The Effects of Blue and Red Light on Physiological Responses Post-Exercise

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Abstract

The connection between color and rate of return to a resting physiological state post-exercise could lead to practical implementation in various fields, such as relaxation after strenuous activity. To measure this rate we focused on mean arterial blood pressure, pulse, and respiratory rate post-exercise in subjects placed in varying lighting conditions, which comprised of normal (white), red, and blue light. Based on limited previous research, we hypothesized that blue light would expedite recovery to resting levels, while red light would inhibit this return with white light implemented as a baseline control. The results suggest there is minimal significant correlative relationship between colored lighting conditions and a return to resting physiological rates post-exercise. Potential limitations of our research included: use of a small sample size, time constraints which led to an incomplete data set, and equipment malfunction.

Introduction

The emotional, psychological, and physical influences of color are complex. Studies have shown different colors can be associated with different moods. For example, red is often associated with excitement, blue with security, green with balance, and yellow with happiness (Adler, 2001). Additionally, colors can have physiological effects beyond mood. For instance, some studies have shown that the color red stimulates appetite because it increases metabolism (Singh, 2006). A different study conducted in Japan, implicated that areas with blue streetlights reduced crime by 9% (Blue Streetlights May Prevent Crime, Suicide). Furthermore, several Eastern countries utilize chromotherapy as a means of treating patients. Chromotherapy is a holistic approach that uses colors, specifically blue to heal because of its supposed soothing effect (Colour Properties, 2015). In these cultures, color is believed to be important for achieving energy balance. Given that these examples demonstrate the psychological and physical effects of color, this study aims to expand knowledge of color's influence on physiological responses. Knowledge of these responses have the potential to benefit fields such as marketing, medicine, and political science.

In our study, mean arterial blood pressure (MABP), heart rate, and respiratory rate in beats per minute (BPM) were measured in white (normal), red (620-750 nm) and blue (450-500 nm) lighting conditions (Colour Properties). We measured each participant's blood pressure, heart rate, and respiratory rate before and after moderate aerobic exercise in each of the lighting conditions. We hypothesized participants' blood pressure, heart rate, and respiratory rate would return to resting rate faster post-exercise in blue light in comparison to red light.

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Several studies examine the human body's variation of blood pressure as people are exposed to blue and red light. Blood pressure is defined as the pressure exerted by blood onto the walls of blood vessels (American Heart Association, 2014). In a study by Gerard, participants viewing red light have recorded higher systolic blood pressures. Results also show lower blood pressure values for participants under blue light (1958). Other studies implicate a correlation between longer wavelengths of light and higher systolic blood pressure (Wohlfarth et al., 1982).

Heart rate is measured by the number of heart contractions per unit of time. The effect of different light wavelengths on heart rate is inconclusive. Experiments performed by Jacobs and Hutsmeyer do not show a significant correlation between heart rate change and various light wavelengths (Jacobs et al., 1974). An additional study measuring heart rate change under red light proved insignificant (Litscher, 2013). However, a study conducted by Deutsch shows significant changes in heart rate associated with observers looking out a window covered with red glass in a room illuminated with red light. These responses may be a result of cognitive associations with certain colors rather than the physiological effects alone (Deutsch, 1937). Litscher et al. results show significant reduction in heart rate during exposure to 10 minutes of 465 nm blue light.

Moderate aerobic activity leads to an increase in heart rate and systolic blood pressure. The muscles of the body need more oxygen during moderate physical activity. The heart pumps more blood in order to deliver more oxygen to the muscles, explaining the increase in both heart rate and systolic blood pressure (New Health Guide, 2015). Studies suggest that respiratory rate is not measured as much as it should be, thus, it has been concluded that respiratory rate is an "ignored vital sign" (Eldridge, 2015). Respiration rate is defined as the number of breaths a person takes per minute. Respiratory rate is measured when a person is at rest and is taken simply by counting the number of breaths a person takes for one minute by counting the number of times their chest rises. A normal respiration rate for an adult person at rest is in the range of 12-18 breaths per minute (Hopkins, 2015). Both an increased and decreased respiratory rate can be a sign that something is amiss in the body. An abnormal respiratory rate is nonspecific, therefore there are many causes for both a rapid and slow rate. One such factor that may increase respiratory rate is exercise. During exercise, muscle cells respire more than they do at rest. This means that oxygen and glucose must be delivered to them more quickly, and waste carbon dioxide must be removed more quickly. This can be achieved by increasing the respiratory rate (BBC, 2014). An elevated respiratory for adults is typically considered as a rate over 20 breaths per minute, with a rate over 24 alluding to a very serious condition (Eldridge, 2015). According to Gerard et al., when measuring chest expansion, respiration rate is greater in red light compared to white light, while respiration rate is lower in blue light than red light (1958). However, experiments by Jacobs et al. do not show significant results correlating respiration rate with light (1974).

