Immediate Effects of Red, Blue and White Lighting on Blood Pressure, Heart Rate, Mood and Stress

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Acknowledgments

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ABSTRACT

This study aims to add to previous research on red, blue and white coloured lighting and the effects it may have on diastolic and systolic blood pressure, heart rate, mood and stress. Coloured light bulbs were used to create the desired environment, with effects counterbalanced to avoid order of effect. Each condition was administered in five minute segments. This was a within subjects, quasi-experimental design. Thirty participants (n=30) were examined in total during this experiment. Brief Mood Introspection Scale by Mayer and Gascher (1988), was used to gain mood scores and Smith Relaxation States Inventory, Smith (2005) was uses to obtain stress levels in participants. The results indicated no significant differences for blood pressure, heart rate, mood and stress under red, blue and white coloured lighting.

INTRODUCTION

1.1 General Overview

"Mere colour, unspoiled by meaning, and unallied with definite form, can speak to the soul in a thousand different ways. " ― Oscar Wilde.

This quote by Wilde conveys how a person can become somewhat seduced by colour resulting in many forms of expression. The purpose of this study is to examine the results of participant's overall mood, levels of emotional stress, heart rate, systolic blood pressure and diastolic blood pressure when they are exposed to red, blue and white, coloured lighting environments. Systolic blood pressure "The term refers to the force of the blood in one's arteries while the heart is beating" Bloodbeat, (2013), while diastolic blood pressure "concerns the force of the blood in the arteries between beats while the heart is relaxing", Bloodbeat, (2013) This study sets out to see if there will be any difference in the results during the aforementioned lighting conditions. The particular colours are based on previous research that will be mentioned in this body of work.

The colours that are selected are not only based on previous research but also on their position in the visible light spectrum. Madigan (2011) explains the visible light spectrum, as being made up of colours that are visible to the human eye with these colours consisting of different wavelengths, see Figure 1. AmazingSpace (nd), explain that wavelength is the unit of measurement of visible light, and measured be examining the distance between waves, see Figure 2 for pictorial explanation. The visible light spectrum is categorised in a range of short to long wavelengths. The colour blue falls in the short wavelength field while the colour red is characterised by its longer wavelength. In the studies that will be discussed there will be a

comparison between the different colours that fall into the short and long wavelength categories.
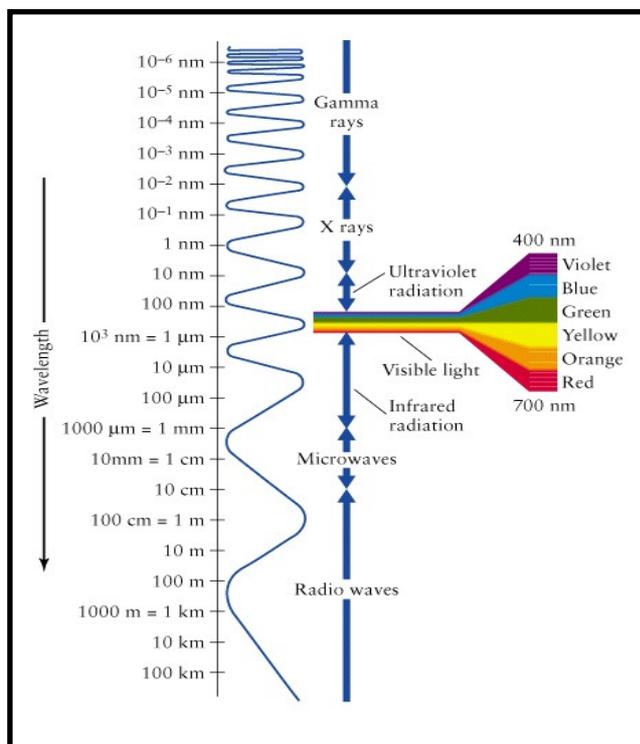

Figure 1 - *Wavelength image from Universe by Freedman and Kaufmann, Image of Visible Light Spectrum, obtained from Madigan (2011)*
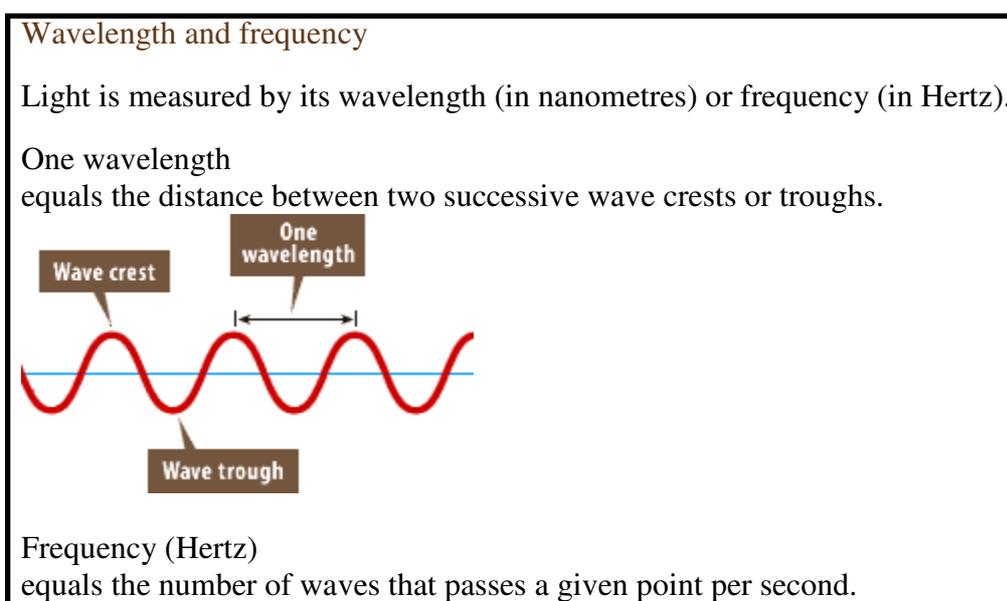

Figure 2 - *Explanation of Light Wavelength in Diagram Form, AmazingSpace (n.d)*

1.2 Colour Association

Moving from the scientific explanation of colour, colour association can be expressed through many avenues. The concept that colours are linked to a person's spirituality, mood and personality has existed for centuries and even been applied in the practice of medicine. Hippocrates "the Father of Modern Medicine" put forward his Humours theory. He proposed that colours could be used to help decipher the ailment and mood of a person. He put forward that green phlegm indicated that a person was sluggish, black bile showed a person suffered with melancholia (depression), yellow bile suggested irritability and blood, which is red implied a changeable temperament.

Colour associations have been involved in various religions for centuries and are particularly seen in the Buddhism and Hinduism Religions. In the Buddhist Religion particular colours are assigned to a state of mind and colour symbolism, with various colours referring to different emotional feeling and the associated states of mind, Kuhmar (2012). Marchard (nd), explains that Hinduism assigns different colours to particular areas in the body in what are known as chakras. New age treatments have become popular in recent years with people turning to a holistic approach, with the use of crystals treatment of their chakras. It is important to note that due to the popularity of this new age treatment in the Western world that people might have preconceived and a predisposition as to what colours illicit a certain response. This way of thinking or response is referred to as the Barnum Affect coined by Meehl, Snyder and Shenkel (1975), in which it states that people accept universally known statements without proof as valid description of their own personality.

