# Color and Colorimetry
# Multidisciplinary Contributions

**Vol. XX A**

Edited by Filippo Cherubini and Andrea Siniscalco


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## Introduction

The Color Conference, organized annually by the Italian Color Association (Gruppo del Colore - Associazione Italiana Colore), reached its Twentieth Edition in 2025.
The international two-day event took place on September 4th and 5th, 2025, at the University of Naples Parthenope in the beautiful city of Naples.

This milestone edition opened with three keynote presentations of exceptional breadth and inspiration. The conference began with Dr. Costanza Miliani from the CNR Institute of Heritage Science, who presented "Writing with Colors: Materials, Techniques, and Cultural Significance in Mesoamerican Codices". The program continued with Studio Waldemeyer, featuring Farahbod Nazanin and Moritz Waldemeyer, and their evocative talk "Where Light Becomes Emotion".
The morning session concluded with the Color Award 2025, conferred to Massimo Cantini Parrini in recognition of his extraordinary contribution to the world of costume and creativity.
The following day opened with an outstanding invited lecture by Dr. Massimiliano Guarnieri from ENEA, who presented "Artificial Intelligence and color features detection: some examples and future perspective".

Sincere thanks go to the Chairs of the Conference, Giuliana Ramella (CNR – Institute for Applied Calculus "Mauro Picone") Francesca Fragliasso (University of Naples Federico II) and Andrea Siniscalco (Dipartimento di Design, Politecnico di Milano), for their valuable guidance and coordination. A heartfelt appreciation also goes to the University of Naples Parthenope, host of this year's edition.
We warmly thank Dr. Sofia Ceccarelli (CNR ISPC) for the local organization, the Program Committee, Professors Angelo Ciaramella and Emanuel Di Nardo (University of Naples Parthenope), Professors Laura Bellia and Francesca Diglio (University of Naples Federico II), as well as Dr. Filippo Cherubini, Secretary of the Association, and all the members of the Scientific Committee, for their fundamental contribution to the dissemination, review, and organization of the conference. Special thanks also go to Tectilia, the event sponsor, whose support helped make this conference both culturally enriching and welcoming.

The 2025 program once again confirmed the richness and interdisciplinarity that have always characterized the work of our community, spanning from design to education, and from cultural heritage to psychology.
These diverse perspectives continue to make the Conferenza del Colore a reference point for researchers, professionals, and enthusiasts working on the multifaceted study of color.

Finally, we extend our gratitude to all authors and speakers for the quality of their contributions, and to the institutions and associations that offered their patronage and collaboration, reinforcing the spirit of unity that defines this event.

The following pages collect the proceedings of the Twentieth Color Conference.

We wish you an inspiring read.

**Alice Plutino**
*October 2025*

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# Index



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# Color Sensitivity: How Hue and Saturation Influence Food Selection in Nickel Allergy

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## Abstract

Nickel allergy is the most common form of allergic contact dermatitis (ACD) worldwide, with notable gender differences in prevalence. While its dermatological effects are well-established, the broader neuropsychological and perceptual implications remain largely unexplored. This study examines the potential influence of nickel hypersensitivity on visual food perception, particularly focusing on how immune sensitization may alter sensory processing and emotional responses to food-related visual stimuli. A cross-sectional study was conducted involving participants with and without confirmed nickel allergy. All participants completed a detailed questionnaire assessing concerns related to food color, anxiety-related behaviors, vividness of mental imagery, and risk perception. Responses were rated using a Likert scale across various color categories. Statistical analyses included t-tests, chi-square tests, Pearson correlations, and multiple regression models controlling for demographic variables. Participants with nickel allergy exhibited heightened concern for specific food colors and demonstrated more vivid mental imagery and greater avoidance behaviors based solely on visual appearance. These perceptual differences remained significant even after adjusting for demographic factors. Nickel hypersensitivity may influence food perception through enhanced sensory vigilance, suggesting that allergic contact dermatitis can extend beyond cutaneous symptoms to affect cognitive and perceptual domains. These findings have potential implications for dietary guidance, food presentation strategies, and a deeper understanding of the psychosocial burden associated with allergic conditions.

**Keywords: N**ickel allergy, Color perception, Food psychology, Sensory vigilance, Cross-modal perception.

## Introduction

Nickel allergy constitutes the most prevalent form of allergic contact dermatitis (ACD) worldwide, representing a significant public health concern with substantial socioeconomic implications. Current epidemiological data indicate that nickel sensitization affects approximately 8.6% of the general European population, with marked gender disparities showing prevalence rates of up to 17% in women and 3% in men (Thyssen et al., 2007; Ahlström et al., 2019). North American surveillance data corroborate these findings, with retrospective analyses revealing an average nickel sensitivity frequency of 17.5% among dermatitis patients between 1994-2014 (Warshaw et al., 2019). The pathophysiology of nickel allergy involves a complex type IV delayed-type hypersensitivity reaction mediated by hapten-specific T-lymphocytes (Schmidt et al., 2010). Upon initial sensitization, nickel ions ($Ni^{2+}$) form hapten-protein conjugates with skin proteins, particularly through cysteine and histidine residues, triggering the activation of Langerhans cells and dendritic cells as antigen-presenting cells (APCs) and subsequent T-helper 1 (Th1) and T-helper 17 (Th17) cell-mediated inflammatory cascades (Martin et al., 2011). This immunological memory results in rapid inflammatory responses upon re-exposure, manifesting as erythema, vesiculation, scaling, and intense pruritus typically occurring 12-72 hours post-contact (Menné & Maibach, 1989; Johansen et al., 2011).

Color represents a fundamental dimension of visual perception that profoundly influences human cognition, emotion, and behavior through both innate and learned associations (Bortolotti et al., 2022; Elliot & Maier, 2014). In the context of food perception, color serves as the primary product-intrinsic sensory cue in establishing expectations regarding taste, flavor, freshness, and safety (Bortolotti et al., 2025a; Spence et al., 2010). Food colors processed through the ventral visual stream, involving interactions between the visual cortex (areas V1-V4), fusiform color area, and limbic structures including the amygdala and orbitofrontal cortex (Hurlbert & Owen, 2015). The neurobiological substrates of color processing involve complex trichromatic mechanisms mediated by long (L), medium (M), and short (S) wavelength-sensitive cone photoreceptors, with subsequent processing through opponent color channels (red-green, blue-yellow, and luminance) (Hunt et al., 2009).These neural pathways contribute to the emotional valence and cognitive appraisal of visual stimuli, with specific colors eliciting predictable psychological and physiological responses across cultures (Palmer &Schloss, 2011).
Research demonstrates that warm colors (red, orange, yellow) typically stimulate appetite and convey ripeness or energy density, while cool colors (blue, green) may suggest freshness, naturalness, or in some cases, spoilage (Spence et al., 2010; Piqueras-Fiszman & Spence, 2014). These associations are mediated by both evolutionary adaptations and cultural learning, with implications for food choice behavior and dietary preferences (Roullet & Droulers, 2005). Despite the theoretical plausibility of allergy-related perceptual alterations, empirical research examining the intersection of allergic contact dermatitis and sensory perception remains limited. This study addresses this knowledge gap by investigating how individuals with patch-test confirmed nickel allergy perceive food colors compared to non-allergic controls, utilizing a comprehensive battery of perceptual, cognitive, and behavioral measures. Based on the theoretical framework of enhanced sensory vigilance and cross-modal plasticity in allergic conditions, we formulated the following a priori hypotheses:

*H1:* Individuals with nickel allergy would demonstrate significantly elevated concern levels for food colors, particularly those associated with warm spectrum colors or foods with potential nickel content.

*H2*: Allergic participants would exhibit enhanced mental imagery vividness and emotional reactivity to food-related visual stimuli compared to controls.

*H3*: Color-based food avoidance behaviors would be more prevalent in the allergic group, independent of actual nickel content, reflecting generalized hypervigilance mechanisms.

*H4*: These perceptual differences would correlate with anxiety levels and risk perception measures within the allergic group, supporting a unified vigilance framework.

**Methods**
Participants were recruited through a multi-channel approach including online platforms, dermatology clinic referrals, and snowball sampling within university networks. The final sample consisted of 40 participants stratified into two groups based on their response to the diagnostic question: *"Hai mai ricevuto diagnosi di allergia o sensibilità al nichel tramite 'Patch Test'?"(*Have you ever received a diagnosis of nickel allergy or sensitivity through patch testing?). Participants responding affirmatively with documented patch test results (n=13) were classified as nickel-allergic, while those responding negatively (n=27) served as controls.

*Color-Based Concern Assessment:* Participants rated their concern (as allergy-related apprehension) toward foods of ten colors using a 5-point Likert scale. Colors were presented in random order.

*Color-Nickel Association:* Participants selected the color they most associated with high-nickel foods and rated agreement with the idea that food color indicates nickel content.

*Food-Related Anxiety and Avoidance*: Assessed frequency of anxiety when choosing foods based on appearance and whether participants had ever avoided food solely due to its color, despite knowing it was low in nickel.

*Vividness of Visual Imagery Food Version* (VVIQ-F): A 20-item questionnaire measured vividness of mental imagery across four domains (visual, olfactory, gustatory, multisensory) using a 5-point scale from the other similar scale like (Bortolotti et al., 2025b; Croijmans & Wang, 2022).

*Nickel Risk Assessment Protocol*
Participants viewed six standardized food images (three high-nickel, three low-nickel) (Figure. 1)

***Figure 1.***
*High-nickel foods: Dark chocolate (>200 µg/100g), Lentils (>100 µg/100g), Green peas (>50 µg/100g). Low-nickel foods:White rice (<10 µg/100g), Potatoes (<10 µg/100g), Carrots (<15 µg/100g)*

*Perceived nickel content*, Willingness to consume Trust in safety based on color (All on 7-point Likert scales)

*Food Attitudes and Behavior Scale:* A 6-item scale measured attitudes and behaviors related to: Food-related anxiety, Avoidance of unfamiliar foods, Perceived dietary control, Disgust toward unusual colors, Social/wellness limitations, Difficulty maintaining restrictive diets

**Results**
The final sample comprised 40 participants: 13 with patch-test confirmed nickel allergy, and 27 controls without nickel allergy. The two groups were comparable in terms of age, gender, and educational attainment, minimizing the risk of demographic confounding.
A clear pattern emerged showing heightened color-related concern among nickel-allergic participants. Subjects in the allergy group reported significantly higher concern scores for foods in warm color spectra specifically red, brown, and orange. For instance, the mean concern for red-colored foods was 2.92 in the allergic group versus 1.85 in controls ($p<0.001$, Cohen's $d=1.06$); brown scored 2.38 versus 1.44 ($p<0.01$, $d=0.99$); and orange 2.15 versus 1.33 ($p<0.05$, $d=0.93$). These differences were robust

and persisted after adjustment for demographic variables, while concern levels for "safe" colors (green, white, gray) showed no significant between-group differences (Figure. 2).

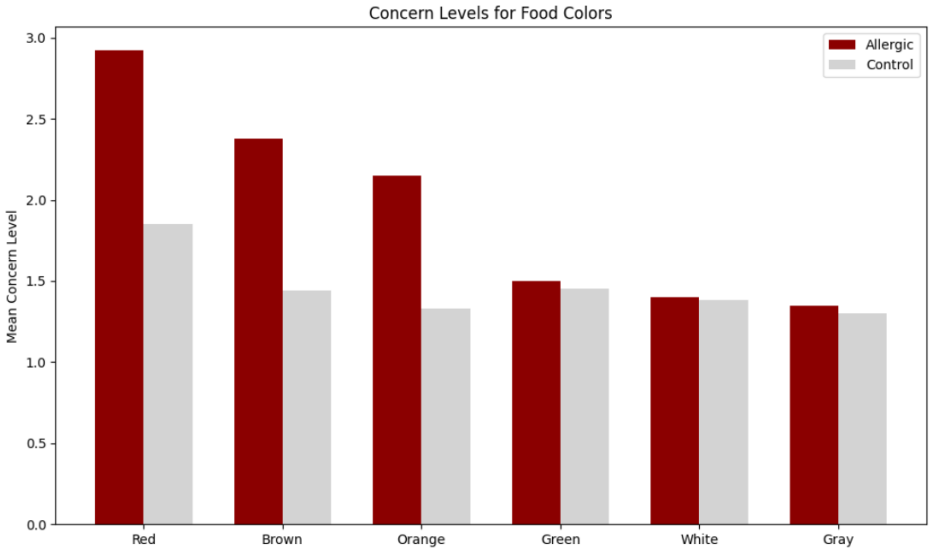


***Figure 2**: Bar chart presenting mean concern levels (1–5 scale) for all food color categories, comparing nickel-allergic participants (dark bars) to controls (light bars).*

Food-related anxiety and avoidance were also considerably more prevalent among allergic individuals. More than 84% of allergic participants frequently or very frequently avoided foods based solely on color, compared to less than 15% of controls. Similarly, 69% of allergic participants reported often or very often feeling anxious when selecting foods based on appearance, in stark contrast to 15% in the control group (Figure. 3).

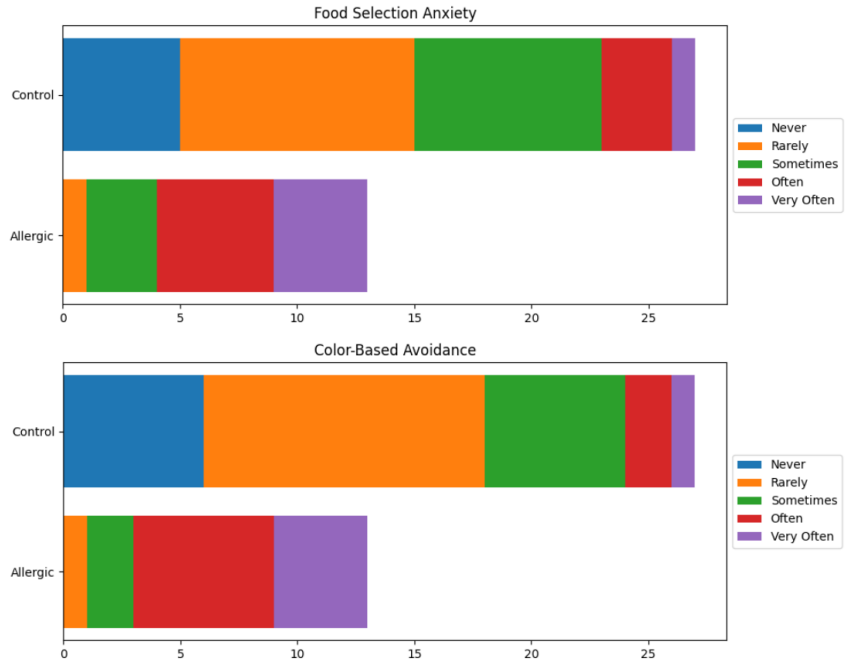


***Figure 3**: Stacked horizontal bar chart illustrating the distributions of food selection anxiety and color-based avoidance frequency in both groups. Different shades represent levels from "never" to "very often."*

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Mental imagery vividness for food-related scenarios was consistently higher among allergic participants, with moderate to large effect sizes. For example, vividness when visualizing chocolate, pizza, or fresh fruit was significantly greater in the allergy group (d range: 0.63–0.87), implying stronger and more emotionally charged food-related mental images (Figure. 4).


***Figure 4****: Radar (spider) chart comparing mean scores for imagery vividness across six food scenarios, with separate lines for allergic and control participants.*

Risk perception and trust in food safety information were also significantly impacted by allergy status. The allergic group expressed markedly higher general concern about food safety (mean=5.23 vs. 3.87, $p<0.001$, $d=1.15$) and perceived risk of contamination, coupled with lower trust in both food safety labeling and information (4.15 vs. 5.41, $p<0.01$, $d=-1.01$).

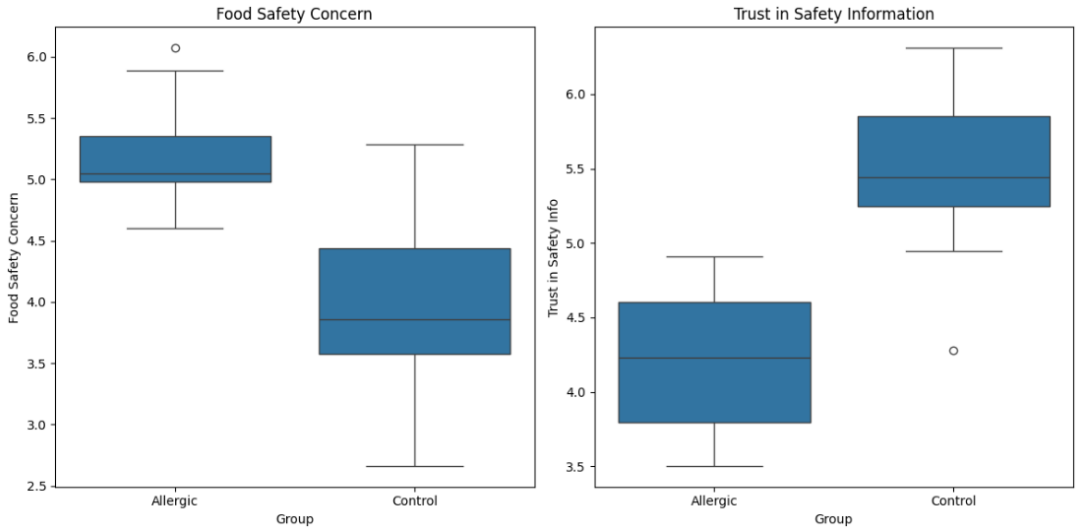


***Figure 5****: Box plots showing distributions of general food safety concerns (left) and trust in safety information (right) for both groups. The allergic group consistently displays wider dispersion and less trust.*

Within the allergic group, strong positive correlations were found among color concern, food selection anxiety, and avoidance behavior (r=0.54–0.74). Trust in external safety information was inversely correlated with these vigilance-related concerns (r=–0.67), indicating that low confidence in information increases reliance on subjective visual cues (Figure. 6).

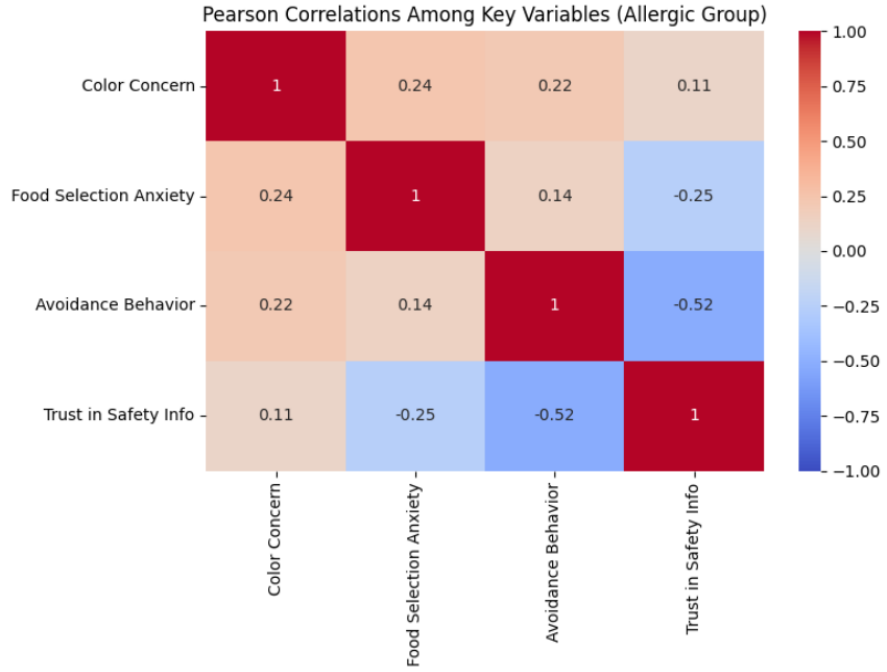


***Figure 6**: Heatmap displaying Pearson correlation coefficients among key variables in the allergic group. Strong associations are highlighted.*

Regarding specific foods, allergic participants discriminated accurately between high- and low-nickel foods but displayed overgeneralized vigilance for colors associated with higher nickel content. For low-nickel foods (such as rice, potatoes, carrots), there was no substantial difference between groups.

**Discussion**

The present study provides novel evidence that individuals with patch-test confirmed nickel allergy exhibit distinct alterations in visual food perception, particularly in relation to color. The findings support the hypothesis that immune sensitization may extend beyond dermatological manifestations to influence cognitive and perceptual domains. Specifically, allergic participants demonstrated significantly heightened concern for warm-colored foods (red, brown, orange), which are often associated with high-nickel content or perceived risk. This aligns with prior research on sensory vigilance and threat detection in allergic individuals, suggesting a generalized hypervigilance mechanism that may be visually mediated. Moreover, the elevated vividness of food-related mental imagery among allergic participants indicates a possible amplification of internal sensory representations, potentially contributing to stronger emotional responses and avoidance behaviors. These results are consistent with theories of cross-modal plasticity, where chronic immune activation may sensitize neural circuits involved in sensory integration and emotional regulation. The observed mistrust in food safety information further compounds this effect, leading to reliance on visual heuristics (e.g., color) as proxies for safety, even in the absence of objective risk.

The strong correlations between color concern, anxiety, and avoidance behaviors within the allergic group underscore the interconnectedness of perceptual, emotional, and behavioral responses. These

findings suggest that nickel allergy may function as a multisensory condition, with implications for dietary behavior, quality of life, and psychological well-being.

Several limitations must be acknowledged. First, the sample size was relatively small (n=40), which may limit the generalizability of the findings. Although statistical power was sufficient to detect medium-to-large effects, replication in larger and more diverse populations is warranted. Second, the study relied on self-reported measures, which may be subject to recall bias or social desirability effects. While the use of validated scales mitigates this concern, future studies could incorporate objective behavioral or physiological measures (e.g., eye-tracking, skin conductance).

Third, the cross-sectional design precludes causal inference. It remains unclear whether heightened visual sensitivity is a consequence of chronic allergy or a predisposing trait. Longitudinal studies are needed to disentangle these temporal dynamics. Finally, the study focused exclusively on nickel allergy; whether similar perceptual alterations occur in other forms of allergic contact dermatitis remains an open question.

**Conclusion**

This study demonstrates for the first time that patch-test confirmed nickel allergy is associated with substantial alteration in color-mediated food perception. Nickel-allergic individuals exhibit pronounced concern toward foods with warm color tones (notably red, brown, orange), paralleled by heightened anxiety and frequent avoidance behavior exclusively based on visual attributes, independent of actual nickel content. Enhanced vividness of food imagery and pervasive mistrust in food safety labelling further amplify these effects, suggesting a mechanism of generalized sensory vigilance driven by both immunological and neuropsychological processes.

These findings extend the clinical understanding of nickel allergy beyond cutaneous symptoms, highlighting substantial cognitive and behavioral implications. The marked avoidance and heightened risk perception may lead to unnecessary dietary restrictions and diminished quality of life, warranting the inclusion of psychological assessment and targeted counselling in allergy management. Trust in food safety information emerges as a potential intervention point to reduce unnecessary avoidance and anxiety. This work characterizes nickel allergy as a multisensory and multidimensional condition. It illustrates the complex interplay between immune activation, visual sensory processing, and psychological coping. Future longitudinal and neurophysiological studies are encouraged to further elucidate mechanisms and inform comprehensive therapeutic strategies.

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