These previous research studies' results align with our expectations regarding change in blood pressure, heart rate and respiratory rate post-exercise under red and blue light. These physiological response will increase more substantially under red light; therefore, the decline towards rest will occur over a longer period of time. With the results of this study, there could be applications in physical therapy, exercise recovery, and sports marketing. For example, locker rooms or cool down areas could be illuminated blue in order to aid recovery after aerobic exercise.

Materials & Methods

To understand the physiological changes in our experiment, we implemented several instruments. We used a digital pulse oximeter (Nonin, Model#9843) clipped to the right index finger to monitor the heart rate for each participant. Baseline heart rate measurements provided the ability to calculate the target heart rate during exercise and measurements continuously after exercise. Target heart rate is defined as an elevation of 60% above resting rate. We used a BSL Respiratory Effort Transducer (BIOPAC Systems, Inc., Model#SS5LB) to determine rate of breathing. The respiratory transducer consists of a flexible belt strapped along the nipple line of each participant and a sensor that measures the stretch of the chest that each breath produces. The respiratory effector transducer was connected with the BIOPAC MP36 system. The Biopac Student Lab Data Analysis includes BSL 4 software run on a Windows 7 Dell desktop computer. A digital, automatic blood pressure cuff (Omron 10 Series+) was placed on the left upper arm of each participant to obtain readings both before and after exercise. We chose to utilize an automatic cuff for rapid standardized and continuous readings. Exercise was performed using a Gold's Gym Cycle Trainer (Model#390R) to raise heart rate to 60% above baseline. Light color was manipulated by placing red and blue tinted cellophane inside the overhead light enclosure.

Twenty students enrolled at the University of Wisconsin-Madison between the ages of 19 and 26 participated in this three-day study to measure the post-exercise recovery rate of physiological responses under different colors of light. Prior to beginning the experiment, the participant signed a consent form detailing the requirements for participation. Participants entered the room, and sat on a Gold's Gym Cycle Trainer while the pulse oximeter was attached to the right index finger, blood pressure cuff was applied to the left upper arm, and respiratory belt was tightened around the nipple line. Participants were instructed to breathe normally while the respiratory transducer belt calibrated. Resting heart rate and blood pressure were recorded. We utilized mean arterial blood pressure (MABP) as opposed to using individual diastolic and systolic blood pressure. Since MABP is the average arterial pressure during a single cardiac cycle, it provides a more consistent blood pressure measurement by controlling for individual changes in blood vessel histology which can greatly alter diastolic and systolic values. We calculated MABP using the equation: MABP=⅓ pulse pressure + diastolic pressure. Pulse pressure is defined as the difference between systolic pressure and diastolic pressure. Participants then pedalled at a speed of 18-20 MPH and resistance of 5 until the pulse oximeter displayed a heart rate elevated to 60% above the individual's baseline heart rate. Participants continued to cycle for one minute once heart rate elevated to 60% above rest to ensure heart rate was sufficiently elevated. Participants were instructed to stop pedalling, and heart rate and blood pressure were immediately recorded. Heart rate and blood pressure were measured at 30 second intervals until the individual's heart rate returned a suitable baseline heart rate defined as within 10% of resting rate. Respiratory rate was continuously recorded throughout the experiment and ended simultaneously with the last measurements of blood pressure and heart rate.

This general procedure was repeated for each of our participants for three separate days of data collection. Each day represented a separate lighting condition: one day white, one red, and one blue. No other procedural changes occurred among the three days other than the lighting condition. See Figure 1 for event timeline of methods.