1.3 Seasonal Affective Disorder and Light Therapy

Shifting from the Holistic approach, colour has been used and is continued to be used in the treatment of medical disorders. In particular, white lighting is used as an effective

treatment in Seasonal Affective Disorder- SAD, with exposure to white lighting as the prescribed and accepted treatment in this disorder. Wesson and Levitt in (1998) described SAD as a recurrent type of mood disorder with a pattern of onset and remission.

The treatment of SAD was investigated by Brainard, Sherry, Skwerer, and Waxler (1990), where they examined the clinical effectiveness of exposure to coloured light. He compared the results of treatments that used red, blue and white lights and his research reinforced the findings that white light achieves the best response in helping to alleviate the symptoms of SAD. In addition to this study was that of Oren et al. (1991), this study looked at exposure to green and red lights only and found that green lighting produced significant results in comparison to the red light. Another study in 1991 by Stewart et al. compared the effects of green and white lighting in participants with SAD, and found that both conditions significantly reduced scores on the Hamilton Depression Rating Scale. However the white light was significantly more effective on reducing scores compared to the green light. These results further reiterate that white light is the optimum lighting to treat SAD with.

1.4 Coloured Light in Clinical Work

Five years after Brainard et al. (1990) study on SADs, McManemin's in 1995 took an unusual approach in the use of coloured light. She looked at coloured lights in the use of clinical work and took one participant who had suffered a severe brain injury a number of years previous to the study. The participant was subjected to a series of strobic coloured lighting conditions over the course of eight weeks. During the exposure the patient was encouraged to speak freely in a manner akin to Freud's free association. The results showed significant results on a number of scales in comparison to the same tests that were administered before the study commenced and showed improvement on memory and

depression was also reduced. However the results from this study require further testing across numerous participants to determine if the treatment can be used clinically.

1.4 Coloured Lighting and Blood Pressure

While the aforementioned studies have provided the basis that coloured light has an effect on memory and depression, this research is also interested in the affects physiological effects on the body, in particular blood pressure. The main theories of interest are Gerard's (1958) study where he examined the effects of exposure to red, blue and white light. A number of variables were examined in this study with blood pressure and heart rate amongst them. It was found that the results indicated significantly greater autonomic and cortical arousal for red light compared to the blue light. The results were based on the mean changes from resting levels for each of the colour conditions. It was noted that during the blue condition that there was significantly greater wellbeing and relaxation and during the red condition there was more tension and arousal reported. He found no significant results in relation to heart rate. It was noted that during this study, participants who scored higher with anxiety were found to be more susceptible to the effects of the lighting. This early study was the basis of further studies to follow.

One such study was by Naveen and Tells (2006), examined the physiological effects of blue and red light. This study found that during the blue light the diastolic blood pressure reduced immediately after the exposure, with no significant results concerning systolic blood pressure. Red light did not have a stimulating effect in this study. The results of this study suggest that the blue lights can be used to induce the lowering of diastolic blood pressure.

Recently a study by Grote et al.(2013), investigated cardio-autonomic and psychological effects from coloured light cycling. Two experiments were carried out consecutively to obtain the results. An explorative and a longitudinal test with a randomised

crossover design test were administered. Significant results found that oscillating red, green and blue colour had an effect on blood pressure and appeared to increase blood pressure. This reaction was reflected soon after the lighting affect was administered.

1.6 Coloured lighting and Heart Rate

The Grote et al.(2013) study also examined heart rate and found that oscillating colour light exposure had significant effects on heart rate, these effects were replicated in the second experiment with white light. These results are supported by McManemin's (2005) study who also examined heart rate response. This study found that there was a significant reduction in heart rate when the participant was exposed to indigo. There was a further reduction in heart rate during the baseline exposure. A critique of this study is that there was no resting period between the exposed periods of colour. Also there was no counterbalancing in relation to which the order the colours were exposed.

Additionally a 2006 study by Schäfer and Kratky, examined the effect of coloured illumination on heart rate. This study yielded significant results in that red and green lighting showed increased heart rate. The blue light exhibited a lower heart rate, this study accepted that white light had an effect on cardiac rhythm and didn't seek to test if further. Twelve participants were used in this study, a larger participant group would to help solidify the findings.

Further studies with heart rate and coloured light by Kohsaka et al. in (2001) studied the effects of bright light on the autonomic nervous system during sleep. Their results indicated that the exposure to bright light had an effect on the heart rate during low wave sleep. Similarly a study on continuous exposure to white light by Yokoi, Aoki, Shimomura, Iwanaga and Katsuura (2006), suggested that this exposure delays the nocturnal decrease in heart rate at rest but maintained heart rate during sleep deprivation.

In addition to these studies, Litscher, Xie, Wang and Gaischek (2009), found significant results that blue laser light exposure lowered heart rate in male adults. A study by Laufer, Láng, Izso and Németh (2009) compared the effects of blue and red lighting, where blue lighting was found to be significantly more activating and unpleasant in comparison to the red light. Heart rate decreased slightly under blue lighting which according to the researchers indicated an increase of the parasympathetic results in comparison to results under the red lighting conditions. The studies mentioned here are relatively new studies that require further testing in order to support the findings.

1.7 Coloured Lighting and Mood

As mentioned previously, studies involving white have been shown to improve the mood of SAD sufferers, and are currently prescribed as an effective treatment for the disorder. In earlier studies employing the use of colour, Aronson (1917) carried out a study on emotional associations to colour. This was done by way of hypnotic suggestion in contrast to exposing participants to coloured lighting environments. While under hypnotic suggestion the participants would see everything in a particular shade of colour. Aronson (1917) found that red had links to the feelings of happiness, while blue elicited feelings of serene and relaxation and evoked a sense of calm. There are however major criticisms of this particular study, one fault is a lack of statistical analysis on the results and has limited scientific value due to the small sample size used.

In addition it would be difficult to replicate this study as it is unknown what order the coloured conditions were administered. Interestingly, it is important to note that the suggestion of colour elicited certain responses. This could be deduced that reactions to a colour is a conditioned response in some people due to popular beliefs as to what colour

depicts what. For example it is sociable acceptable that red is the colour of love and associated with St. Valentine's Day, a day of love.

Additionally a study by Knez and Kers (2000), investigated the impact of indoor lighting on mood. The researched suggested that younger adults indicated a negative mood in the reddish light in comparison to the older adults while the inverse was observed in the bluer lighting conditions. Similar research conducted by Kellur and Wetterberg (2007), shows that lighting when experienced as too dark, mood became negative and additionally if the light was experienced too bright this resulted in an unpleasant mood also. These results were based on white lighting conditions, but highlight the importance of optimal lighting conditions. Consequently, it is important to attend to the strength of the lighting administered in further studies.

Furthermore, the recent study previously mentioned by Grote et al. (2013), found corresponding results that coloured light does affect mood. This however was only noted in the longitudinal study. Overall the results of these studies do suggest that colour lighting does have an effect on mood, but there is conflicting evidence as to how long exposure is required to cause the outcome.

