color Effects" and "Disable" please check that none of the options have a check mark on the left.

5. Click on "Preferences" and the "f.lux preference" window should appear.

6. The "f.lux preference" window

7. On the "f.lux preference" window please check that the location is set to "47.0071,   -120.54".

8. Please think of the earliest time each week that you would prefer to go to bed at.

Earliest time each week that I would prefer to go to bed _____

9. Subtract 2 hours from the time. For example, if you had 11PM as your previous answer subtracting 2 hours you would get 9 PM

    Earliest time each week that I would go to bed minus 2 hours _____

10. Add 8 hours to the amount you got in the previous step. For example, if you had 9 PM as your previous answer, adding 8 hours, you would get 5 AM.

    Previous time adding 8 hours_____

11. Please set the time in "is when I wake up" to the time that you got in the previous answer.

12. Please check that the option box on the right hand corner is selected to the recommended colors.
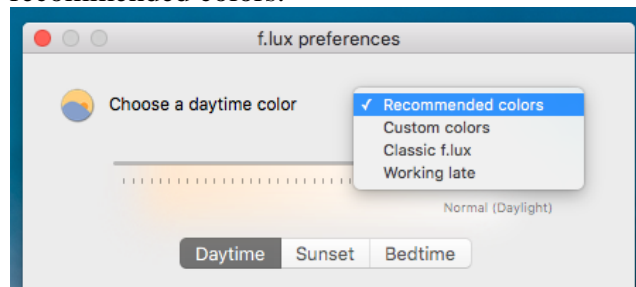
13. Please check that the "Start f.lux at login" option at the bottom left hand corner of the window is checked.
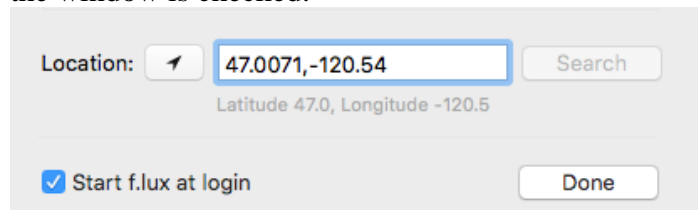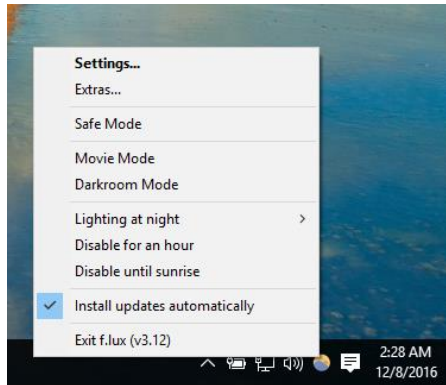
Appendix L

Windows Uninstallation Instructions
Below are instructions for uninstalling f.lux on your computer
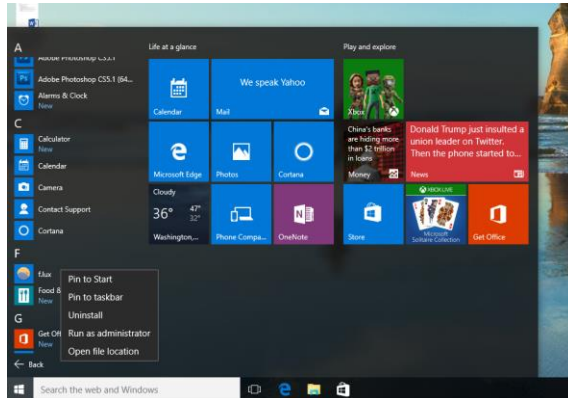1. Right click the f.lux icon in the bar on the lower right hand corner of your screen.
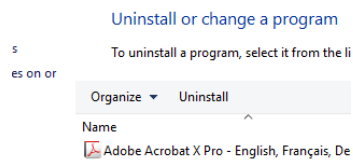

2. Click on "Exit f.lux".

3. Click on your start menu. Click on "All apps". Right click on "f.lux". Click "Uninstall"
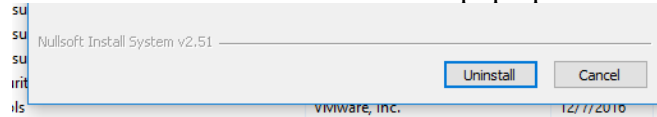

4. The "Programs and Features" window will pop up. Select "f.lux" from the programs below.
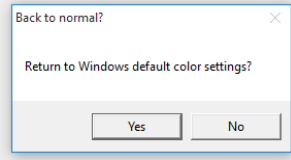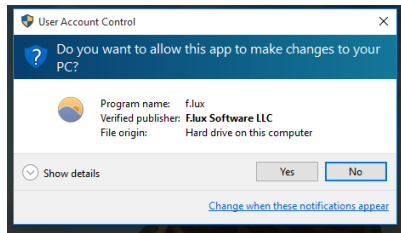

5. Click on "Uninstall".

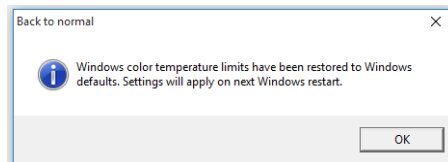6. The "f.lux Uninstall" window will pop up. Click on "Uninstall".

