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Color Perception and Saliva Stimulation - Decoding Connections: Direct, Indirect or None?

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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Short Research Article

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ABSTRACT

Background of the Study: The potential link between color perception and saliva stimulation, hypothesizing that specific hues, regardless of being warm or cool, can trigger salivation.
Objective: The objective of this study is to explore the potential connection between color perception and saliva stimulation, hypothesizing the existence of saliva stimulation associated with specific hues, regardless of whether they are warm or cool tones. Furthermore, the study aims to identify which category of colors and shades could potentially influence saliva stimulation.
Methods: A questionnaire-based approach was employed to gather data from a substantial sample of participants. These questionnaires were structured to encompass segments probing participants' inclinations regarding color perception, experiences of saliva stimulation and their opinions on food preferences related to different hues. Participants were asked to self-report their perceived color sensitivity and provide insights into their saliva stimulation levels.

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Results: Preliminary analysis suggests a potential correlation between color perception and saliva stimulation. Participants indicated a stronger inclination towards warm colors (68% almost; 58% often) in contrast to cool colors (32% almost; 42% often), positing that warm hues may possess the capacity to trigger saliva production more effectively than cooler ones.

Conclusion: These findings suggest a plausible link between color perception and saliva stimulation, warranting further investigation through controlled experiments and physiological measurements. Understanding this potential association could have implications for various fields, including psychology, sensory perception, and oral health research.

Keywords: Color perception; neural connections; psychophysiological response; saliva stimulation.

1. INTRODUCTION

The processing of sensory information exhibits considerable diversity among individuals, captivating researchers with the intricate dynamics inherent in sensory perception (Marks et al., 1964). Within this domain, the interplay among different sensory modalities has long intrigued scholars, offering a rich terrain for exploring the multifaceted nature of human cognition. Notably, color perception, saliva stimulation and gustatory perception emerge as pivotal facets of human experience, each governed by unique physiological and psychological processes (Shapley & Hawken, 2002). Despite their importance, the extent of interaction between these ostensibly distinct sensory domains continues to be a topic of ongoing investigation and discourse within the scientific community.

At the molecular level, the process of color perception commences with the interaction between light and specialized photoreceptor cells situated in the retina, termed cones (Baylor et al., 1984). These cones are classified into three types, each exhibiting peak sensitivity in the blue, green, and red regions of the spectrum, corresponding to absorption peaks near 445 nm, 535 nm, and 565 nm, respectively. They are often denoted as S, M, and L cones, in trichromatic theory, reflecting their responsiveness to short, medium, and long wavelengths (Smith & Pokorny, 1975; Pasmanter & Munakomi, 2022). Within these cones reside the photopigments, such as opsins (melanopsin), which undergo a structural alteration upon exposure to photons of specific wavelengths. This alteration initiates a series of biochemical cascades, culminating in the generation of electrical signals. Subsequently, these signals are conveyed along the optic nerve to the visual cortex in the brain. Within the confines of the visual cortex, intricate neural circuits process and amalgamate this information, ultimately shaping the perception of color based on the wavelengths of light detected by the cones. Numerous recent findings have shed light on the retino-hypothalamic tract, a pathway directly connecting the retina to the hypothalamus (Nathans et al., 1986). This pathway plays a pivotal role in linking colors to the autonomic nervous system (ANS). The autonomic nervous system (ANS) oversees the sympathetic and parasympathetic systems, which exhibit contrasting functions. Warm colors are modulated by sympathetic nerve pathways, whereas cool colors are influenced by parasympathetic nerve pathways (Gouras, 1968; Rowe, 2002).