1.8 Coloured Lighting and Stress

Corresponding previous studies have examined stress and coloured light. In 1975 Jacobs and Suess studied the effects of colours on anxiety states. After fifteen minutes of exposure the results showed red yielded significantly higher scores on anxiety states in comparison to the blue colour which did not show any significant changes towards positive or negative results.

A further study in stress by Kutchma (2003) looked at the effects of room colour on stress perception with regards to white, red and green environments. Correlations were found between red room colour and emotional stimulation and green colours were associated with inhibitory effects. It was found that subjects in the red condition had higher stress rating scores compared to the green or white condition. Therefore, due to the results of this study, importance should be placed on colour environment as it can have effects on a subject's level of stress.

1.9 Brief overview of the experiment

The author will obtain the results by way of experiment. All participants will be exposed to the three lighting conditions red, blue and white. The effects will be administered for five minutes in total. The experiment will be counterbalanced to obtain the best results. After each lighting condition is received the participant's blood pressure and heart rate will be obtained by blood pressure cuff and heart rate monitor. Levels of mood and levels of stress will be obtained by self-administered questionnaires that are completed after each condition. The questionnaires used in this experiment are the Brief Mood Introspection Scale (BMIS) by Mayer and Gaschke, (1998) and the Smith Relaxation States Inventory 3(SRSI3) by Smith (2005).

1.10 Purpose of this Study

This study was intended to build upon the previous research mentioned, and intended to investigate the findings of coloured lights on the physiological and psychological effects on participants. Very little research has been completed in this area to date and this study aims to widen the spectrum of interest. In addition it's this studies intention to add validity to "pop

psychology" as very little scientific work has been done in this area previously. This study intends to add to the previous research by examining red, blue and white light. The physiological responses that this research will focus on are blood pressure (systolic and diastolic) and heart rate. Levels of mood and levels of stress are the psychological responses that will be examined in this body of work.

The research intends to find if the results contribute to the previous studies and to further reinforce any significant findings. This study sets out to combine variables from selected studies to aid further research. It is accepted that white light has a positive effect on mood disorders, Brainard et al. (1990), but this investigation delves to discover if red or blue will produce significant results in relation to any of the variables mentioned. This research could help provide the basis for alternative colours used in therapies if the findings are significant.

1.11 Possible uses for Significant Results

Further uses of significant results could be used in a medical setting if a person had adverse side effects to prescription medicine, Bloodbeat (nd) state that "different people can have different side-effects from the same medicine". If one colour produces effects of lowered blood pressure or heart rate it could help in achieving an alternative to prescription blood pressure tablets or to be used in conjunction with prescribed medication. Correspondingly, in relation to low blood pressure which is harder to treat with prescription medication results could indicate what colour light would be affective to raise blood pressure

Additionally, the results gained with relation to heart rate could be used in the medical setting but also in a sporting capacity. If one type of lighting is more effective at lowering heart rate this could be utilized to enhance athletic performance or to aid a quicker recovery. Furthermore, significant findings could impact on lowering levels of stress and improving

overall mood levels. The research mentioned states that the colour of environment has an impact on mood and stress and this can be alleviated or improved by changing the environment.

Environments that could benefit from changes could be that of hospital waiting rooms or treatment rooms which would assist the patient or family for example in a time of distress. Classrooms and study rooms could also benefit from new and improved environments and could produce a more conducive setting for learning. Other possibilities from the findings of this research are special needs centers. The findings could help to indicate the best color for lighting, equipment and room colour to provide relief and comfort.

This research could also disprove or prove some of the new age treatments which are not based on scientific findings but on popular psychology. It's the author's hope that this research will help identify and further confirm the effects of coloured light on the body and add to the research that exists.

1.14 Proposed Hypothesis

Hypothesis 1- There will be a difference in diastolic blood pressure levels when participants are exposed to red light, blue light and white lighting conditions.

Hypothesis 2- There will be a difference in systolic blood pressure levels when participants are exposed to red light, blue light and white lighting conditions.

Hypothesis 3- There will be a difference in heart rate levels when participants are exposed to red light, blue light and white lighting conditions.

Hypothesis 4- There will be difference in overall levels of pleasant mood when participants are exposed to red light, blue light and white lighting conditions.

Hypothesis 5– there will be a difference in levels of emotional stress when participants are exposed to red light, blue light and white lighting conditions.

METHOD

2.1 Participants

A sample of convenience of thirty participants from different backgrounds took part in this study, including family members, friends and college students. The participants were recruited by oral invitation and took part willingly with no monetary rewards offered. A total of twenty females and ten males took part. All participants received each conditions of this experiment. The different conditions were administered by a counterbalanced design to control for order of effects, as this was a repeated measures design experiment.

Inclusion criteria for participants required them to be over the age of eighteen, be able to read and write and understand instruction. Exclusion criteria in this particular experiment is anyone under the age of eighteen, suffering from any heart issues such as high blood pressure or is colour blind due to colours administered in the experiment. All participants were required to sign a consent form agreeing to take part in the experiment. The details of the experiment were explained in full to the participants before commencement and they were also informed that they were free to leave at any stage of the experiment. Additionally they were informed that the results would be kept for up to one year and then destroyed. Ethical approval was granted previous to participants undertaking this study by the Board of Ethics in Dublin Business School.

2.2 Design

This is a quasi-experimental design, with mixed qualitative and quantitative research. This is a within subjects experiment with all participants receiving every conditions with comparisons of results examined across the different conditions. This was a counterbalanced design experiment.

The independent variables in this experiment are red lighting conditions, blue lighting conditions and white lighting conditions. The dependent variables are heart rate, blood pressure (systolic and diastolic), levels of overall pleasant mood and levels of emotional stress. The participants received each lighting condition, as well as two types of questionnaires. Participants are required to complete the questionnaires after every condition.

2.3Materials

This experiment was conducted in the Media Laboratory in Dublin Business School. The nature of this study necessitates that the experimenter have the ability to control the surrounding environment. The media laboratory was fit for purpose as it had blackout blinds which controlled the entry of natural light. This room provided other materials needed as a chair, desk with access to power sockets for the use of the apparatus. Additional material required were a stopwatch, and paper and pen questionnaires with printed consent forms. Two types of questionnaires were utilized in this study.

The first was Brief Mood Introspection Scale by Mayer and Gaschke (1988), which obtained the overall pleasant mood of participants. This one page questionnaire has sixteen adjectives consisting of eight positive and eight negatively orientated words. The positive words were happy, loving, lively, peppy, caring, calm, content and active. The negatively oriented list consisted of sad, grouchy, gloomy, jittery, fed up, nervous, tired and drowsy. A copy can be seen in the appendix. Participants were required to circle the best response that indicated how they felt at that present moment. Four response options were given "definitely do not feel, do not feel, slightly feel and definitely feel" Mayer and Gaschke (1988). This measure has been utilised in many studies and cited in numerous articles to date. It appeared in a recent publication of Journal of Personality and Social Psychology a 2012 edition, in a

study by Maner et al. (2012) on Fundamental motives enhance people's sensitivity to basic social categories.