7. A window called "Back to normal?" will pop up. Click on "Yes".

8. A window called "User Account Control" will pop up. Click on "Yes".

9. A window called "Back to normal" will pop up. Click on "OK".

10. Restart your computer.

Appendix M

MacOS Uninstallation Instructions

Below are instructions for uninstalling f.lux on your computer

11. Click on the icon in the toolbar on the upper right hand corner of your screen.
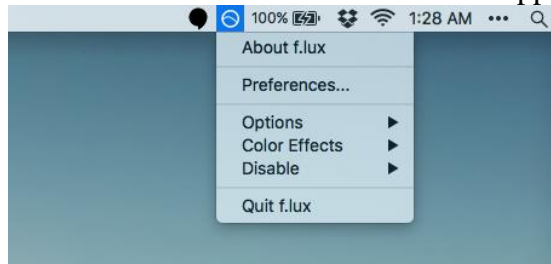
12. Click on "Quit f.lux".
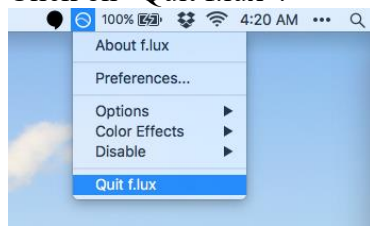
13. Open the Finder application

14. Go to the "Applications" folder.

15. In the "Applications" folder find the "f.lux" icon.

16. Right click the "f.lux" application and click on "Move to Trash".

17. Restart the computer.

Appendix N

Troubleshooting F.lux

Below are instructions pasted from the f.lux website (https://justgetflux.com/faq.html) on how to solve common problems with 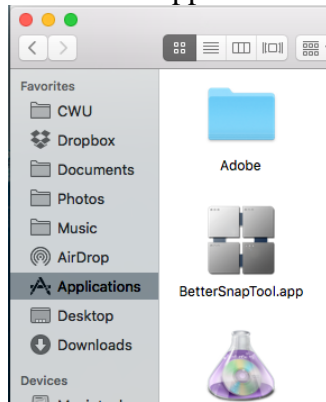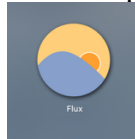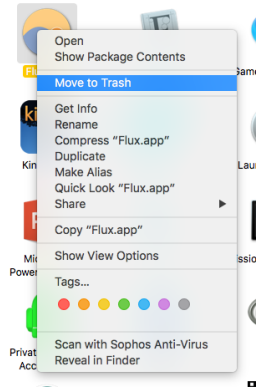f.lux. If you continue to have difficulties or questions please contact the principle investigator, Jonathan Chi at 240-479-4023.

- **f.lux doesn't work on Windows 10. Help?**
  Immediately after upgrading to Windows 10, many machines are using a basic video driver that does not work with f.lux. Windows Update will usually get a better driver (within a day) to a version that works with f.lux. In some cases this does work on its own, so we recommend that you update your drivers with the manufacturer's latest version.

- **I installed f.lux but I can't see any change.**
  Is it past your local sunset time? Just wait, and f.lux will kick in at sunset.
  Is your location set correctly under Settings?
  Check that your night-time settings are not set to Daylight.

- **I uninstalled f.lux and my computer is still orange, what gives?**
  Some users have encountered a problem where f.lux is no longer running but the screen still appears tinted. If you have checked the Processes tab in Task Manager and there is no f.lux process present, this means another program has absorbed the f.lux color profile. The workaround to restore your screen to its normal profile is as follows: Reinstall f.lux. In the Settings Menu, set both the Night and Daytime sliders to daylight. After 24 hours, any other programs should have re-absorbed the new profile, and you may uninstall f.lux with no more changed colors.

- **F.lux makes my mouse stutter, makes my computer slow, or it doesn't seem to change my colors at all.**
  Most problems like this can be fixed by updating your video drivers.
  Try one of these links: NVIDIA drivers, AMD Radeon drivers, Intel drivers.

- **Uh oh, my Surface Pro 3 is freezing!** (or my Intel-based laptop is slow with f.lux).

Early-2014 Intel HD Windows 8.1 drivers have some bugs that give problems with f.lux, and you may not have the latest one (Surface Pro 3 does not as of September 2014). **To make sure you have the latest:**

1. Run **Device Manager** and navigate to **Display Adapters : Intel HD Graphics Family**. Pick the **"Driver"** Tab.

2. Check which version you have. If it's **less than 10.18.10.3907**, you'll want to update (the early-2014 drivers that end with "3412" up to "3621" can cause slowdowns and crashes with f.lux).

