Multi-sensory Perception of Chemical Heat and Coldness

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INTRODUCTION

Chemical heat and coldness create a similar sensation experienced by hot and cold temperatures, activating the TRPV1 and TRPM8 trigeminal receptors, respectively; however, primary afferent receptors are depolarized by specific chemical binding instead temperature monitored firing. Common foods using each in the industry are hot sauces (using capsaicin) and confectionary candies (using Wilkinson-Sword (WS) agents) which are often described as spicy and cool, respectively. Although these chemical agents are commonly used in the food industry, little is known about their interaction with other senses present while eating.

OBJECTIVES

- **Measure the influence of color and odor on chemical heat.**
- **Measure the influence of color and odor on chemical cooling.**

MATERIALS AND METHODS

Spicy stimuli / serving

- Odor: Aji Dulce (*Capsicium chinense*)
  - "Habenero" aroma with no heat
- Centrifuged to remove natural color
- Colors: Green, Red, Orange
- Presented in 2oz serving cups with lid
- Palate cleanser: cold 3.5% milk (4 C)

Cool stimuli

- Odor: Mint (Givandan, #112606)
  - No perceivable cooling[1]
- Colors: Green, White, Blue
- Presented in 2oz serving cups with lid
- Palate cleanser: warm water (54 C)

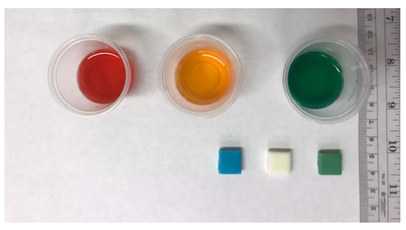


Table 1. Model stimuli used for experiments

No Odor	Odor	Amount
DI Water	DI Water	64 %
-	Aji Dulce Peppers	50 g
Distilled Vinegar	Distilled Vinegar	19%
Lemon Juice	Lemon Juice	16 %
Salt	Salt	.8 %
Garlic Powder	Garlic Powder	.16%
Onion Powder	Onion Powder	.16%
Capsaicin	Capsaicin	500 SHU

No Odor	Odor	Amount
Unsalted Butter	Unsalted Butter	16%
-	Givandan #112606	.03%
Confectioners' Sugar	Confectioners' Sugar	80%
Milk (3.5%)	Milk (3.5%)	3.5 %
WS-3 cooling agent	WS-3 cooling agent	.075%

Methods

Separate, but similar experiments were ran for each chemesthesis condition: chemical heat (Experiment 1) and coldness (Experiment 2).

Subjects (Experiment 1): Thirty-seven (18 women) volunteers with a mean age of 34 years (std. dev. ± 11 years) were screened for heathy olfaction (with Sniffin' Sticks ID) and color-blindness (Ishihara Color Blindness Test).

Subjects (Experiment 2): Forty-nine (29 women) volunteers with a mean age of 33 years (std. dev. ± 12 years) were screened for heathy olfaction (with Sniffin' Sticks ID) and color-blindness (Ishihara Color Blindness Test).

Procedure

All tests were done within a off-white, sectioned sensory booth at The University of Tennessee Sensory Center. Before the test, individuals were given a practice test to rate the intensity of "black color" of five images that varied in hue on a generalized Labeled Magnitude Scale (gLMS)[2]. Next, they evaluated all conditions (randomized) on its appearance, aroma, consistency, taste and chemical feeling (heat or coldness). Pleasantness of the appearance, aroma, and flavor was rated on a 9-point hedonic scale ("Dislike extremely" to "Like Extremely"). Intensity of aroma and chemical feeling were rated on a gLMS. Lastly, a Just-about-right (JAR) style question was asked about consistency to make it feel more like a consumer test.

Additional Session Procedure (for Cooling only)

Individuals came to a second session to evaluate colors and odors more precisely. Here, individuals were given a hue, saturation and value (HSV) color wheel and asked to match each labeled intensity ("Strongest", "Very Strong", "Strong", "Moderate", and "Weak") of coldness with a color. They were also asked why they chose this color. Lastly, they were asked to rate the expected coldness intensity (on a gLMS) and associated color for the first session's mint odor (at 0.03%).

ANALYSIS & RESULTS

Chemical Heat

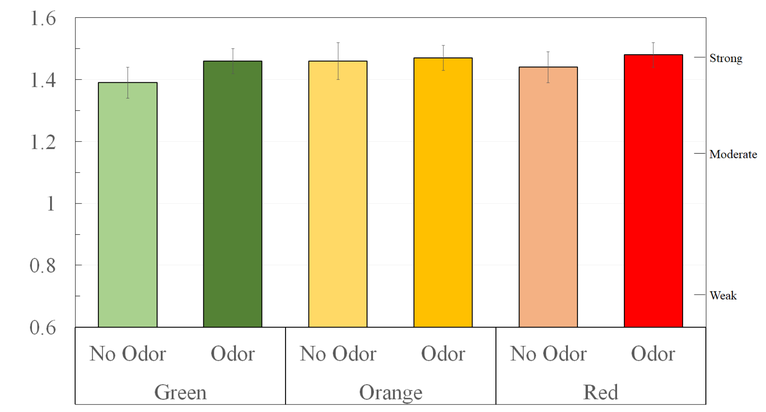
Analysis

- A repeated-measured ANOVA was conducted with either pleasantness, aroma intensity, and spice/heat regressed on color, odor and its interaction.

Results

- **There was a significant difference in aroma intensity between the odor and non-odor stimuli ($p < 0.001$).**
- **All stimuli were equally liked in flavor ($p > 0.05$), but orange color was liked the most for appearance ($p < 0.001$).**
- **There were no effects of color, odor or their interaction on perceived spiciness ($p > 0.05$).**

Figure 1. Perceived spiciness for each stimuli.



Chemical Cooling

Analysis

- A repeated-measured ANOVA was conducted with either pleasantness, aroma intensity, and cool/coldness regressed on color, odor and its interaction.
- Cochran's Q was used to look at differences in color matching across cooling/coldness intensities
- A three-way ANOVA was used to look at HSV assignment across cooling intensities.
- Cochran's Q was used to look at differences in colors chosen for mint aroma.

Figure 2. Perceived coolness for each stimuli.

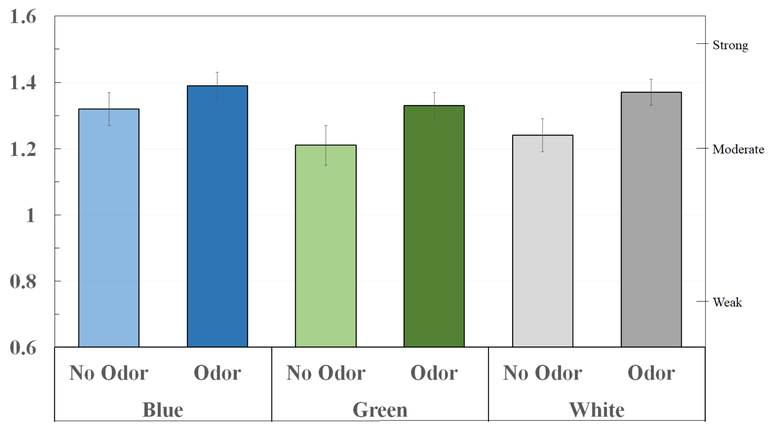


Table 2. Color-association with mint odor.

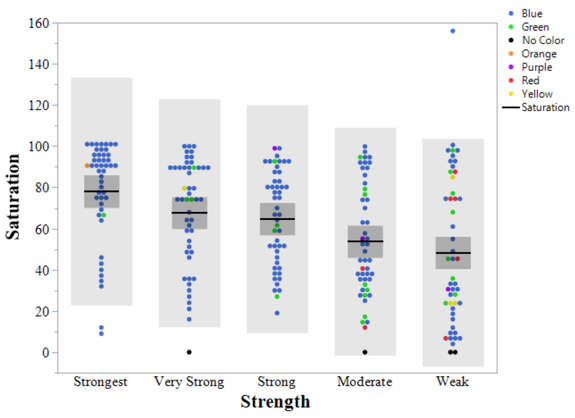
Color	Association (%)
Blue	43.28%
Green	31.48%
White	19.34%
Purple	3.93%
Yellow	1.97%
Red	0.00%
Black	0.00%
Orange	0.00%

- **There was a significant difference in aroma intensity between the odor and non-odor stimuli ($p < 0.001$).**
- **Odor was expected to be cooling if found in a food product (rated moderate-strong on gLMS).**
- **The white stimuli were liked more than the green in appearance ($p = 0.005$) and odor samples were liked more in flavor ($p < 0.001$).**
- **There was an effect of odor ($p = 0.03$) and color on increasing cooling sensation ($p = 0.04$).**
- **The effect of mint odor on cooling could be driven by the specific-associations with the aroma, but could also stem from hedonics, as the samples with odor were more liked.**

Table 2. Color association with strength of Coolness/Coldness.

Color	Cooling Strength (gLMS Level)				
	Strongest	Very Strong	Strong	Moderate	Weak
Blue	95.83%	90.00%	89.80%	75.51%	61.22%
Green	2.08%	6.00%	8.16%	16.33%	16.33%
No Color	0.00%	2.00%	0.00%	2.04%	4.08%
Orange	2.08%	0.00%	0.00%	0.00%	0.00%
Purple	0.00%	0.00%	2.04%	2.04%	2.04%
Red	0.00%	0.00%	0.00%	4.08%	10.20%
Yellow	0.00%	2.00%	0.00%	0.00%	6.12%

Figure 3. Saturation change with strength of coolness/coldness.



- **Blue was the dominant hue associated to a cooling sensation (Table 2).**
- **Saturation and value increase ($p < 0.001$ and $p = 0.005$) with increasing cooling sensation.**
- **Blue increased cooling of stimuli compared to the average of the other two colors ($p = 0.01$)**

CONCLUSION

- **Spice/Heat does was not influenced by color or odor in hot sauce. However, all stimuli were liked the same for flavor and the intensity of spice was moderate to strong.**
- **Cooling/Coldness was influenced by odor and color at a moderate level of coolness. Odorized and blue samples were perceived to have a higher cooling sensation.**
- **The effect of color seems to be related to the associated coldness of the blue color.**
- **Chemical cooling sensations appear to be more linked to odor than chemical heat sensations.**

1. Labbe, D., Gilbert, F., Antille, N., & Martin, N. (2009). Sensory determinants of refreshing. Food Quality and Preference, 20(2), 100-109.
2. Green, B. G., Dalton, P., Cowart, B., Shaffer, G., Rankin, K., & Higgins, J. (1996). Evaluating the 'Labeled Magnitude Scale for measuring sensations of taste and smell. Chemical senses, 21(3), 323-334.