The Smith Relaxation States Inventory 3 (SRSI3) by Smith (2005), consists of thirty eight items which assess feeling in the present moment on a 6 point likert scale. The scale ranges from negative ascending to positive with 1 corresponding to "not at all", 2 "a little", 3 "mildy moderate" 4 "moderately" 5 "a lot" and 6 equivalents to "maximum", Participants were instructed to circle the number that best indicated how they felt in the present moment. The items of interest to the experimenter were the statements corresponding to stress such as item number 9 "I am worrying". The full questionnaire can be seen in the appendix. Smith (2005), states that reliability for the SRSI3 has yet to be determined and Chronbach alpha reliabilities for previous versions of this inventory (excluding three new mindfulness items) range from .60 to .88. Permission was requested and granted for use of this particular questionnaire and this correspondence can be seen in the appendices.

2.4 Apparatus

The apparatuses in this experiment were a blood pressure and heart rate monitor and two desk lamps with colour LED light bulbs. The blood pressure and heart rate monitor is a combined unit manufactured by German company Sanitas and are available to purchase online or in shops. This is an automatic monitor and measures systolic and diastolic blood pressure and heart rate which displays on a LCD screen.

The "Livarno Lux" LED bulb manufactured and distributed by Milomex Ltd. provided the light source in this experiment. One bulb provides a total of sixteen colours and is controlled by a wireless remote. The Luvarno Lux, bulb is an LED bulb with 3.7w and 230v-50Hz, model number 59021. Only three colours were used from the colour panel provided, red, blue and white. The advantage of one bulb providing all colours avoided

unnecessary changing of individual bulbs. The lamp used was a standard desk lamp available from many sources and was white in colour. Two lamps fitted with the aforementioned bulb were used to enhance the immediate environment further.

2.5 Procedure

As this was a convenience sample of participants they were known to the experimenter and were asked to take part verbally. Once involvement was confirmed an appointed date and time was allocated to the possible participant. In the Media Laboratory, the room was set up with a chair and desk with two desk lamps placed on the table facing the chair.

Upon arrival the prospective participant was invited to sit at the table. The experiment was explained in full and they were invited to ask any questions. Information was provided that results were anonymous and they were free to leave at any stage with no negative repercussions. The participant was then presented with a consent form and general question sheet which inquired if they suffered from any heart of blood pressure issues. These forms can be seen in full in the appendices. Anonymity was ensured, by placing the signed consent form in an envelope and stored away from the results gained.

The experiment began once the main light in the room was switched off and the light from the LED bulbs were switched on. The order of administration was counterbalanced where all participants received a random order of light sequence. The blackout blinds were pulled down to block out any natural light entering the room. A stopwatch was used to time each condition for five minutes which was controlled by the experimenter. The experimenter also controlled the LED lights and the room's main lighting source.

After the five minute exposure to each condition the room's main light source was turned back on and the LED bulbs turned off. The wireless controlled remote allowed for ease of change in a fast and effective manner. The participant's systolic and diastolic blood pressure along with heart rate was taken by the experimenter. The results were then tabulated by the experimenter and the corresponding condition was also noted (results chart in appendix).

Following the recording of the physiological results the participants were then invited to complete the BMIS and the SRSI3 questionnaires. This was self-administered by the participants and was completed by pen and paper. The questionnaire was marked with R for red, B for blue and W for white depending on the lighting condition they were completed after. This was done to identify the corresponding results to the appropriate environmental condition. The completed questionnaires were then placed in an envelope with no markings or identifiable marks on it.

Leading on from completion of the BMIS and the SRIS3 the rooms lighting was then turned off and the LED light source was turned on this time exhibiting a different colour. This was once again timed by stopwatch by the experimenter for a total of five minutes. The above process was completed again for the second condition.

In total this process was carried out three times by experimenter and participant under each lighting condition. The experimenter was present in the room at all times during experiment. The experiment took approximately thirty to thirty-five minutes to complete. Examples of the coloured lighting administered can be seen in figure 2, figure 3 and figure 4.

Figure 3- *Blue light, Taken during experiment consent form in Appendix*

Figure 4- *Red Light, Taken during experiment, consent form in Appendix*

Figure 5- *White Light, Taken during experiment, consent form in Appendix*

RESULTS

Over the duration of the experiment data was gathered from each participant and inputted in the computer programme Statistical Package for Social Sciences (SPSSv18). The BMIS by Mayer and Gaschke (1988) and the SRSI3 by Smith (2005) were computed and recoded and overall scores were obtained. Eight items on the BMIS by Mayer and Gaschke (1988) were reversed scored to gain the overall outcome. The SRSI3 by Smith (2005) was computed to gain the result for stress. The cleaned and recoded data set was then used for the purpose of analysis.

As mentioned previously a total of thirty participants comprised this study, twenty females (n=20) and ten males (n=10). The participants were not placed in groups and received all the conditions of the experiment. This study set out to see if differences occurred during red, blue and white lighting on, systolic and diastolic blood pressure, heart rate, mood and stress. The data was tested for normality, it was found that all data was normally distributed except for stress. The appropriate tests were run.

3.1 Descriptive statistics

Descriptive statistics were run on all the variables involved in this study including Blood Pressure (systolic and diastolic), heart rate, levels of mood and stress and the lighting conditions under which they were obtained. The mean and standard deviation scores for red, blue and white light and the related variables are outlined in Table 1.

Table 1 *Descriptive Statistics of Systolic and Diastolic Blood Pressure in red, blue and white light.*

Variables	Groups	Mean	SD	*F*	d*f*	*p*
Systolic BP	Red light	121.43	16.400	2	2.209	.119
Systolic BP	Blue light	118.10	19.633			
Systolic BP	White light	124.10	19.009			
Diastolic BP	Red light	79.83	17.458	2	3.055	.055
Diastolic BP	Blue light	74.90	10.192			
Diastolic BP	White light	85.60	23.51			
Heart Rate	Red light	77.23	13.390	1.946	.502	.603
Heart Rate	Blue light	78.77	10.595			
Heart Rate	White light	78.17	12.570			
Overall Mood	Red light	37.23	5.302	1.609	1.697	.198
Overall Mood	Blue light	35.90	4.551			
Overall Mood	White light	36.80	4.172			

*p significant at .05 level

Descriptive statistics were also obtained for stress levels under the red, blue and white lighting conditions. Normal distribution was not found and the percentiles were obtained and are outlined in table 2.