3. Download a new intel driver here: Intel HD drivers
   If using a "standard" Intel video card, just get the EXE and install it. You're done!

If using a Surface Pro 3 or "customized" OEM driver, pick the ZIP download so we can force the install.

4. If you picked the ZIP, unzip it and then:

   1. Back in Device Manager, click "Update Driver" and "Browse my computer..."
   2. Choose the Downloads folder and the zip folder you just extracted.
   3. If Windows refuses this new driver, you should Uninstall and Delete the existing driver and start again from step #1. Windows will use its basic driver in the interim (you won't be without video.)

- **Ok, but CCC.exe on my AMD Radeon card is still using 1% CPU all the time, and I don't want that.**

  The Catalyst Control Center is an optional component that can be uninstalled, and you might consider doing this if you're not frequently adjusting your settings for gaming or other reasons. Use Add/Remove Programs, and choose "AMD Catalyst Install Manager" to proceed.
  Do not uninstall the Install Manager, but instead use it to uninstall Catalyst Control Center. In our test, this didn't even require a reboot. Also, leave a note on this page (with the driver version) so we can report it to AMD.

- **My Macbook Pro is having trouble with f.lux, and it flashes sometimes.**
  On dual-GPU machines we write an ICC profile in order to make the "switch" between video cards more seamless. In some older machines, and every so often, this doesn't work so well. To read about how this system works and turn it off if you want, check out our description here: Notes about f.lux changes to ICC profiles.

  If your Macbook is crashing due to switching between cards, or just to understand when it happens, a really great workaround is to downloadgfxCardStatus and use only one of the two video cards.

- **I use Shades on my Mac, and f.lux is fighting with it.**
  Users have reported flashing and flickering when using these together. We recommend you only use one of these programs at a time.

- **I can't drag the program to the Trash on my Mac.**
  First quit f.lux from the Settings menu, to the left of your system clock.

- **I adjusted my color / gamma settings using Windows "Calibrate Display" or NVIDIA's controls and f.lux removes them. Can you keep these settings and use f.lux?**
  Unfortunately, these systems do not write their settings in a format that f.lux can access (we read VCGT headers only). For better results, we recommend the use of hardware calibrators such as the very good x-rite i1 Display or ColorMunki

Display, which write settings in standard ICC files that f.lux can read. If you don't have access to a device like this, you might find a suitable profile for your display online at the TFT Central Monitor Settings Database.

Several people have reported that QuickGamma works well and produces good profiles that f.lux can read.

If you use a Spyder, the software profile loader may cause f.lux to flash periodically. You can disable the Spyder software on startup, and use f.lux instead to load the profile. Also, when you're calibrating a display, you'll want to do the opposite and quit f.lux before you do.

- **My ASUS laptop is flickering for a minute after startup.**
  See if you can find an "ASUS Splendid Video Enhancement" feature and uninstall it.

- **My Sony VAIO is flashing every time it wakes up.**
  See if you can find a "Color Mode Setting" in Vaio Control Center > Display, and change it to "Do not apply color mode".

- **I have a new tablet (e.g., a Dell Latitude 10 or an ATIV 500T) that does nothing when I run f.lux. Is there a way to make f.lux work?**
  These Atom-based machines use the PowerVR SGX545, a mobile-class video card that doesn't currently support color controls. We've had many reports of failures with this chipset, so right now we don't anticipate a better result.

- **I have a DisplayLink USB monitor adapter. Is there a way to make f.lux work for this display?**
  DisplayLink has no support for color calibration, so f.lux can't make changes to DisplayLink monitors. Unfortunately, you can only use f.lux today on displays that are directly connected to your computer. (e.g., it usually won't work over remote desktop either.)

- **Since upgrading to Windows 10 Anniversary, my non-DisplayLink screen is flashing a lot, but only when I have my USB monitor or docking station plugged in**
  Yes, we had a bug that caused this. Please get an updated build here: flux 3.11.

- **My PC's Anti-Virus program flagged f.lux as malware.**
  As long as you've downloaded f.lux from this site, you don't have any malware. Every once in a while we get flagged as a potential threat due to the nature of our installer and updater. If this happens to you, please send us a note with your anti-virus program and details and we will contact them for review.

- **Something else is going wrong with f.lux for Windows**
  We always recommend updating video drivers as a first line of defense. If you're experiencing flickering or problems, please upgrade your drivers. If that doesn't work, we love to fix bugs. Please send us a note with information on your operating system, video card, and any other information that might be helpful to us.

- **iOS: Why do I need Location Services enabled?**
  f.lux uses Location Services to determine the time of your local sunrise and sunset. In the future we will include an option to choose times manually.