Results

We used the same 20 participants in each lighting condition. Due to timing constraints, only 4 of these 20 participants were tested in blue light. We used ANOVA to calculate p-values for each measurement parameter. We found no statistical significance for the difference of decline among the three lighting conditions for mean arterial blood pressure (p-values and data are found in table 1). Figure 2 shows the graph of mean arterial blood pressures over 30-second intervals for the three lighting conditions. The graph depicts an exaggerated decline for the red treatment compared to the data points for the blue and white treatments. However, due to the lack of significant p-values, this was most likely due to random variation.

P-values deemed the variation of respiratory BPM over time insignificant as seen in table 2. Figure 3 shows the graph of BPM over time for different lighting conditions. As before, there was an observable yet insignificant decrease for the red lighting condition compared to white and blue treatments. We recorded a more drastic decline in BPMs upon cessation of exercise for white and blue lighting conditions.

We used pulse measurements in assessing both the number of 30-second intervals required to return to baseline and measuring the decline rate among lighting conditions. We found no statistical significance among the required time periods to return to baseline in any treatments. As seen in table 3, most time periods, except for the one-minute mark, had p-values higher than 0.05. This indicates there is a lack of statistical evidence to suggest the pulse readings at each individual time period are not the same. At one-minute, a p-value of 0.049 indicated sufficient statistical evidence to suggest there is a difference between the means of all color groups at that time. Further analysis showed the significant difference to be exclusively between the white and red group. This suggests the possibility of a slower rate of return to normal resting pulse in the first minute post-exercise in red light.

Discussion

Our results indicate that red and blue light do not significantly affect the rate of decline to resting levels of pulse, blood pressure, and respiratory rate post-exercise. With the exception of pulse rate at one-minute post-exercise, all p-values are greater than 0.05 showing insignificant variability; therefore, we cannot reject the null hypothesis at the majority of time points. Our hypothesis that red and blue lighting conditions produce slower and faster declines, respectively, in returning to resting pulse, blood pressure, and respiratory rate cannot be proven within the experiment performed.

Pulse Rate

At the one-minute time point after the completion of exercise, a statistically significant p-value of 0.049 shows substantial difference between white, blue, and red lighting condition recordings. This evidence supports our hypothesis that red light decreases the pulse rate recovery post-exercise. However, because no significance is seen before and after one minute we cannot conclude red lighting conditions show significant effects on returning to baseline post-exercise. No significance is reported for pulse rate recovery time post-exercise in blue lighting conditions relative to white lighting conditions.

Respiratory Rate

No significance is found for the respiratory rate recovery time in both red and blue lighting conditions relative to white lighting conditions. Insignificance may be due to misalignment or tightness of the respiratory belt. Also, some participants reported feeling self-conscious breathing heavily post-exercise causing them to restrict their normal breathing patterns. Others appeared to be exaggerating their breaths to return to a less noticeable breathing rate. These irregular breathing patterns could be a possible reason why no significance is found in the respiratory data set.

Mean arterial blood pressure

We utilize mean arterial blood pressure as opposed to diastolic pressure or systolic pressure individually. Mean arterial blood pressure (MABP) provides a more consistent measurement. No significance is seen in red or blue lighting conditions when compared to measurements under white light. To measure blood pressure we used an automated blood pressure cuff. One advantage of this was we were able to take multiple recordings and eliminate human error or bias. However, we experienced technological errors during data collection. Errors could be due to the following: cuff alignment, tightness, or technological malfunction with our chosen hardware. To account for the missing MABP measurements due to the errors, we averaged values from neighboring recorded values to estimate an appropriate measurement.

Our study results were limited due to small sample sizes, time constraints, and equipment malfunction. Due to a lack of time and lack of participant's schedule availability, only 20 participants contributed within the red and white-light categories and four participants contributed to the blue category. As stated above, variability in respiratory belt measurements generated inaccurate data. Additionally, the automated blood pressure cuff malfunctioned unpredictably resulting in missing data points.

Future studies

Future studies could benefit by utilizing a larger sample size and blocking variables to reduce standard deviation. It could be useful to screen participants before testing using age, gender, fitness/dietary schedule, medications, heart problems, smoking and/or recreational drug use habits, the time of day data is recorded, and general stress/anxiety levels. Also, follow-up surveys could be distributed to gauge color preferences. This could reduce individual variability and increase our ability to control for underlying factors. Repeating participants under each lighting condition could allow for more tractable results.

To address observed participant insecurities about exaggerated breathing, it would be ideal to alter our method to allow data collection from outside the experiment room. This would allow a more natural and accurate representation of respiratory decline post-exercise.

Sourcing standardized color filters to manipulate lighting conditions could narrow the range variability among and between treatments. It would be useful to use a light meter to control for light intensity. Additionally, further experimentation could utilize different light intensities to elicit different strengths of physiological responses. Time constraints limited us to red and blue lighting conditions, however, future experiments could examine the effects of other wavelengths.

While these results are preliminary, they are promising. In conducting this experiment, we found potential relationships to study further and we believe by improving upon our methods using the suggestions above we could generate more applicable results.

Acknowledgments

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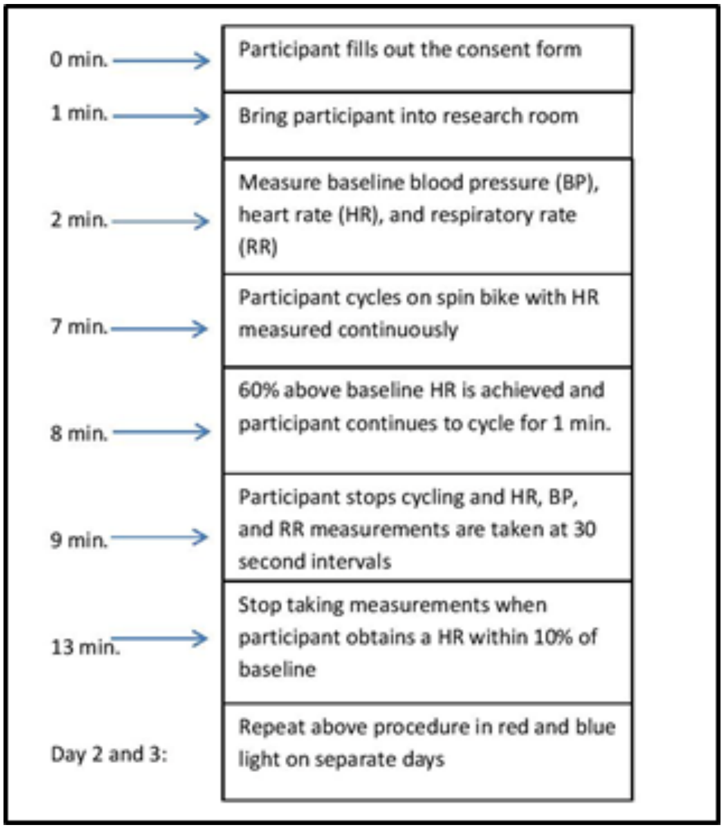
Figure 1. Timeline of Methods



0 min. → Participant fills out the consent form

1 min. → Bring participant into research room

2 min. → Measure baseline blood pressure (BP), heart rate (HR), and respiratory rate (RR)

7 min. → Participant cycles on spin bike with HR measured continuously

8 min. → 60% above baseline HR is achieved and participant continues to cycle for 1 min.

9 min. → Participant stops cycling and HR, BP, and RR measurements are taken at 30 second intervals

13 min. → Stop taking measurements when participant obtains a HR within 10% of baseline

Day 2 and 3: Repeat above procedure in red and blue light on separate days

Figure 2. Graph of average MABP's over time for each lighting condition.

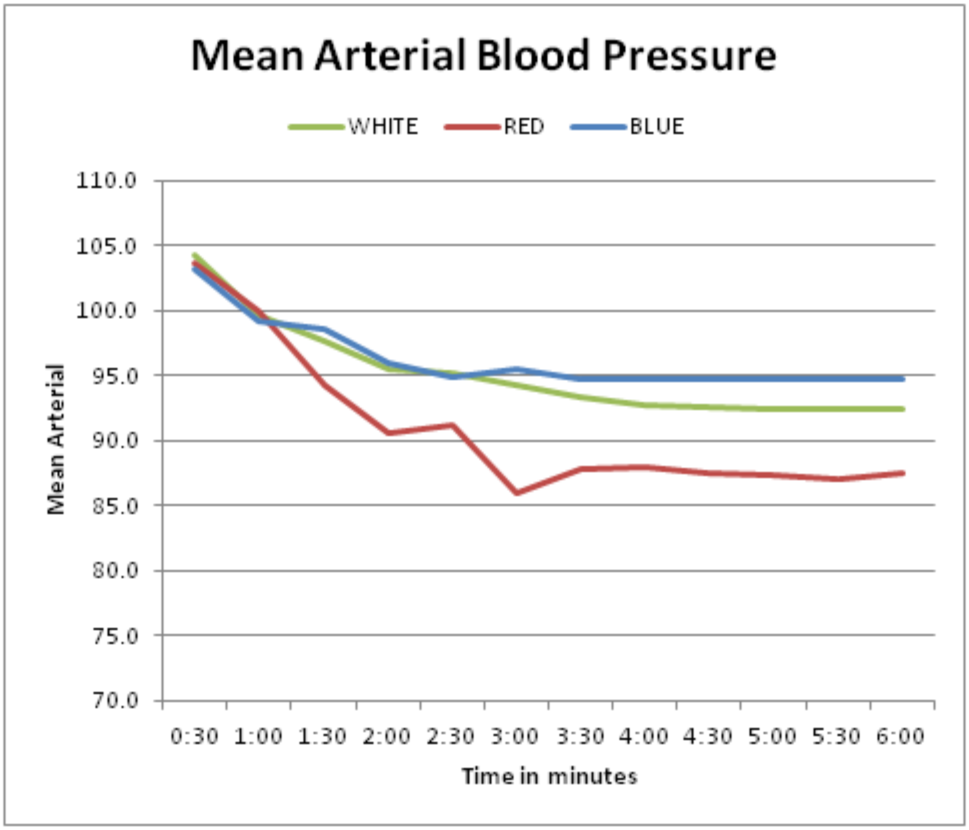


Table 1. Group averages of MABPs post exercise with included ANOVA p-values.

	0:30	**1:00**	**1:30**	**2:00**	**2:30**	**3:00**	**3:30**	**4:00**	**4:30**	**5:00**	**5:30**	**6:00**
White	104.3	99.7	97.7	95.5	95.1	94.2	93.4	92.8	92.6	92.4	92.4	92.4
Red	103.7	99.9	94.3	90.6	91.2	86.0	87.9	88.0	87.5	87.4	87.1	87.5
Blue	103.3	99.2	98.6	96.0	94.8	95.5	94.8	94.8	94.8	94.8	94.8	94.8
ANOVA p values	0.979	0.991	0.474	0.223	0.343	0.109	0.290	0.366	0.309	0.301	0.261	0.324

Figure 3. Graph of mean respiratory BPMs during and post exercise for each lighting condition.

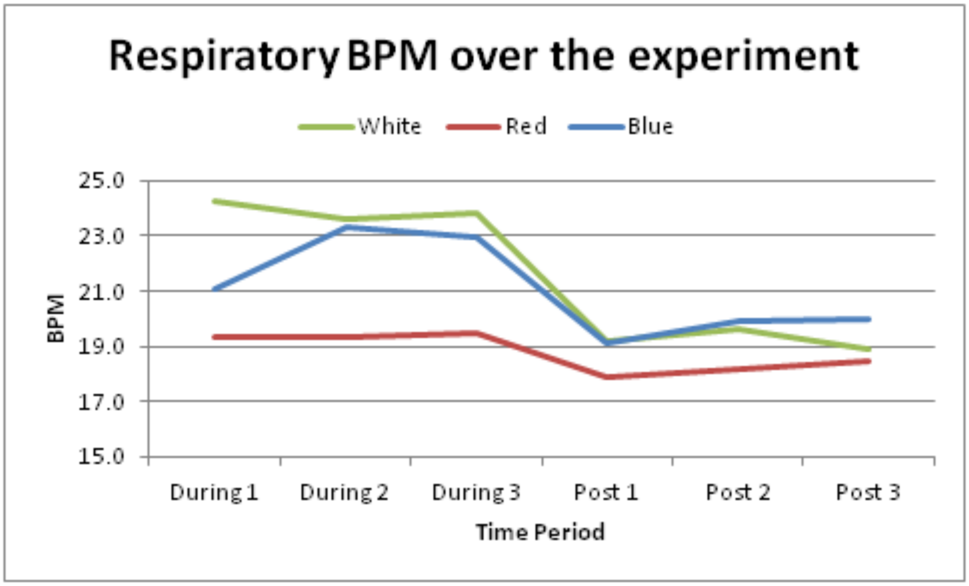


Table 2. Group averages of respiratory BPM during and post exercise, with included ANOVA p-values.

	BPM1 during	BPM2 during	BPM3 during	BPM1 post	BPM2 post	BPM3 post
White	24.3	23.6	23.8	19.2	19.6	18.9
Red	19.3	19.4	19.5	17.9	18.2	18.4
Blue	21.1	23.3	23.0	19.1	19.9	20.0
ANOVA p value	0.245	0.150	0.101	0.691	0.619	0.827

Figure 4. Graph of average pulse rates post exercise for each lighting condition.

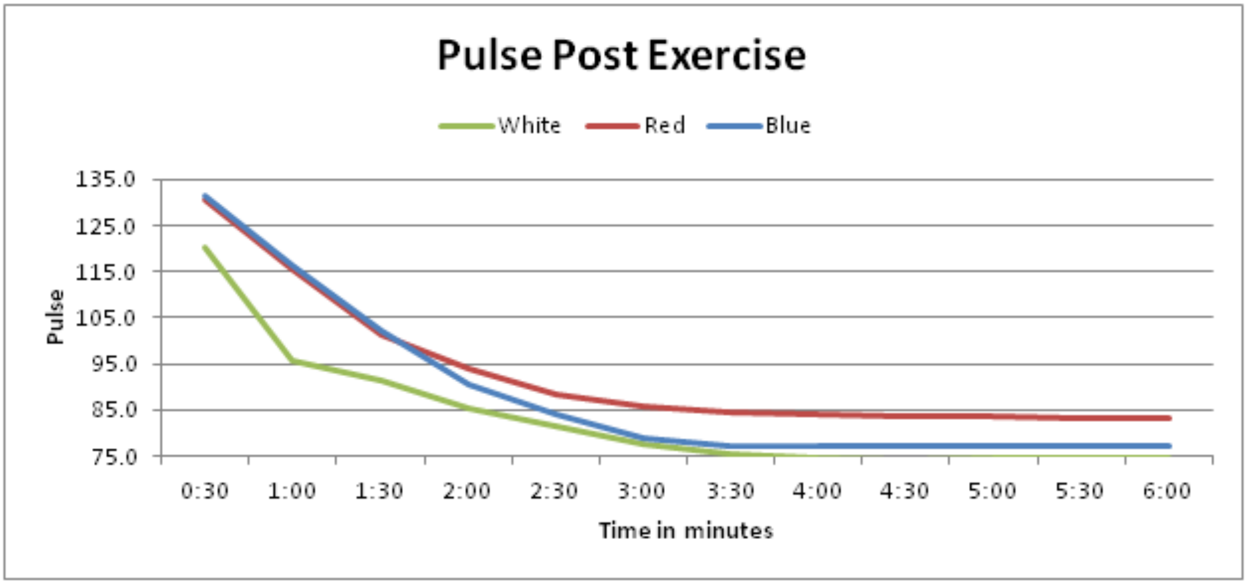


Table 3. Group averages of pulse rates post exercise and time periods required to return to baseline for each of the lighting conditions with ANOVA p-values.

	Time Periods Required	**0:30**	**1:00**	**1:30**	**2:00**	**2:30**	**3:00**	**3:30**	**4:00**	**4:30**
White	5.1	120.2	95.8	91.5	85.2	81.6	77.6	75.3	74.5	74.3
Red	6.5	130.8	115.3	101.5	94.2	88.6	85.6	84.6	84.0	83.8
Blue	6.3	131.3	116.5	102.3	90.5	84.0	78.8	77.0	77.0	77.0
ANOVA p value	0.165	0.148	0.049	0.357	0.391	0.509	0.322	0.181	0.157	0.143

Bibliography

"Blood Pressure During Exercise." New Health Guide. Web. 17 Feb. 2015. http://www.newhealthguide.org/Blood-Pressure-During-Exercise.html

Satyendra Singh, (2006) "Impact of color on marketing", Management Decision, Vol. 44 Iss: 6, pp.783 - 789

Litscher, D., Wang, L., Gaischek, I., & Litscher, G. (2013). The Influence of New Colored Light Stimulation Methods on Heart Rate Variability, Temperature, and Well-Being: Results of a Pilot Study in Humans. *Evidence-Based Complementary and Alternative Medicine : eCAM*, *2013*, 674183. doi:10.1155/2013/674183

Kaiser, P. K. (1984), Physiological response to color: A critical review. Color Res. Appl., 9: 29–36. doi: 10.1002/col.5080090106
R . M. Gerard, Lh'JJrrential c~Ject.s ($colored lights, unpublished
Ph.D. dissertation, University of California at Los Angcles, 1958.

K. W. Jacobs and F. E. Hustmyer, Effects of four psychological primary colors on GSR, heart rate and respiration rate, Percept. Mof. .Skills 38, 763-766 (1974).

Wohlfarth and C. Sam, The effects of color psychodynamic cnvironment modification upon psychophysiological and behavioral reactions of severely handicapped children, In!. J. Biosoc. Kes. 3. 10 38(1982).

F. Deutsch, Psycho-physical rcactions to the vascular system to influence of light and to impressions gained through light, Folia Clin. Orient. 1, 137-144, 207-218 (1937).

"The Psychology of Color: Exploring cultural associations between colors and emotions." Psychologist World. Web. 17 Feb. 2015. http://www.psychologistworld.com/perception/color.php

"Effect of exercise on breathing." BBC. Web. 2014. http://www.bbc.co.uk/schools/gcsebitesize/science/add_edexcel/organism_energy/respirationrev3.shtml

DiMenna, F. (2011), How does exercise affect breathing? *Livestrong.com*. Web. http://www.livestrong.com/article/402142-how-does-exercise-affect-breathing/

Eldridge, L. (2015). What is a normal respiratory rate? *About Health.* Web. http://lungcancer.about.com/od/Respiratory-System-Function/a/Normal-Respiratory-Rate.htm

"Blue Streetlights May Prevent Crime, Suicide." Blue Streetlights May Prevent Crime, Suicide. Phys Org, 10 Dec. 2008. Web. 17 Feb. 2015. <http://phys.org/news148153021.html>

"Vital Signs (Body Temperature, Pulse Rate, Respiratory Rate, Blood Pressure)." *Johns Hopkins Medicine Health Library.* Web. 17 Feb. 2015. http://www.hopkinsmedicine.org/healthlibrary/conditions/cardiovascular_diseases/vital_signs_body_temperature_pulse_rate_respiration_rate_blood_pressure_85,P00866/

"Colour Properties." *Colour Properties*. Colour Therapy Healing, n.d. Web. 17 Feb. 2015. <http://www.colourtherapyhealing.com/colour/colour_properties.php>.

Adler, Linda. "Responding to Color" *University of Kentucky; College of Agriculture* Web. 2001. 17 Feb 2015. http://www2.ca.uky.edu/hes/fcs/factshts/HF-LRA.151.PDF

"Understanding Blood Pressure Readings." *Understanding Blood Pressure Readings*. American Heart Association, 17 Nov. 2014. Web. 11 Feb. 2015. <http://www.heart.org/HEARTORG/Conditions/HighBloodPressure/AboutHighBloodPressure/Understanding-Blood-Pressure-Readings_UCM_301764_Article.jsp>.

Litscher, D., Wang, L., Gaischek, I., & Litscher, G. (2013). The Influence of New Colored Light Stimulation Methods on Heart Rate Variability, Temperature, and Well-Being: Results of a Pilot Study in Humans. *Evidence-Based Complementary and Alternative Medicine : eCAM*, *2013*, 674183. doi:10.1155/2013/674183