Table 2 *Descriptive Statistics of Levels of Stress under red, blue and white lighting conditions*

showing Percentile Ranges

Variable	25th Percentile	Median Percentile	75th Percentile
Overall Stress- Red	3.00	4.00	6.25
Overall Stress- Blue	2.33	3.33	5.50
OverallStress-White	3.00	3.00	5.25

3.2 Hypothesis 1

Hypothesis 1 stated that there would be a difference in diastolic blood pressure levels when participants were exposed to red light, blue light and the white lighting conditions. As preliminary analysis found the data to be normally distributed, a Repeated Measures Anova was used to determine whether or not a statistically significant difference exist between diastolic blood pressure under the red light conditions, blue light conditions and the white light conditions. This resulted in $(F(1.663, 48.225) = 3.055, p=.065)$, level of significance at $(p=0.05)$, hence no statistical significant difference was found; therefore the null hypothesis was accepted in this case. Although the null hypothesised was accepted, it should be noted that $(p=.065)$ under the Anova test. This result was closest to the level of significance at $(p=0.05)$ in comparison to the other findings in systolic blood pressure, heart rate and mood, but not enough to be accepted. A bar chart showing the means of diastolic blood pressure

under red, blue and white light, show the mean score of white diastolic blood pressure to be higher than red and blue the different conditions is depicted in Table 5.
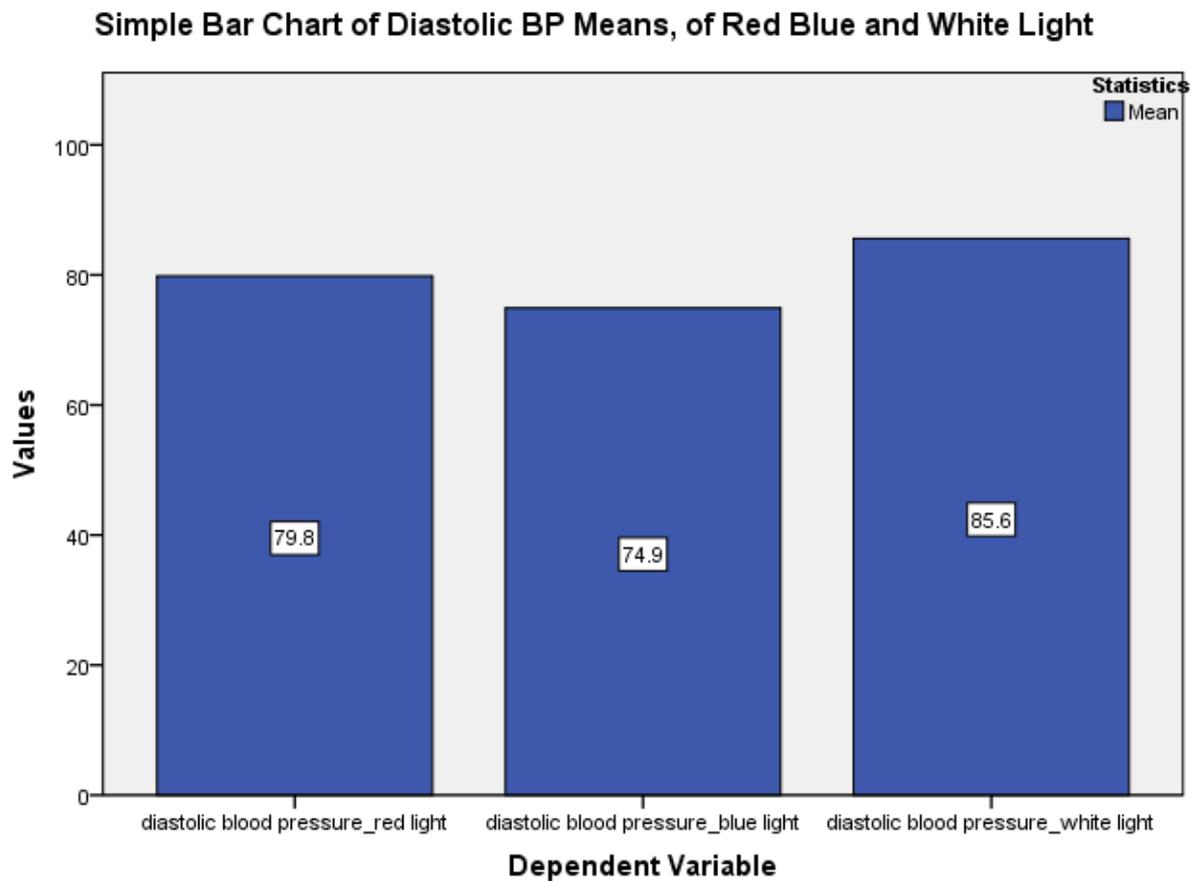
Figure 6 *Bar Chart of Systolic Blood Pressure Means of Red, Blue and White Lighting Conditions*

3.3 Hypothesis 2

Correspondingly a Repeated Measures Anova was also run for systolic blood pressure as there was normal distribution. It was hypothesised that there would be a difference in systolic blood pressure when compared across the red, blue and white lighting conditions .There was no statistically significant difference found between the groups,($F_{(1.845, 53.518)}$

= 2.209, p=.125). The level of significance was (p=0.05), thus the null hypothesis was accepted.

3.4 Hypothesis 3

Hypothesis 3 aimed to find if there was a difference in heart rate levels when compared across the different conditions of red, blue and white light. Preliminary tests conducted found normal distribution, which resulted in a Repeated Measures Anova being carried out. The results were not significantly different, (F (1.946, 56.424) = .502, p=.603), level of significane (p=0.05), so the null hypothesis was accepted in this circumstance.

3.5 Hypothesis 4

Further investigations were carried out to explore if any significant results were found between the red, blue and white lighting groups and levels of overall pleasant mood in participants. As normal distribution was found a Repeated Measures Anova was completed. There were no significant differences found, (F (1.609, 46.668) = 1.697, p=.198),level of significance (p=0.05) due to these results the null hypothesis was accepted.

3.6 Hypothesis 5

Non parametric testing was carried out as the data was not normally distributed. A Freidman's test was run to establish if there was a significant difference between levels of emotional stress in the red, blue and white lighting conditions. There was a statistically significant difference found, (X^2= (2) 12.400, p=.002) at a significant level (p=0.05) between

the groups. However the Friedman's test informs that there is a perceived difference but does not state where the difference lies without post hoc tests being performed.

The post hoc analysis used was Wilcoxin Signed Ranks Test. This compares the groups individually to find where the significant result is located. Significance values have to be adjusted in order to compensate for multiple comparisons and this was done manually. The Bonferroni adjustment was calculated by taking the initial significance level (p=0.05) and divide by the number of tests run which was 3. This now gives the level of significance as (p=0.017).

Wilcoxin tests yielded the following results when the different groups were compared applying the Bonferroni correction, where (p=0.017). The emotional stress levels in the red and blue groups, showed no statistical differences (Z=-2.548, p=.11). While this result was not significant at the level of (p=0.017), the low value (p=.11) does indicate a relationship with red light and stress in comparison to blue light and stress levels when compared. The means of red, blue and white light can be seen in Figure X. a noticeable difference can be seen in the table between red light and blue light.