- **Why isn't f.lux available in the Apple App Store? I don't want to / can't jailbreak my device.**
  We would love to make f.lux available for all iOS devices. To make f.lux work on iOS, we've had to go outside the bounds of what apps are normally allowed to do. Currently, iOS does not allow developers to access the Private APIs we need to make f.lux work on iOS.
  Apple values their customers' feedback, so if you have a minute to let them know how f.lux has helped you, and that you'd like to see it available for all iOS devices, send a note at iPhone feedback or iPad feedback.

- **When is the Android version coming out?**
  f.lux on Android requires a rooted phone, but it's on the play store here.

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Appendix O

Student Medical and Counseling Clinic

The Student Medical and Counseling Clinic (SMCC) is a CWU resource for students to use. The SMCC can offer consolations, medical treatment, counseling, resources and referrals for students. If you feel that sleep issues or substance use is interfering with your daily activities or bringing you distress it is advised that you contact the SMCC.

Services Provided

- All general medical services (illnesses & injuries)
- Mental health medical evaluation and treatment
- Sports Medicine
- Sports, ROTC, and routine physicals
- Removal or biopsy of skin lesions
- Female exams/PAP tests
- Sexually transmitted disease screening and treatment
- Pregnancy testing and counseling
- Immunizations
- Lab and X-ray services

How do I make an appointment?
- You can make same-day appointments either online through the Patient Portal, or via phone (Medical 509-963-1881, Counseling 509-963-1391).
- On the day of your appointment please arrive 20 minutes early to fill out new patient forms.
- A no-show fee of $25 will be charged to your student account if you are more than 10 minutes late or fail to cancel the appointment.

MEDICAL: (509) 963-1881
COUNSELING: (509) 963-1391
FAX: (509) 963-1886

Suggested Guidelines to Follow

While you are in this study it is highly encouraged that you follow some of these guidelines.

- Do not take naps during the day.
- Do not drink alcohol 5 hours before you plan on going to bed
- Do not use Marijuana 5 hours before you plan on going to bed
- Do not ingest caffeine 5 hours before you plan on going to bed
- Do not exercise or engage in moderate to strenuous physical activity 2 hours before you plan on going to bed

Appendix Q

Extended Daily Questionnaire **(to be given at the one-week point of the data collection)**

Thank you for your continued participation in this study. **Today we ask you to quickly check that the f.lux settings have not changed.** If you cannot remember the required settings, please refer to the f.lux settings handout. When you are done please fill out the questions below to the best of your abilities.

<u>Due to the sensitive nature of some of the questions we ask that you fill out the survey in a private location</u>

We also ask that you please take the time today to **backup your computer to an external hard drive.**

1. Were the f.lux settings different than what you set them to when you activated the program?

Yes/No

   a. (if the person answered yes) Please write in the box below how were the settings different.

(Short Answer)

2. Did you take any naps yesterday?

Yes/No

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c. (If the participant answered no the question skip logic will skip this question) How many naps did you take and for how long did you take the nap(s).

(Short Answer)

3. Did you drink alcohol 5 hours before going to bed?

Yes/No

4. Did you drink any caffeine drinks 5 hours before going to bed?

Yes/No

5. Did you use any marijuana 5 hours before going to bed?

Yes/No

6. Did you use any other drugs, medication or herbal supplements the day before?

d. (If the participant answered no the question skip logic will skip this question) Please list the drugs, medication or herbal supplements that you used.

(Short Answer)

7. Did you exercise or engage in moderate to high physical activity 2 hours before going to bed?

Yes/No

8. Did you use your computer at any time two hours before you tried to go to sleep?

Yes/No

e. (If the participant answered no the question skip logic will skip this question) Was F.lux in effect when you used your computer during the two hours before you tried to go to sleep?

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<div align="right">Yes/No/Don't Know</div>

f.   (If the client answered yes) Roughly, how many minutes did you use the

computer while F.lux was in effect?

<div align="right">____Hr____Min</div>

Appendix R

Debriefing

Thank you for participating in this study. This study is important because while past research has looked at how blue light can negatively affect sleep, little research has been done on the effectiveness of software that changes the computer color before bedtime. This study was designed to see if screen color and brightness affected the sleep of users. It is hypothesized that users who set software f.lux to display a color temperature of 1900 K (more red light) for at least 2 hours before going to bed will report an overall shorter sleep onset and longer sleep duration compared to those who set the color temperature to 5000 K (more blue light) before bedtime. You were assigned in the (K) group.

You can choose whether you want to uninstall or continue using the f.lux program. Attached are the uninstallation instructions for the f.lux program. If you have any difficulties with uninstalling the software or if you have any further questions please feel free to call the principal investigator, Jonathan Chi, at 240-479-4023.