The Myth of Baker-Miller Pink: Effects of Colored Light on Physiology, Cognition, and Emotion?

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***Abstract*—Besides aesthetic aspects, color can have impact on human perception and behaviour. A special pink hue, the so-called Baker-Miller pink, is assumed to induce calming effects. In this study, we evaluated pink and white lighting conditions with N = 29 subjects, through tests of attention, measurements of skin conductance and emotional state ratings. With an exposure time of 15 minutes including measurements, no color effect was found in skin conductance and attentional performance. There was also no difference in ratings of emotional valence and arousal between the two lighting conditions. Although, subjects rated Baker-Miller pink light significantly less activating than white light. A significant sex effect showed that women preferred pink light more than men. These results indicate that there are indeed differences in subjective perception of white and Baker-Miller pink light although they cannot be found in objective measures of physiological and cognitive processes.**

***Index Terms*--arousal, attention, Baker-Miller pink, light color, skin conductance**

INTRODUCTION

In everyday life, color is one of the most omnipresent aspect of peoples' sensory perception. Beside aesthetic aspects, like color harmony, people tend to share color specific associations. Green, for example, is commonly considered as the color of hope, blue as the color of tranquility. Red seems to be more ambiguous, being the color of love and danger at the same time. The omnipresence of colors and their associations raises the question, if color can cause specific effects on humans' perception and behavior. In the 1970s Alexander Schauss proposed a pink hue, the later called Baker-Miller pink, which he regarded to unfold a broad impact on humans within 15 minutes exposure [1]-[2]:

- faster reduction of physiological arousal compared to other colors, from a heightened level of physiological arousal,
- reduction of muscle strength and,
- as consequence of these two effects, the reduction of aggressive behavior.

First observations with pink colored prison detention cells seemed to support these effects [2]. As a result, prison detention cells all over the world were painted with Baker-Miller pink [3]. Following laboratory experiments produced conflicting results. Two studies found a significant muscle strength reduction when suspects were exposed to a pink compared with a blue board [4]-[5]. Other similar studies with slight methodical improvements could not replicate this effect [6]-[8]. No significant differences in blood pressure, pulse and attentional performance after exposition to Baker-Miller pink vs. white could be confirmed [6]. A recent study investigating the effects of prison detention cells painted in Baker-Miller pink found no aggression reducing effects [3]. Based on these results, one should doubt the proposed effects of Baker-Miller pink.

Nevertheless, latest psychological research revealed color effects on psychological processes. The *color-in-context* theory [9] provides a theoretical framework on how the measured color effects on cognitive performance and emotion are caused. The authors suggest that color effects are caused by classical conditioning and biological predispositions. The effect is shaped by the psychological context of presentation. As an example, the color red can decrease performance in an intellectual achievement situation [10], whereas viewing red in a competitive sports context is associated with enhanced performance [11].

By virtue of this knowledge, the present study was designed to investigate possible effects of Baker-Miller pink colored light on cognition, physiology and emotion with up-to-date methods. In the exploratory study design, differences between a Baker-Miller pink colored light and a neutral white light were investigated. In focus of interest were (1) cognitive performance, operationalized by a test of attention, (2) physiological arousal, operationalized by skin conductance, and (3) emotional valence and arousal, operationalized by self-report. Additionally, we measured the participants' individual color preferences.

METHODS

A. Participants

The sample consisted of 29 Fraunhofer IAO Stuttgart employees aged from 20 to 50 years (*M* = 28.07, *SD* = 6.05, 15 females). Each individual had normal or corrected-to normal vision and no color deficiencies. Participation was voluntary and could be withdrawn at any time. All participants were informed about the procedure and purpose of the experiment and gave written consent in advance of participation.

B. Materials

The laboratory was a windowless room with constant temperature (21°C) and noise (20 dB). A vertical 2.85m x 2.25m diffuse light wall, developed by Fraunhofer IAO, with a total of 6912 LED lights, emitted the colored light. In the CIE 1931 color space, the Baker-Miller pink colored light was located at x = 0.3947 and y = 0,2931 and thus almost identical with Baker-Miller pink as wall paint color (x = 0.3946, y = 0.2978). A neutral white light served as control condition. Illuminance was measured on eye level and was comparable for both, pink light (228,91 lux) and white light (224,87 lux). The spectral characteristics are shown in Figure 1.