The comparison of the red and white emotional stress levels groups also showed no statistical differences (Z=-1.354, p=.176). Finally the comparison of the white and blue stress level groups showed no statistical difference (Z=-1.684, p=.092). While this result was not significant at the level of (p=0.017), the low value (p=.092) does indicate a relationship with white light and stress in comparison to blue light and stress levels when compared. The means of red, blue and white light can be seen in Figure X. a noticeable difference can be seen in the table between white light and blue light. Interestingly red light and white light showed high levels of stress with a the highest mean of (4.8) for red light and (4.467) mean

for white light, indicating that they produced the same effects. The lowered score for blue

light is indicative that blue light lowers stress in comparison to red light and white light.
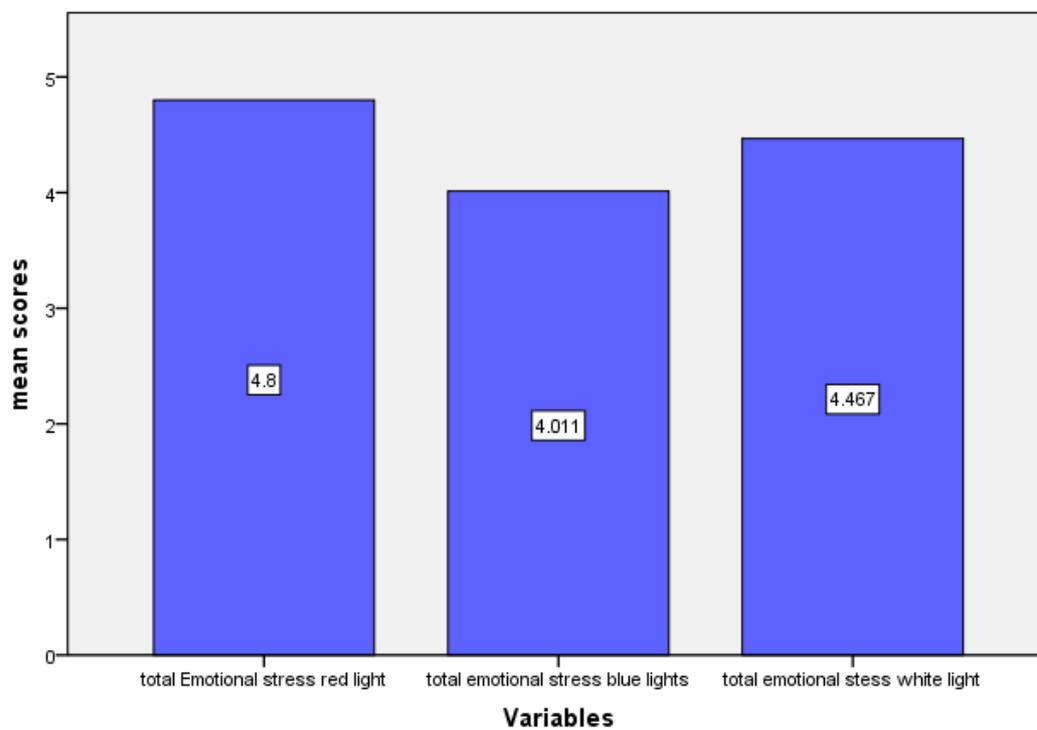

Figure 7- *Bar Chart of Emotional Stress Means of the Red, Blue and White Light*

DISCUSSION

The purpose of this study was to explore if red, blue and white coloured light had significant effects on systolic and diastolic blood pressure, heart rate, mood and stress. It was hypothesised that there would be differences in results due to exposure to the various colours.

Interestingly, this research presented no significant results in contrast to the aforementioned studies in this body of work. This study revealed no significant difference on systolic and diastolic blood pressure when subjected to the previously mentioned colours. These finding were in contradiction to even the most recent studies such as Grote et al. (2013), Naveen et al. (2006). Even though no significant results were found, the Anova test on diastolic blood pressure produced (p=.65), this was the lowest score in compared to Systolic blood pressure, heart rate and mood. This gives an indication that diastolic is more susceptible to the effects of coloured light. No significant difference was found when heart rate was exposed to the various particular colours in this study. These findings contradict the majority of former studies in this area, Grote et al,(2013), McManemin, (2005),Schafer and Kratky, (2006). This study found no significant difference in mood and coloured light in distinct contrast to previous studies by Grote et al 2013, Knez and Kers,(2000). This study also contradicted earlier research which found coloured light had effects on stress Kutchma (2003), Jacobs and Suess (1975) and discovered no significant different in stress under the varied coloured lights. However, while the results involving stress and colured light were not significant, it was found that red light and white light appeared to have high levels of stress scores in comparison to blue light scores in this particular study.

4.1 Coloured Light and Blood Pressure

It was hypothesised that red, blue and white light would have an effect on diastolic blood pressure and there would be a difference in the results. The results were not significant,

but diastolic blood pressure was closer to the accepted significant value (p=0.05) in comparison to systolic blood pressure. This suggests that diastolic blood pressure is perhaps more receptive and sensitive to coloured lighting compared to systolic blood pressure. It was also hypothesised that red, blue and white light would have an effect on systolic blood pressure. The null hypothesis was accepted as the results indicated no significant findings. This was in contradiction to previous research by Gerards (1958), study where he found a difference in results of the blue and red light, this research did not support these findings. Interestingly, a study by Naveen et al. found that the blue light had a significant effect on diastolic blood pressure only. No significant difference was found in systolic blood pressures under the various conditions and it was found that red light had no effect. This study supports some of Naveen et al. findings, except for blue light having a significant effect on diastolic blood pressure, but the current research found diastolic blood pressure to be more reactive in comparison to systolic blood pressure.

The current results are inconsistent to the findings in one of the more recent studies by Grote et al. (2013). Their results indicated that after exposure to oscillated lighting, red, blue and green there was an increase in blood pressure soon after the administered conditions and the same results were replicated in the second longitudinal study involving white light where the effects were seen soon after the experiment began. Although this research does not support this, it should be noted that oscillating coloured light was used and the sequence of colour was repeated in one sitting whereas this research took each colour on an individual basis.

4.2 Coloured lighting and Heart Rate

It was hypothesised that there will be a difference in heart rate when participants were exposed red, blue and white lighting conditions. No significant results were found in this

instance and the null hypothesis was accepted. The results of this study are in conflict with previous findings by Grote et al. (2013), which indicated that heart rate responded to both coloured light and white light. This study did not support these findings. Correspondingly McManemins (2005), study was not supported by the outcome of this research, where results found a significant reduction in heart rate when exposed to indigo/blue. The current research did not support Schafer and Kratky's (2006), study, where significant results yielded a response that red and green light increased heart rate and blue decreased heart rate.

Further studies by Litscher et al. (2009), found that blue laser light exposure lowered heart rate, this study did not support these findings, however it is important to note the lighting in this study was LED and not laser which could account for the discrepancy in findings. Also a 2009 study by Laufer et al, compared the effect of red and blue lighting and found significant results that heart rate is affected, though this is not supported by the current research.

4.3 Coloured Light and Mood

It was hypothesised that red, blue and white light would have an effect on mood of participants. Subsequently, on examining the results this was not supported and the null hypothesis was accepted in this case. While a study by Aronson (1971), found that emotions were linked to colour, this was carried out by hypnotic suggestion and not under the influence of light. While Aronson's study was important as it founded future studies it was not conducted with a light source, thus this study did not support the findings however the tests were not conducted in the same manner.

