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Research report

Blue lighting decreases the amount of food consumed in men, but not in women ☆

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ABSTRACT

Previous research has demonstrated that colors of lighting can modulate participants' motivation to consume the food placed under the lighting. This study was designed to determine whether the colors of lighting can affect the amount of food consumed, in addition to sensory perception of the food. The influence of lighting color was also compared between men and women. One-hundred twelve participants (62 men and 50 women) were asked to consume a breakfast meal (omelets and mini-pancakes) under one of three different lighting colors: white, yellow, and blue. During the test, hedonic impression of the food's appearance, willingness to eat, overall flavor intensity and overall impression of the food, and meal size (i.e., the amount of food consumed) were measured. Blue lighting decreased the hedonic impression of the food's appearance, but not the willingness to eat, compared to yellow and white lighting conditions. The blue lighting significantly decreased the amount consumed in men, but not in women, compared to yellow and white lighting conditions. Overall flavor intensity and overall impression of the food were not significantly different among the three lighting colors. In conclusion, this study provides empirical evidence that the color of lighting can modulate the meal size. In particular, blue lighting can decrease the amount of food eaten in men without reducing their acceptability of the food.

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Introduction

The color of lighting was found to influence consumers' motivation to eat the foods placed in that color (Hasenbeck et al., 2014; Suk, Park, & Kim, 2012). In addition, previous studies have found the influence of lighting illuminance on the amount of food consumed. It is generally understood that soft or dim lighting condition leads patrons not only to spend more time in their eating places, but also to order additional foods (Wansink, 2004; Wansink & Van Ittersum, 2012). However, little attention has been paid to the question as to whether or not the color of lighting can affect the amount of food consumed. Herein, it is worth noting that the surface color of foods has been used as an indicator of the quality of foods (Francis, 1995). From evolutionary and ecological perspectives, the mechanism of color vision in animals has varied depending on the requirements for survival (Hutchings, 1999; Walls, 1963). In other words, each animal species has evolved its own retinal cone pigments to search for their foods more efficiently (Hutchings, 1999; for a review, see also Vorobyev, 2004). Yellow and orange colored fruits are predominantly eaten by Old World monkeys because these colors are easily detected against a background of green foliage (Hutchings, 1999). By contrast, green or brown colored fruits are primarily taken by ruminants and rodents (Hutchings, 1989). In this way, since fruits were a major source of the primate diet, trichromatic color vision could have evolved in humans to effectively aid in finding the foods (Mollon, 1989; Vorobyev, 2004). Humans have also learned the color codes representing the time when individual foods can be eaten with safety and satisfaction (Hutchings, 1999). For instance, humans eat tomatoes when their surface color turns from green to red. Furthermore, the surface color of foods affects consumers' expectation and attitudes toward the foods (Morrot, Brochet, & Dubourdie, 2001), which may modulate food choice (Walsh, Toma, Tuveson, & Sondhi, 1990) and consumption (Rolls, Rowe, & Rolls, 1982).

Ambient lighting modulates food perception and acceptance. It has been reported that the colors of ambient lighting could alter the perception of sour taste (Wilson & Gregson, 1967) and wine flavor (Oberfeld, Hecht, Allendorf, & Wickelmaier, 2009). The colors of ambient lighting also modulated consumers' acceptability for the appearance of foods: bell peppers (Barbut, 2003; Hasenbeck et al., 2014) and meat cuts (Barbut, 2001). In a recent study, Hasenbeck et al. (2014) asked participants to rate their liking of the food's appearance based on photos of bell peppers taken under five colored

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light-emitting diode (LED) lighting. Yellow and blue lighting conditions increased consumers' acceptance of the appearance of bell peppers the most and the least, respectively. Furthermore, participants were the most willing to consume the bell peppers placed in yellow lighting, while they were the least willing to consume those placed in blue lighting. Similarly, Suk et al. (2012) also showed that yellow lighting increased participants' appetite, whereas red and blue lighting decreased their motivation to eat foods.

Building on previous research showing the effect of lighting color on willingness to eat, this study aimed to determine whether the color of lighting can modulate not only overall flavor intensity and overall impression of the foods, but also the amount consumed. Furthermore, the effect of lighting color on food perception and consumption was compared between men and women. This was based on previous observations that men and women differ in neural responses to visual food cues (Cornier, Salzberg, Endly, Bessesen, & Tregellas, 2010; Killgore & Yurgelun-Todd, 2010). For instance, women, in comparison to men, showed greater neural responses to food-related visual cues in the brain regions involved in inhibitory control and self-controlling (Cornier et al., 2010; Killgore & Yurgelun-Todd, 2010). Likewise, these studies raise the possibility that the effect of lighting color on food perception and intake can be shown as differing between men and women.

The overall objective of this study is to determine whether lighting color can influence sensory perception and the amount of food consumed, while additionally determining this influence as a function of gender.

Materials and methods

Ethics statement

This study was conducted according to the Declaration of Helsinki for studies on human subjects. The protocol was approved by the University Institutional Review Board of the University of Arkansas (Fayetteville, AR, USA). The experimental procedure was thoroughly explained to all participants and a written informed consent was obtained from each prior to participation.

Participants

A total of 131 volunteers (all Caucasians; 76 men and 55 women) ranging in age from 18 to 58 years [mean ± standard deviation (SD) = 32 ± 10 years] participated in this study. Participants were screened for olfactory impairment, gustatory impairment, and color blindness using the "Sniffin' Sticks" screening test (Burghart Instruments, Wedel, Germany; Hummel, Konnerth, Rosenheim, & Kobal, 2001), taste spray test (Burghart Instruments, Wedel, Germany; Vennemann, Hummel, & Berger, 2008), and the Ishihara color test (Ishihara, 1986), respectively. Based on the results of the screening tests, 19 participants were excluded. Therefore, data from 112 participants (62 men and 50 women) were used for data analysis. All participants reported that they had no clinical history of major diseases such as cancer, cardiovascular disease, diabetes, or renal disease. In addition, all participants reported that they regularly consumed breakfast in their everyday lives.

Participants were attributed to one of three lighting groups: white, yellow, and blue, depending on their order of appearance. As shown in Table 1, three groups were not significantly different from each other in terms of mean age, mean BMI, and gender ratio ($P > 0.05$).

Lighting condition

Using the multi-color LED light-bulb (ThinkGeek, Inc., Fairfax, VA, USA), three lighting colors: white, yellow, and blue, were provided at individual sensory booths in the University of Arkansas Sensory Service Center (Fayetteville, AR, USA). These three colors were chosen based on the previous findings (Hasenbeck et al., 2014) that under yellow and blue lighting colors, participants' motivation to consume was the most and the least, respectively. Thus, yellow and blue colors were chosen as experimental conditions, while white was used as a control condition. The illuminance levels of the three different colored-lightings were controlled, with a range between 9.0 and 13.5 lux.

Table 1
Mean age, body mass index (BMI), and gender ratio of the participants in the three lighting color groups.

Group	Age	BMI	Number of participants	
			Men	Women
White	31.8 (±11.1)[a]	27.1 (±7.3)[a]	20	16
Yellow	31.9 (±9.6)	26.6 (±6.3)	20	17
Blue	30.2 (±7.7)	27.9 (±7.1)	22	17

[a] Mean (±standard deviation).

Food samples and preparation

For the food samples, ready-to-eat (RTE) foods: (1) ham and cheese omelets (Ham & Cheese omelet, Jimmy Dean®, Chicago, IL, USA) and (2) mini pancakes (Heat-N-Go Mini Pancakes – Maple Burst'n, Pillsbury®, Minneapolis, MN, USA), were used. Omelets and pancakes were chosen since these are staple breakfast foods in the United States. These products were purchased from a local supermarket (Fayetteville, AR, USA) and stored at approximately –4 °C before preparation. The omelets and pancakes were prepared following microwave instructions given on the packages before serving. The omelets and mini pancakes were heated in a microwave (Model No: JES1160DPWW 1100W, General Electrics, Fairfield, CT, USA) at 100% power for 240s and 70 s, respectively. The portion sizes of one omelet and one individual package of pancakes were about 122 g (250 kcal) and about 80 g (180 kcal), respectively.

Procedure

As stated, participants were randomly attributed to individual sensory booths illuminated with one of three lighting colors: white, yellow, and blue. Each participant was asked to consume as much as they wanted of the breakfast meal under one of these three lighting colors. Until the breakfast meal was actually served, the participants did not know what kind of meal was served in this study.

To control participants' hunger status, this study was conducted between 7:30 and 8:30 a.m. All participants were instructed to refrain from consuming any foods and beverages, except water, for 12 hours before participating in this study. Prior to being served a meal, participants were asked to rate their current hunger/fullness status on a 9-point Likert scales ranging from 1 (extremely hungry) to 9 (extremely full). They were also asked to rate their current mood on a 9-point Likert scales ranging from 1 (extremely bad) to 9 (extremely good). Overall, prior to being served the meal, participants reported that they were "very hungry" (mean ± SD = 2.6 ± 0.8) and their mood was "slightly good" (mean ± SD = 6.6 ± 1.6).

After each food sample was weighed, it was served as shown in Fig. 1. Two omelets and 8 mini-pancakes were served on a white plastic plate (26 cm diameter) identified by a three-digit code, along with a white plastic fork and knife, under one of the three colored lightings at individual sensory booths. Also, 120-mL of spring water (Clear Mountain Spring Water, Taylor Distributing, Heber Springs, AR, USA) in a 150-mL plastic cup and a white paper napkin (16.5 cm × 12.5 cm) were provided. Prior to consuming the meal, participants were asked to rate their willingness to eat the meal on a 9-point Likert scale ranging from 1 (extremely unwilling) to 9