In parallel, the regulation of salivary stimulation or secretion involves a complex interaction among the retino-hypothalamic tract, parasympathetic, and sympathetic nerve pathways. Electrical signals generated by stimulated melanopsin-containing ganglion cells travel along the retino-hypothalamic tract to reach the suprachiasmatic nucleus (SCN) of the hypothalamus (Proctor, 2016). Functioning as the master circadian pacemaker, the SCN integrates these signals with internal biological rhythms, thereby controlling the timing of various physiological processes, including those governed by the autonomic nervous system (ANS). Through communication with regions such as the paraventricular nucleus (PVN) within the hypothalamus, the SCN modulates ANS activity. The PVN, acting as a central hub for autonomic regulation, coordinates the functions of the sympathetic and parasympathetic nervous systems (Jacobs, 2014; Brown & Lindsey, 2013). Under the influence of the PVN, the sympathetic nervous system stimulates salivary gland secretion by releasing neurotransmitters like norepinephrine. Conversely, the parasympathetic nervous system, also regulated by the PVN, promotes salivation through the release of acetylcholine. Upon binding to their respective receptors on salivary gland cells, neurotransmitters initiate intracellular signaling cascades that regulate ion channels and transporters responsible for saliva production and secretion (Edwards, 2002).

Extensive research has been conducted within each domain independently; however, the potential convergence between color perception and salivary stimulation has received limited investigation. Emerging theoretical frameworks and anecdotal evidence indicate the presence of cross-modal interactions, wherein stimuli from one sensory modality affect perceptual experiences in another (Radeljak et al., 2008). This prompts an intriguing question: could there be a discernible link between color perception and saliva stimulation, two seemingly distinct sensory realms with the potential for interconnectedness?

In pursuit of elucidating this inquiry, a comprehensive questionnaire study was designed to uncover the potential relationship between color perception and saliva stimulation. Rooted in principles of cross-modal sensory integration and psychophysical methodologies, this investigation aims to systematically explore participants' perceptual experiences and physiological responses to color stimuli alongside varying expressions of salivary stimulation.

2. EXPERIMENTAL DETAILS

2.1 Survey Design

To accomplish the research goal, an online Google Form was devised to enhance participant accessibility. This form encompassed 24 inquiries concerning food color preferences, considering diverse factors such as frequency, emotional and physical contexts, textures and consistency, participants' perceptions of the relationship between color psychology and physiology, and varying experiences of saliva stimulation. Each question offered five response options indicating frequency: "almost, often, sometimes, rarely, and never." This approach aimed to elucidate the frequency and intensity of the influence exerted by food color preferences on varying experiences of saliva stimulation. All participants were presented with an identical set of questions to ensure consistency across responses.

The survey was distributed exclusively within the national scope by means of social media postings targeted at the intended audience. Respondents were furnished with a link, facilitating access to the questionnaire across multiple devices, including smartphones, tablets, laptops, and desktop computers. The survey ensured anonymity for data collectors and refrained from gathering, retaining, or analyzing personal information except for demographic details (age and gender) and dietary preferences categorized by dietary basis. Participants provided consent for data collection by agreeing to participate in the study. Completion of the questionnaire was conducted solely online and was anticipated to require approximately 6-7 minutes. Survey progress was monitored on a weekly basis, with two additional reminders dispatched via social media over a 35-day period.

2.2 Quality Control

To enhance result accuracy and mitigate bias, each question offered two primary options: "Warm colors" and "Cool colors." Participants were prompted to express their opinions on both warm and cool colors across all 24 questions, with each color category featuring identical frequency options.

2.3 Data Analysis

The data obtained from participants underwent analysis. Descriptive statistics (inclusive of counts and percentages) were utilized to summarize and elucidate the collected data.

3. RESULTS AND DISCUSSION

3.1 Population Percentage

Given the potential association between color perception and saliva stimulation, a hypothesis was formulated, prompting the selection of a pilot study design involving 105 participants. The population percentage is described in Fig. 1. All respondents fell within the age bracket of 21 to 55 years (21-40 years(n=81); 41-55 years(n=24)). Of these, 55.38% (n=55) were male and 47.61% (n=50) were female. Regarding dietary preferences, among the 105 respondents, 36.19% (n=38) adhered to a vegetarian diet, while 63.8% (n=67) followed a dietary regimen comprising both vegetarian and non-vegetarian components.

3.2 Response Metrics and Proportions

A group of 105 participants were presented with a set of 24 inquiries featuring two main options categorized as warm and cool colors. Each respondent was required to express their views on both warm and cool colors. This approach effectively mitigated potential biases and enabled the identification of the frequency of food preferences eliciting saliva stimulation. The frequency of food preferences eliciting saliva stimulation was classified into five major types using a Likert scale: almost, often, sometimes, rarely, and never. This frequency scale aims to shift the focus towards determining which colors influenced saliva stimulation for respondents, according to their perspectives.

The likelihood of obtaining responses for warm colors and cool colors was estimated to be 98.45% and 96.90%, respectively, inclusive of unanswered options and frequency per question as well as the comprehensive distribution of response percentages for each question across all five frequency options pertaining to both warm and cool colors has been depicted in Fig. 2, utilizing a pie chart format.

In the domain of scientific investigation, the quantity of responses indicating the frequency option "almost" across the 24 questions has been observed to be greater in warm colors, constituting 68% (n=852 responses), in contrast to cool colors, which accounted for 32% (n=402 responses).This trend becomes apparent in questions where there is a notable increase in responses indicating the "almost" frequency option, such as question 3 (n=51 responses) (Do you think the brightness or intensity of a color plays a role in its ability to stimulate saliva production?), question 6 (n=54 responses) (Do you believe that certain colors have the ability to stimulate saliva production?), question 16 (n=60 responses)(Do you believe that the presentation of food, including vibrant colors, influences your food cravings and overall enjoyment of a meal?), question 17 (n=57 responses) (Have you ever noticed any food advertisements that use bright colors to make you feel hungrier or salivate?), and question 19 (n=60 responses)(Do you believe understanding how colors influence saliva production could be beneficial for cooking or meal choices?).

Likewise, the quantity of responses indicating the frequency option "often" across the 24 questions has been observed to be marginally greater in warm colors, comprising 58% (n=672 responses), as opposed to cool colors, which accounted for 42% (n=489 responses). This inference is clearly discernible in questions where there is a notable increase in responses indicating the "often" frequency option, such as in question 1 (n=51 responses) (How frequently do you consume foods based on the color?).

The number of responses indicating the "sometimes" frequency option across the 24 questions has been observed to be higher in cool colors, constituting 60% (n=912 responses), in contrast to warm colors, which accounted for 40% (n=606 responses). This trend is notably apparent in question 5 (n=51 responses) (How likely are you to seek out foods or beverages of specific colors based on their potentiality to stimulate saliva production or enhance taste perception?), question 13 (n=51 responses) (How likely are you to associate specific flavors or tastes with certain colors?), and question 15 (n=51 responses) (Do you think the perception of colors differs between children and adults in terms of saliva production or stimulation?). In the analysis of responses across the 24 questions, it was noted that the number of responses indicating the "rarely" frequency option was

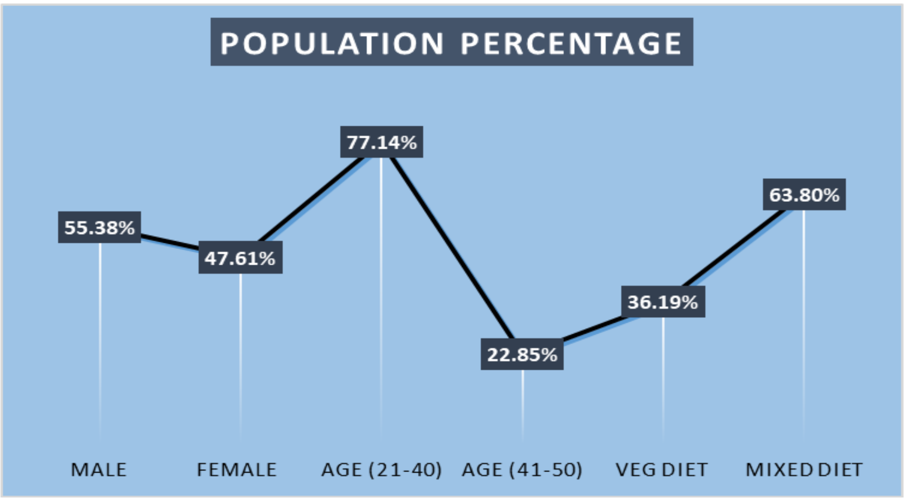

Fig. 1. Depicts the population percentage involved in this study

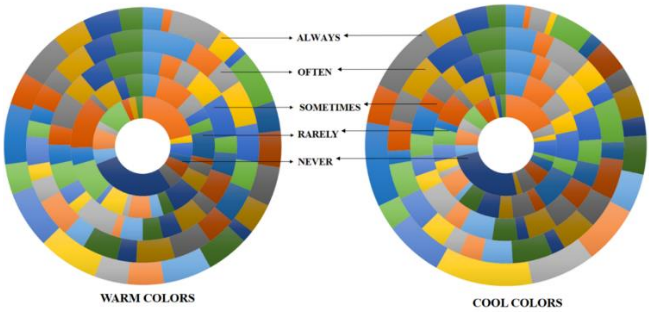

Fig. 2. Depicts the comprehensive distribution of response percentages for each question across all five frequency options pertaining to both warm and cool colors

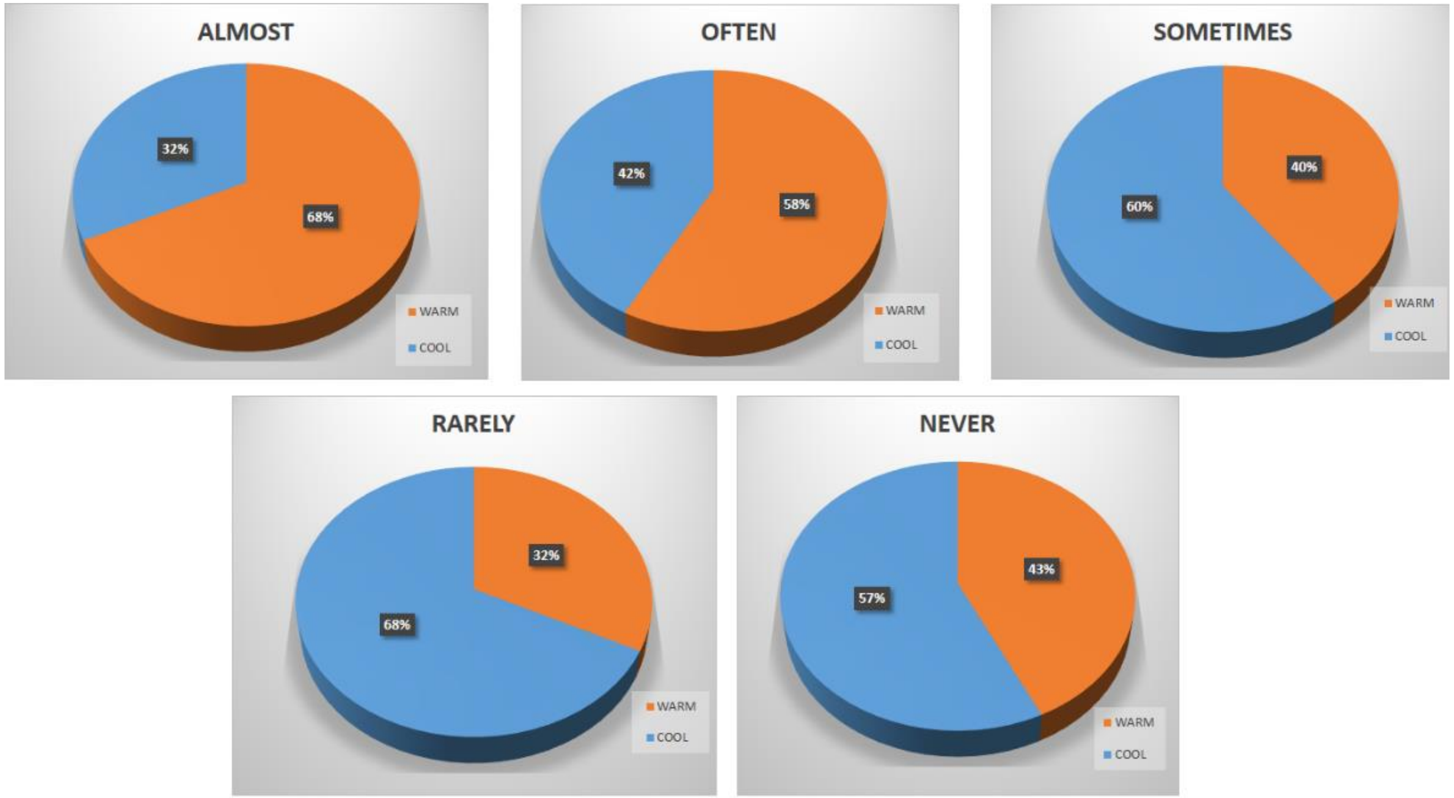

Fig. 3. Depicts the distribution percentage among the frequency options “always”, “often”, "sometimes", "rarely" and “never”

Table 1. Depicts the overall distribution percentage of responses.

S.No	Questions	colors	Always	Often	Sometimes	Rarely	Never
1	How frequently do you consume foods based on the color?	WARM	20%	48.57%	20%	8.57%	0
		COOL	8.57%	20%	45.71%	22.85%	0
2	Have you ever consciously used specific colors to enhance your saliva production or appetite?	WARM	8.57%	28.57%	20%	17.14%	25.71%
		COOL	2.85%	11.42%	22.85%	31.42%	28.57%
3	Do you think the brightness or intensity of a color plays a role in its ability to stimulate saliva production?	WARM	48.57%	22.85%	20%	8.57%	0
		COOL	8.57%	25.71%	34.28%	22.85%	5.71%
4	How often do you experience changes (increase) in saliva production in response to visual stimuli such as colors?	WARM	22.85%	40%	31.42%	0	2.85%
		COOL	2.85%	17.14%	57.14%	20%	2.85%
5	How likely are you to seek out foods or beverages of specific colors based on their potentiality to stimulate saliva production or enhance taste perception?	WARM	8.57%	34.28%	42.85%	5.71%	5.71%
		COOL	0	11.42%	48.57%	31.42%	8.57%
6	Do you believe that certain colors have the ability to stimulate saliva production?	WARM	51.42%	25.71%	17.14%	5.71%	0
		COOL	17.14%	28.57%	37.14%	14.28%	2.85%
7	Can you recall any specific instances where a particular color influenced your perception of taste or saliva stimulation?	WARM	28.57%	31.42%	22.85%	14.28%	2.85%
		COOL	5.71%	11.42%	34.28%	40%	5.71%
8	Do you think your emotional state affects how colors influence your saliva production?	WARM	34.28%	25.71%	31.42%	2.85%	5.71%
		COOL	14.28%	25.71%	37.14	11.42%	8.57%
9	Which colors, if any, do you believe are most effective in stimulating saliva production?	WARM	37.14%	34.28%	14.28%	5.71%	5.71%
		COOL	8.57%	20%	20%	22.85%	8.57%
10	Do you think the	WARM	28.57%	34.28%	28.57%	8.57%	0

S.No	Questions	colors	Always	Often	Sometimes	Rarely	Never
	association between how we see colors and saliva production be related to differences in how our bodies work or how we perceive things?	COOL	14.28%	22.85%	42.85%	14.28%	2.85%
11	Have you ever heard or read about any scientific studies linking colors to saliva production or stimulation?	WARM	11.42%	17.14%	20%	14.28%	34.28%
		COOL	8.57%	8.57%	17.14%	22.85%	40%
12	How do you think the texture or consistency of foods with colors affects saliva production or stimulation?	WARM	40%	31.42%	20%	5.71%	0
		COOL	17.14%	25.71%	37.14%	20%%	0
13	How likely are you to associate specific flavors or tastes with certain colors?	WARM	45.71%	20%	22.85%	5.71%	5.71%
		COOL	17.14%	20%	48.57%	5.71%	5.71%
14	Have you ever noticed differences in saliva production when consuming foods with colors in different environment (e.g., at home, at a restaurant)?	WARM	34.28%	34.28%	8.57%	11.42%	8.57%
		COOL	25.71%	14.28%	28.57%	22.85%	8.57%
15	Do you think the perception of colors differs between children and adults in terms of saliva production or stimulation?	WARM	31.42%	20%	40%	2.85%	2.85%
		COOL	28.57%	11.42%	48.57%	5.71%	5.71%
16	Do you believe that the presentation of food, including vibrant colors, influences your food cravings and overall enjoyment of a meal?	WARM	57.14%	14.28%	11.42%	11.42%	0
		COOL	42.85%	17.14%	25.71%	11.42%	0
17	Have you ever noticed any food advertisements that use bright colors to make you feel hungrier or salivate?	WARM	54.28%	25.71%	17.14%	2.85%	0
		COOL	25.71%	22.85%	28.57%	17.14%	0
18	Do you think there are cultural differences in how colors influence saliva	WARM	28.57%	14.28%	25.71%	20%	11.42%
		COOL	11.42%	22.85%	34.28%	17.14%	8.57%

S.No	Questions	colors	Always	Often	Sometimes	Rarely	Never
	production or stimulation?						
19	Do you believe understanding how colors influence saliva production could be beneficial for cooking or meal choices?	WARM	57.14%	14.28%	20%	8.57%	0
		COOL	37.14%	8.57%	42.85%	8.57%	0
20	Do you believe there might be health consequences related to the impact of colors on saliva production or stimulation?	WARM	31.42%	20%	20%	25.71%	2.85%
		COOL	17.14%	20%	22.85%	28.57%	8.57%
21	Can the saturation and color of food packaging have an effect on the salivary response?	WARM	42.85%	17.14%	34.28%	2.85%	0
		COOL	31.42%	20%	31.42%	8.57%	0
22	Do you find that seeing familiar colors in the food on the table makes you salivate more? (i.e, same colors or shades in different dishes on the table)	WARM	31.42%	31.42%	22.85%	11.42%	2.85%
		COOL	14.28%	25.71	22.85%	25.71	2.85%
23	Is there a difference in salivation response between warm and cool colors?	WARM	34.28%	25.71%	28.57%	5.71%	0
		COOL	14.28%	28.57%	40%	8.57%	2.85%
24	Does the duration of exposure to certain colors affect the salivation response?	WARM	22.85%	28.57%	37.14%	8.57%	2.85%
		COOL	8.57%	25.71%	40%	14.28%	2.85%

higher in cool colors, comprising 68% (n=471 responses), as opposed to warm colors, which accounted for 32% (n=225 responses). Additionally, slightly elevated responses were observed in the "never" frequency options for cool colors, totaling 57% (n=168 responses), compared to warm colors, which constituted 43% (n=126 responses). Fig. 3 illustrates the distribution percentage among the frequency options "always", "often", "sometimes", "rarely" and “never”.

The distribution of responses of a total of 105 respondents across 24 questions is given above in Table 1.

3.3 Discussion

The phenomena of color perception and saliva stimulation intersect within the domain of sensory physiology, presenting a compelling area for scientific exploration. The process of perceiving color in humans involves intricate interactions among visual processing, neural transmission, and cognitive interpretation, exerting significant effects on emotional, behavioral, and physiological states (Neitz et al., 2002; Bots et al., 2004). Similarly, saliva stimulation, regulated by the complex dynamics of the autonomic nervous system and salivary gland activity, plays essential roles in maintaining oral health, facilitating digestion, and contributing to sensory experiences (Alhajj & Babos, 2023; Ghannam & Singh, 2023). Although historically investigated as distinct areas of study, contemporary research has commenced unraveling the fascinating interrelations between color perception and saliva stimulation, revealing insights into how visual cues impact physiological reactions. This comprehension of their interplay offers potential for uncovering fundamental tenets of sensory integration, with implications extending across disciplines from psychology and neuroscience to marketing and healthcare, promising practical applications.

In this survey-based investigation, the potential association between color perception and saliva stimulation has been examined. The study primarily centers on categorizing colors based on temperature, distinguishing between warm and cool hues. It also explores the frequency of food preferences associated with various hues, recognizing their significant impact on saliva stimulation experiences, and solicits participants' opinions on food preferences linked to different color tones.

The categories of the colors examined in this study are warm and cool colors. In scientific inquiry, analyzing the responses to 24 questions reveals valuable insights into participants' perceptions of colors and their experiences with saliva stimulation. The distribution of responses between warm and cool colors is pivotal. Notably, the combined percentage of "almost" and "often" responses stands at 61%, with 34% and 27% respectively. This majority share surpasses other frequency responses such as "sometimes" (25%), "rarely" (9%), and "never" (5%), which together constitute 39%. Warm colors, such as red, orange, and yellow, evoke feelings of warmth, energy, and excitement in human perception (Lotto & Purves, 2002). These hues are commonly linked to increased arousal and stimulation. In the visual system, warm colors undergo processing through specialized neural pathways (sympathetic), including regions like the primary visual cortex and the ventral stream, which manage color perception and object recognition. This aligns with a study conducted by Linda et al., exploring the physiological and psychological aspects of color (IntroBooks Team, 2019). Neurons within these pathways exhibit selectivity to various wavelengths of light, particularly favoring the longer wavelengths characteristic of warm colors. Additionally, as visual signals travel from the retino-hypothalamic tract, regions of the brain responsible for emotional processing, such as the amygdala and orbitofrontal cortex, are activated, contributing to the emotional experience elicited by warm colors.

Conversely, Exposure to cool colors, like blue and green, has been linked to sensations of tranquility and relaxation, potentially leading to a decrease in sympathetic nervous system activity and a corresponding decline in physiological arousal, including salivary response and ingestion (Lotto & Purves, 2002; Papaconstantinou et al., 2009). A study demonstrated by Michael Kalloniatis et al indicates that exposure to cool colors may engage specific neural pathways in the brain related to relaxation and emotional regulation (Kalloniatis & Luu, 2005). Aspects of the brain such as the prefrontal cortex and anterior cingulate cortex, crucial for cognitive control and emotional processing, may exhibit increased activation in response to cool color stimuli (Sugita, 2004). This heightened neural activity can prompt a shift from sympathetic to parasympathetic nervous circuits, resulting in diminished physiological arousal which can be attributed to the study demonstrated by Zrenner et al., (1981). This phenomenon becomes readily apparent through an examination of participant responses to 24 questions. Notably, there is a notable escalation in the distribution percentage within the frequency options of "sometimes" (37%), "rarely" (19%), and "never" (7%), collectively comprising 63%. This cumulative figure surpasses that of the alternative frequency options "always" (17%) and "often" (20%), which together constitute 37%.

These findings align with the hypothesis suggesting that color perception influences saliva stimulation through both direct and indirect pathways. Based on this hypothesis, a questionnaire-based study was devised. Following confirmatory analysis, further investigations could delve into the biochemical aspects of this relationship, providing insights into the molecular mechanisms underlying the association between color perception and saliva stimulation.

4. CONCLUSION

In summary, the results of this questionnaire-based study illuminate the intricate interplay between color perception and saliva stimulation. These findings not only validate existing hypotheses but also pave the way for deeper exploration into the underlying mechanisms at both the perceptual and molecular levels. A further area of investigation could involve the inclusion of salivary biomarkers and their influence on color perception, exploring any potential connection with oral health status. By shedding light on this complex relationship, this study contributes to our understanding of sensory experiences and opens avenues for future research in this fascinating area of study.

CONSENT

All participants were thoroughly informed about the study details and were invited to share their perspectives and opinions regarding the research.

ETHICAL APPROVAL

The study was entirely questionnaire-based, with no involvement of human tissue samples. Participants' inputs and preferences were documented, and a hypothesis was formulated based on the findings, considering the pilot nature of the study.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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I sincerely acknowledge the valuable opinions and perspectives shared by the participants, which have played a pivotal role in shaping this pilot study. Their contributions will serve as a foundation for future research, which aims to expand into the exploration of salivary biomarkers and their potential association with color perception.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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