In a more related study by Knez and Kers (2000), indoor lighting on mood was investigated. This particular research looked at the effects of lighting on younger and older adults and found that younger adults elicited a negative mood under the reddish light and the

inverse was seen with the older adults with a more positive mood shown under the bluish lighting. This research did not support these findings but it is valuable to note that age was taken into account in Knez and Kers (2000), work and not in this particular study, perhaps indicating that age should be a factor if conducting further research in this field.

Interestingly recent work by Grote et al, (2013), found significant results that light does affect mood. This was found in the longitudinal study involving white light, two experiments were carried out in this research and found no significant results concerning mood in the explorative experiment and only in the longitudinal experiment. This research was not supported in this study, however, it is important to note that mood showed improvement over a longitudinal study with white light and did not show immediate effects as was predicted in this study.

4.4 Coloured Light and Stress

This research hypothesised that there would will be a difference in stress levels when exposed to red, blue and white lighting. There were no significant results found after a Wilcoxin test applying the Bonferroni correction was applied. However in group comparisons of red light and blue light the low score (p=.11) at a significance of (p=0.017), indicated a relationship, just not one of significance. This suggests that red light has more of an effect on stress levels in comparison to blue light. Results while not significant, also suggested the white light had more of an effect on stress in comparison to blue light at the value (p=0.092), level of significance (0.017). Interpretation of these observations, suggest that red and white light have higher scores on stress levels in comparison to the blue light scores on stress. Earlier studies in 1975 by Jacobs and Suess examined the effects of colours on anxiety states incorporating stress, showed red yielded significant results while blue did not show any. This research supports the finding that the blue colour had no significant results but did not

endorse the significant findings of red. Although, the observations made in this study are suggestive that red light increases stress which is in agreement of Jacobs and Suess (1975).

Additionally Kutchma (2003) reported the findings of room colour and stress perception and found correlations that red colour does produce higher stress ratings scores compared to white colour. These findings were not supported in this study and no significant results were obtained for any colour. However as stated previously, observations indicate that red light scored higher stress levels in comparison to blue light which gives strength to this study, just not with significant findings.

4.5 Critique of this Study

A positive aspect taken from this research is the interesting observations that diastolic blood pressure appears more reactive in comparison to systolic blood pressure under the lighting conditions. This research did not seek to directly compare diastolic blood pressure and systolic blood pressure and only looked at these variables in relation to the coloured lighting groups. This observation provides encouraging reasons to pursue this comparison further.

While no significant results were found, observations suggested that red light in comparison to blue light showed higher scores in stress levels, which is in line with previous studies, but also noted was the higher scores of stress in white light in contrast to blue light, which was not stated in previous studies, which gives cause for further investigation of these observations.

The main limitation in this research was the lack of previous literature. Few studies have been completed in the aforementioned areas with the majority of the research conducted in recent years. This however can be taken in a positive way as this research adds to a

relatively new area of interest and can help further studies avoid any unnecessary errors. A newer study which the findings were not available prior to the commencement of this research was Grote et al. (2013), the experiment with conducted oscillating light alternating the colours in one session and found significant results in terms of heart rate and blood pressure. The lighting in this study was administered in separate segments and if this current study were to be repeated could be run in a manner like Grote et al. (2013) to support those findings.

A longitudinal study would have perhaps worked best when examining the results of mood and stress. Again in Grotes et al. (2013) study showed that mood improved in the longitudinal study and not in the immediate study. The effects of white light on mood can be seen in other longitudinal studies in relation to SAD studies by Brainard et al.(1990), Oren et al. (1991). Overall this supports that longitudinal exposure to white light produces significant results compared to immediate exposure and this research reinforces this as no significant results were found in the immediate effects. An improvement upon this research could be to change the study to a longitudinal one in order to support the previous findings. However a longitudinal study might not fit best with the physiological variables of heart rate and diastolic and systolic blood pressure as some studies found immediate effect or a soon affect effect such as Naveen et al. (2006), Grote et al. (2013) ,McManimin et al. (2005) and Schafer and Kratky (2006). This suggests that changes need to be made to the manner at which the current test was administered.

A possible cause of no significant results was the available infrastructure. The blackout blinds in the media lab worked best in the late evening where the optimum level of coloured light was achieved in comparison to during the day as natural light still entered the room. This study was run in the morning and evening and these differences were not taken into account. Also the particular room used was located at the top floor of a building and no

elevator service was provided, due to this participants had to walk a number of flights of stairs. Visible signs of exertion were observed in some participants, panting of breath and flushed face with sweat were seen. Due to time restraints on the room, proper recovery time was not allocated for before the experiment commenced.

The questionnaires used in this experiment caused some participants confusion, particularly those where English was not their native tongue. This was observed during the Brief Mood Introspection Scale (REF), where participants got stuck on the word "peppy" in the word list. This had to be explained by the experimenter during the experiment and may have caused confusion or embarrassment due to lack of understanding. This casts doubt as to whether all participants understood all the words especially those that asked for no explanation. This also calls into question if this particular questionnaire was answered correctly and produced correct results.

The participants involved were tested in one sitting with exposure to each lighting condition lasting for five minutes with a break in between to allow for completion of questionnaires and to obtain heart rate, diastolic and systolic blood pressure results. Perhaps if the experiment was to be repeated at a later date and run in the same way it would allow for comparisons of the same participant across different dates which might yield significant results.

Another possible limitation was the presence of the experimenter in the room at all times during the experiment. This may have caused participants to feel uneasy and unable to relax in order for the lighting to have an effect. Also this might have caused the questionnaires to be filled out inaccurately, as the participant might have fears that the experimenter will know what their own particular answers were. However this study was anonymous and explained at the start of the study, but possibly may have caused unease.

4.5 Implications for future research

Due to an unexpected observation that diastolic blood pressure appears to be more reactive to the coloured light in comparison to systolic blood pressure, is an encouragement of further research in this area. A more tailored study to suit this observation could perhaps produce significant results. Also while no significant results were found with stress and coloured light, observations are inciting further research as red light was observed to have higher stress scores in comparison to blue light and it was observed that white light also had higher scores in comparison to blue light. These observations are encouraging for further research with a reoriented structure in relation to the variables mentioned.

Interestingly in some of the studies discussed has found that people who suffer from depression or mood disorder are more susceptible to the effects of light. Gerard (1958) study, found that participants who scored higher with anxiety were found to be more susceptible to the effects of lighting compared to those with low scores. This can be seen with the studies involving SADs where significant results were found that coloured light including white, red and blue were found to have an effect on participants, Brainard et al. (1990), Oren at al. (1991), Stewart et al.(1991). If the inclusion criteria for this study had been participants who suffered from depression or with a mood disorder it could have possibly produced significant results on the basis that they are more susceptible to light. However, this would be ethically wrong in an undergraduate setting to deal with sufferers of depression or any other mood disorder, as the experimenter has no recognised qualifications to deal with that particular type of participant nor the expertise to provide any assistance if needed. This proposed research could be continued at higher level of education to add validity to the previous research and to examine other colours and the effects they may have. Also as previously mentioned, a longitudinal study would perhaps produce significant results in relation to mood and stress.