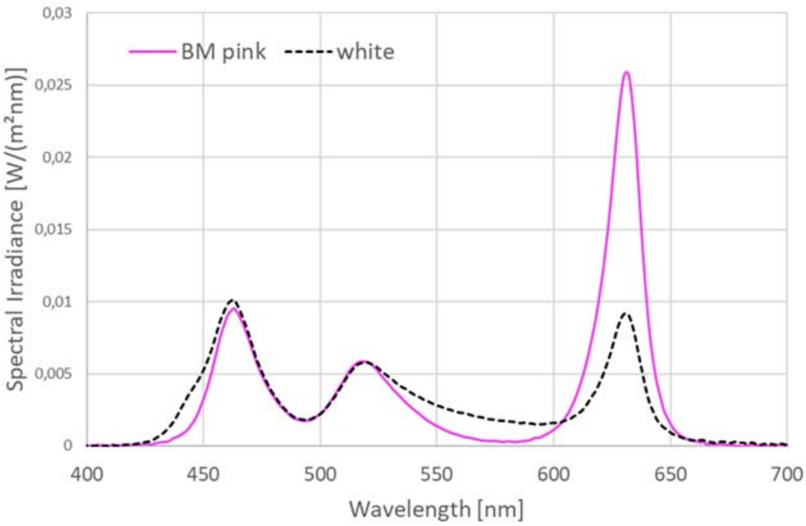

Figure 1. Spectral characteristics of Baker-Miller pink and white light color

Participants were seated in front of the diffuse light wall, at a distance of 1.60 m. The light wall occupied a viewing angle of approximately α = 85.67°.

C. Design

In order to compare Baker-Miller pink colored light with white light, a 2x2 mixed design with light color as within-subject factor was adopted. Sequence of color presentation (pink-white vs. white-pink) was balanced and included as between-subject factor. Dependent variables were measured through physiology, cognition and emotion.

Physiological arousal was operationalized by skin conductance in microSiemens (µS), a convenient measure of sympathetic arousal [12]. The BIOPAC MP 150 sampled skin conductance at a rate of 40Hz, using two Ag-AgCl electrodes attached to the distal phalanx surface of the fore and middle finger of the nondominant hand. As cognitive measure, the d2-R test of attention, a paper and pencil based mental speed test, was used to assess concentration and attention performance. This cancellation test has a high reliability with Cronbach's Alpha ranging from 0.82 – 0.96 [13] and is considered as a valid measure of attention [14]. The derived parameter concentration power corresponds to the total number of correctly cancelled target characters. The parameter percentage of errors corresponds to the amount of errors divided by the total number of processed characters. The Self-Assessment Manikin (SAM) served as measure for emotional status [15]. Ratings of valence and arousal were registered using a 9-point Likert scale. Emotional status

and physiological arousal were both assessed three times during each color condition with time of measurement as additional within-subject measure (2x2x3 mixed design).
As additional subjective measures, two 5-item questionnaires registered perceived activation and visual fatigue via 6-point Likert scale. Another 5-item questionnaire was developed to assess general beliefs about the impact of the colors pink and white and colored light. The questionnaire also used a 6-point Likert scale and was completed at the end of the experiment. To test for color preference, participants were given an additional item: "This test will now be repeated with the light color of your choice (white or pink). Which color do you choose?"

D. Procedure

After completing the informed consent, electrodes were attached and baseline measurements of skin conductance (30 seconds), emotional status and visual fatigue were assessed during normal ceiling lighting. Throughout the experiment, measurements of skin conductance and emotional status were assessed simultaneously. After baseline measurements, the first lighting condition started. Participants were instructed to watch the light wall for 10 minutes. A task of counting a pulsating dot at the light wall ensured looking onto the wall while producing only mild cognitive load. This was followed by measurement of skin conductance and emotional status. Next, participants completed the d2-R test, followed by another measurement of skin conductance and emotional valence, the questionnaires about visual fatigue and perceived activation. At the end of the first light color condition, skin conductance and emotional status were measured a third time.
After a 5-minute break, the second lighting condition with the same order of measurements started. Finally, the light wall was switched off and participants completed the questionnaire concerning general beliefs about the colors and colored light. In total, the study lasted about 50 minutes. Only one person was tested at a time.

E. Statistical Analysis

Baseline-corrected values were used for further analysis of emotional valence and arousal as well as skin conductance. For each questionnaire, mean values were calculated. All variables were tested for normal distribution using Shapiro-Wilk test. Mixed Analyses of Variance (ANOVA) were calculated for each, skin conductance, concentration power, emotional valence and arousal, activation assessment and visual fatigue. Percentage of errors in d2-R test were analysed with Wilcoxon test. A χ^2-test investigated the association between sex and color preference. All results were retrieved from two-sided tests.

RESULTS

Age and sex were approximately equally distributed among the two sequence groups: The white-pink group consisted of 8 females and 7 males (age: M=26.67, SD=4.07); the pink-white group consisted of 7 females and 7 males (age: M=29.57, SD=7.51). As can be seen in Table 1, all dependent variables show only slight differences in physiological, cognitive and emotional measures between Baker-Miller pink and white light.

TABLE I. MEANS AND STANDARD DEVIATIONS FOR COGNITIVE, PHYSIOLOGICAL AND EMOTIONAL MEASURES, PERCEIVED ACTIVATION AND VISUAL FATIGUE

Measures		**Light color**	
		Baker-Miller pink *M (SD)*	***White*** *M (SD)*
Physiology	Δ Skin conductance (µS)[a]	1.64 (1.51)	1.61(1.55)
Cognition	Concentration power[b]	191.69 (39.47)	190.55 (40.09)
	Errors (%)	7.40 (7.31)	8.93 (9.65)
Emotion	Δ Valence[a]	-0.55 (0.94)	-0.37 (0.98)
	Δ Arousal[a]	-0.26 (1.65)	0.01 (1.20)
Perceived activation[b]		3.13 (0.76)	3.74 (1.05)
Δ Visual fatigue[a]		0.41 (0.64)	0.46 (0.71)

a. Skin conductance, emotional valence and arousal and visual fatigue are baseline-corrected: positive values indicate a higher level than at baseline, negative values indicate a lower level than at baseline.
b. Values of concentration power (higher values indicate better performance) perceived activation (1=not at all activating; 6=very activating) are absolute values.

Physiological arousal was investigated using a 2x2x3 (color x sequence of light color x time of measurement) mixed ANOVA to test for differences in skin conductance. Light color (pink and white) and time of measurement (three times throughout one trial) served as within-factors, sequence of light exposure (pink-white and white-pink) served as between-factor. The color*sequence interaction was significant, $F(1,27)=5.67$, $p<0.05$, indicating a general skin conductance increase during the second lighting condition. The ANOVA revealed no significant main effects.

To assess effects on cognition, a 2x2 (color x sequence) mixed ANOVA, including light color as within-factor and sequence as between-factor, investigated concentration power in the d2-R test of attention. The significant interaction color*sequence, $F(1,27)=192.72$, $p<0.001$, corresponds to a clear learning effect throughout the second test execution. No significant main effects were found, meaning there were no performance differences caused by the different lightning conditions or by dissimilar groups. The nonparametric Wilcoxon test, testing for percentage of error differences during pink and white light exposure, indicated no significant difference.

Emotional status was evaluated with two 2x2x3 mixed ANOVAs which separately investigated emotional valence and arousal. For emotional valence, a significant interaction was found for time of measurement*sequence, $F(2,54)=3.36$, $p<0.05$. This interaction is based on a difference of valence ratings between group pink-white and group white-pink at the first measurement after light exposure. Group pink-white rated emotional valence significantly higher at this point than did group white-pink. There were no significant main effects. For emotional arousal, a significant main effect was found for the variable time of measurement. Pairwise comparisons showed an increase between measurement 1 (after 10 minutes light exposure) to measurement 2 (after d2-R test) as well as a decrease between measurement 2 and measurement 3 (after further questionnaires), independent of the light color. This interaction suggests that the participants were subjectively aroused due to the d2-R test and calmed down again towards the end of a light condition. No further significant effects were found in this ANOVA.

To assess perceived activation of the light color, a 2x2 (color x sequence) mixed ANOVA was conducted. A significant main effect was found for color, $F(1, 27)=11.40$, $p<0.01$, but not for sequence. These results show that white light was rated more activating than pink light, independent of the sequence of light color exposure. The additionally significant interaction color*sequence, $F(1,27)=7.18$, $p<0.05$, suggests that this effect was caused mostly by the group which was exposed to first pink light and then white light. The white-pink group showed no such difference in ratings of perceived activation. No significant effects in ratings of visual fatigue for light color or sequence were found in a 2x2 (color x sequence) mixed ANOVA. This shows that neither color put more strain on the participants' visual system than the other.

Discussion

The goal of this study was to investigate effects on physiology, cognition and emotion of Baker-Miller pink light compared with white light. Although subjective differences in perceived activation through light color were shown, no effects in physiology and cognition were found: Due to the light exposure, skin conductance as physiological measure showed increased values compared to baseline but did not differ between colors. Results of the d2-R test indicated strong learning effects but no differences between colors. There was also no color effect evident in the measure for emotional status. The only measure detecting a difference between colors was that white light was rated as more activating than Baker-Miller pink light. This effect should be interpreted carefully because only the group which was exposed to pink light first and white light second showed this effect. Therefore, these differences might have been caused by sampling artefacts.

However, some aspects should be taken into account. Importantly, color exposure time was limited to 15 minutes which might have been too short to induce detectable effects. But, since usually skin conductance reacts to changes in physiological arousal already after few seconds with a reliable latency of one to three seconds [16], it can be regarded as improbable to assume effects after longer exposure time. In addition, as the *color-in-context* theory [9] proposes, psychological context plays an important role in color effects. Of course, the present laboratory setting differs completely from a real-life prison setting, for which Schauss [2] reported results of calming and aggression reducing effects of Baker-Miller pink. Nevertheless, this is not the first study which fails in replicating the proposed effects, even in the same context [3], arguing against a specific prison context effect. But, social desirability cannot be ruled out to having impacted our effects: Previous research [17] indicated that especially female sex is associated with the color pink already starting in early childhood. In fact, post hoc analyses investigating a possible association between sex and color preference showed a significant sex effect ($\chi^2(1)=5.97$, $p<0.05$): Women clearly preferred the Baker-Miller pink light over white light while men showed a slight preference for white light suggesting that the context might have played a role.

In the current study, arousal levels were compared between colors. It is important to note that this does not test Schauss' initial hypotheses, which claims that, starting with a high arousal level, exposure to Baker-Miller pink leads to faster arousal decrease compared to other colors. Therefore, including the induction of a higher arousal level prior to color exposure should be considered in further research. Based on the current study examining also physiological and cognitive measures, the results do not support the proposed strong calming effects of Baker-Miller pink [2].

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