4.6 Conclusion

In conclusion, this study has successfully added to an under investigated area of research. Interesting observations were made in relation diastolic and systolic blood pressure, suggesting that diastolic blood pressure is more reactive to coloured light and this provides a foundation for further research. While the null hypothesis was accepted in all cases, it does however give support to longitudinal studies that the effect of coloured lighting is seen over a longer period of time, in particular to psychological variables such as mood. Although the findings of this research did not yield any significant results, it categorically does not mean that there is absolutely no relationship between blood pressure, heart rate, mood and stress under the effects of red, blue and white lighting. This research helps provide more information for future studies, which will enable them to obtain a more beneficial means of testing.

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Appendix

Copy of email, granting permission to use SRSI3

Permission granted. Use www.lulu.com/stress.

Jonathan Smith, PhD

To Whom it concerns,

With relation to the above, I wish to apply for permission to use the Smith Relaxation States Inventory 3 (SRSI3) questionnaire.

I am a student at Dublin Business School in Dublin Ireland, and I am currently completing undergraduate Honours Degree in Psychology. I would like to use this questionnaire in my thesis study, in which I am looking at the effects of different coloured lighting on the stress, mood, heart rate and blood pressure on a person.

I would be obliged if you could let me know if permission is granted,

Regards,

Ciara Kirwan

Consent Form

I agree to take part in this study. I understand the experiment that I am being asked to take part in. I understand that it is my own decision to take part. I understand that I am free to leave at any stage.

I understand to take part in this experiment that I have to be over the age of 18 years, not suffer from any heart complaint or have colour blindness for red/blue.

I have been informed that the data acquired in this study will be kept anonymous and will be kept for one year after the study is completed. It will then be destroyed.

Signed:⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯

Date:⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯

If you have any further questions in relation to this research project I can be contacted on ▮▮▮▮▮▮▮ or email ▮▮▮▮▮▮▮▮▮▮.

Research supervisor is Dr. Rosie Reid of Dublin Business School ▮▮▮▮▮▮▮▮

Please answer the following;

Do you suffer from high blood pressure?   Yes [   ]   No [   ]

If yes can you please explain?_____

_____

_____

Do you suffer from an abnormal heart rate? Yes [   ]   No [   ]

If yes can you please explain?_____

_____

_____

Male [   ]   Female [   ]

Age _____

Have you signed consent from? Yes [   ]   No [   ]

RIGHT NOW, I FEEL THIS

1	2	3	4	5	6
Not at All	A Little	. . Moderately . .		A Lot	Maximum

Circle the number which represents you best

1. My mind is SILENT and calm (I am not thinking about anything).   **1 2 3 4 5 6**

2. My muscles feel TIGHT and TENSE (clenched fist or jaws; furrowed brow).   **1 2 3 4 5 6**

3. I feel AT PEACE   **1 2 3 4 5 6**

4. I feel DROWSY and SLEEPY.   **1 2 3 4 5 6**

5. Things seem AMAZING, AWESOME, and EXTRAORDINARY   **1 2 3 4 5 6**

6. Right now I recognize the wisdom of sometimes ACCEPTING things as they are   **1 2 3 4 5 6**

7. My muscles are SO RELAXED that they feel LIMP.   **1 2 3 4 5 6**

8. I am HAPPY.   **1 2 3 4 5 6**

9. I am WORRYING   **1 2 3 4 5 6**

10. I feel AT EASE   **1 2 3 4 5 6**

11. I feel DISTANT and FAR AWAY from my cares and concerns   **1 2 3 4 5 6**

12. I feel ENERGIZED, CONFIDENT, and STRENGTHENED.   **1 2 3 4 5 6**

13. I am DOZING OFF or NAPPING .   **1 2 3 4 5 6**

14. I feel THANKFUL.   **1 2 3 4 5 6**

15. I feel like I am living fully and SIMPLY in the PRESENT, not distracted by past or future concerns.   **1 2 3 4 5 6**

16. Things seem TIMELESS, BOUNDLESS, or INFINITE   **1 2 3 4 5 6**

17. I feel IRRITATED or ANGRY.   **1 2 3 4 5 6**

18. I feel JOYFUL.   **1 2 3 4 5 6**

19. I feel SAD, DEPRESSED, or BLUE.   **1 2 3 4 5 6**

20. I feel AWARE, FOCUSED, and CLEAR.   **1 2 3 4 5 6**

21. My hands, arms, or legs are SO RELAXED that they feel WARM and HEAVY   **1 2 3 4 5 6**

22. I feel INNOCENT and CHILDLIKE.   **1 2 3 4 5 6**

23. My BREATHING is NERVOUS and UNEVEN (Or shallow and hurried).   **1 2 3 4 5 6**

24. I feel LOVING   **1 2 3 4 5 6**

25. Things seem FRESH and NEW, as if I am seeing them for the first time.   **1 2 3 4 5 6**

26. I feel INDIFFERENT and DETACHED from my cares and concerns.   **1 2 3 4 5 6**

27. I feel PRAYERFUL or REVERENT.   **1 2 3 4 5 6**

28. I feel PHYSICAL DISCOMFORT or PAIN (backaches, headaches, fatigue)   **1 2 3 4 5 6**

29. My mind is QUIET and STILL   **1 2 3 4 5 6**

30. I feel ANXIOUS.   **1 2 3 4 5 6**

31. I sense the DEEP MYSTERY of things beyond my understanding   **1 2 3 4 5 6**

32. I feel RESTED and REFRESHED   **1 2 3 4 5 6**

33. I feel CAREFREE.   **1 2 3 4 5 6**

34.. TROUBLESOME THOUGHTS are going through my mind.   **1 2 3 4 5 6**

35. My body is PHYSICALLY RELAXED.   **1 2 3 4 5 6**

36. Presently I feel there's no need to try to change things that simply can't be changed.   **1 2 3 4 5 6**

37. I feel fully focused and ABSORBED in what I am doing   **1 2 3 4 5 6**

38. I feel OPTIMISTIC, HOPEFUL, or TRUSTING that I can rely on someone or something   **1 2 3 4 5 6**

INSTRUCTIONS: Circle the response on the scale below that indicates

how well each adjective or phrase describes your present mood.

	(definitely do not feel)	(do not feel)	(slightly feel)	(definitely feel)
	XX	X	V	VV

_____

Lively	XX	X	V	VV
Drowsy	XX	X	V	VV
Happy	XX	X	V	VV
Grouchy	XX	X	V	VV
Sad	XX	X	V	VV
Peppy	XX	X	V	VV
Tired	XX	X	V	VV
Nervous	XX	X	V	VV
Caring	XX	X	V	VV
Calm	XX	X	V	VV
Content	XX	X	V	VV
Loving	XX	X	V	VV
Gloomy	XX	X	V	VV
Fed up	XX	X	V	VV
Jittery	XX	X	V	VV
Active	XX	X	V	VV

_____

Condition	Blood Pressure	Heart Rate

<u>Consent Form</u>

I hereby give consent for my image/s to be used in this body of work. I understand that my image will be printed and submitted as part of a Thesis.

Signed: