Proceedings of ICADSS 2025 Symposium: Consciousness and Cognition in Language Acquisition and Literary Interpretation
DOI: 10.54254/2753-7064/2025.HT25744

The Influence of Language on Color Perception

Jingxuan Xu

Liberal Arts College, Shueyan University, Hong Kong, China
jingxuan200604@163.com

Abstract: Language serves as a basic tool for human cognition, and its impact on sensory perception has been a topic of interest in psychological research for a long time. So this paper explores the complex relationship between language and color perception from the perspective of psycholinguistics. This study aims to explore the influence of language on color perception, including verifying the neural mechanism of language shaping color cognition, analyzing the perceptual differences between cross-cultural and bilingual groups, so as to provide a basis for education, design and other fields, and finally reveal the active role of language in color perception. Through the classic theories (such as the Sapir-Whorf hypothesis) and literature analysis(including cross-linguistic color naming, color discrimination experiments, and neuroimaging research), this paper finds that it not only affects human color classification and memory, but it also interacts with cultural and individual factors to shape color perception.

Keywords: Color Perception, Linguistic Relativity, Categorical Perception, Cross-Cultural Cognition, Neuropsychology

1. Introduction

Color perception, as a basic sensory experience, is traditionally considered to be determined by physical properties of light and physiological structures of the eye. However, growing evidence suggests that language also plays an important role in this process. This paper systematically shows the psycholinguistic research on the interaction between language and color, and integrates evidence from multiple disciplines to comprehensively understand this complex phenomenon. However, the research landscape has gaps. European languages have been overemphasized, leaving other language families underexplored. The developmental journey of children acquiring color categories and forming associated perceptual biases is not fully charted. This paper addresses several fundamental questions: the extent to which language shapes color perception, the neural mechanisms underlying language-color interactions, and whether these effects vary across cultures and developmental stages. The significance of this paper extends to education, design and technology development. Understanding how language shapes color perception can help create better learning materials, improve product design for the global market, and develop more effective visual technologies.

DOI: 10.54254/2753-7064/2025.HT25744

2. Theoretical foundations of color perception

At the physiological level, Palmer pointed out that the human retina contains three types of cone cells sensitive to red, green, and blue light, which form the basis for color vision [1]. These visual signals are transmitted to the primary visual cortex (V1/V2) and the specialized color processing area (V4) through the lateral geniculate body to complete the neural decoding and integration of color information.

In terms of psychological model, International Commission on Illumination color space quantifies color features through three dimensions of hue, saturation and lightness, but it can not fully explain the differences in subjective perception. Dougherty et al. used this model to demonstrate the quantitative representation of color perception in the human mind [2]. The model provides a standardized framework for comparing color cognition across different languages and cultures, laying a foundation for studying the influence of language on color categorization and discrimination.

3. Linguistic relativity and color cognition

The Sapir-Whorf hypothesis proposes that language determines thought and that linguistic categories limit and determine cognitive categories. This perspective acknowledges that while all neurologically typical humans share the same physiological apparatus for color vision, including three types of retinal cone cells sensitive to short, medium, and long wavelengths, the linguistic categorization of colors can significantly influence perceptual processing. As this paper has mentioned before, Russian speakers show faster discrimination responses and more accurate memory for these hues compared to English speakers. Similarly, Himba speakers in Namibia, whose language groups green and blue under one term, but they make finer distinctions between shades of green. And they also show big differences in the color perception tasks. However, research supports a weaker version of linguistic relativity, where language influences but does not strictly determine perception. According to the debate of linguistic relativity in color perception, Berlin and Kay suggested that while languages vary in their number of basic color terms, there exists a universal hierarchy in color term development [3].

Building on these insights, modern interactionist theories propose a dynamic, bidirectional relationship between biological and linguistic factors in color perception. The human visual system provides the foundational hardware for color vision, however, language and culture act as sophisticated software that can tune this system. The most important thing is that these impacts are not absolute, but probabilistic. Although language affects color perception, it does not completely override sensory reality. This balanced view helps to explain the universality of human color vision and the fascinating changes observed between different languages and cultural groups.

4. Language and color categorization

4.1. Research on color discrimination and memory

Kay & Regier conducted a classic cross-linguistic study and found that although there are universal basic color terms across languages, such as black, white, red, and the number and boundaries of color categories vary significantly [4]. For example, the Himba people use a single term ("zoozu") to cover English speakers' blue, green, and purple. These suggest that language may guide speakers to categorize colors differently.

DOI: 10.54254/2753-7064/2025.HT25744

Roberson et al. in their study on the Himba people found that language affects color discrimination [5]. Speakers who have more precise color terms in their language show higher accuracy in color discrimination within their own language category, which reflects the "category perception" effect. It shows that language tags can enhance the discrimination of a specific color range. And this effect has been demonstrated across multiple languages and experimental paradigms. For instance, Greek speakers, who have distinct terms for light ("ghalazio") and dark ("ble") blue, show a category effect at the blue boundary that is absent in English speakers.

Category effect shows that language not only provides labels for pre-existing perceptual categories, it also actively shapes the perceptual organization of color space.

Research has also demonstrated that verbal labels influence color memory. The classic study by Heider showed that colors with readily available verbal labels (focal colors) are remembered more accurately than non-focal colors, even when the actual perceptual distance is controlled for [6]. They compared color memory between English and Dani speakers and found that English speakers, with richer color vocabulary, had better memory for color categories. This study shows that language tags provide cognitive anchor points, which improve the storage and retrieval efficiency of color information.

4.2. Research of neurobiological mechanism

Neuropsychological research has revealed that verbal coding of colors is primarily a left-hemisphere function. Through neuroimaging technology, Martin & Chao found that when processing color-related language, brain regions such as language-related left lower frontal gyrus, and visual cortex showed significant functional connectivity [7]. This shows that language and color perception share a neural basis, which provides a biological basis for their interaction. Studies of healthy participants show that when people remember colors, the left hemisphere has increased activation in language areas; Patients with left hemisphere damage often show disproportionate impairment in color memory tasks compared to those with right hemisphere damage. This highlights the close coupling between the language system and the perceptual system in color cognition.

At the same time, event-related potential (ERP) studies show the temporal dynamics of this interaction. Language-mediated effects on color discrimination emerge as early as 100-200ms post-stimulus (P1/N1 components), indicating rapid top-down modulation of sensory processing [8]. Subsequent components (P300 and N400) reflect categorical decision-making and semantic integration processes, respectively, demonstrating how linguistic categories influence multiple stages of perceptual analysis. These findings indicate that the influence of language on color perception is a whole process from early perceptual processing to late conceptual integration.

5. Factors influencing the effect of language on color perception

5.1. Cultural factors

5.1.1. Cultural differences in color symbolism

Besides basic color categories, cultural differences in color symbolism can influence perception and cognition. Eckhardt & Houston pointed out that color symbols vary across cultures [9]. For example, in China, the red color represents luck, but danger in Western cultures; in Western culture, white symbolizes purity, but in some Asian cultures, it represents mourning. These symbolic associations may affect people's attention, memory and evaluation of color. This memory advantage shows that

DOI: 10.54254/2753-7064/2025.HT25744

cultural meaning, like language labels, provides an additional cognitive framework for organizing color information.

5.1.2. Cultural specificity of language use frequency

The frequency of using color terms in daily communication may also affect color cognition. The color frequently mentioned in a language is often more significant in perception for the speaker of the language. This reflects the dynamic relationship between language input and perceptual experience.

Interestingly, the frequency effect seems to be domain specific. It means that frequent naming will especially enhance the perception of named dimensions (such as color), but it does not necessarily enhance the perception of other dimensions (such as shape or texture). This specificity shows that the influence of language experience is directional rather than universal.

5.2. Individual factors

5.2.1. Acquisition of color language and development of perception in children

The relationship between color perception and language has emerged in the early stages of children's development. With the improvement of language ability, children will establish corresponding color categories according to the color vocabulary in their mother tongue. This process is not a simple vocabulary memory, but involves the reconstruction of the perceptual system. Research shows that as children master more color words, their ability to identify and name colors gradually improves, which shows that the influence of language on color perception follows a developmental track.

5.2.2. The influence of bilingual proficiency on color perception

Bilinguals provide us with a unique window to observe the interaction between language and perception. Its color perception often presents the confrontation between two language systems: The first is to balance bilinguals (the proficiency of the two languages is equal). They often show a "compromise effect" in color classification tasks, and their color boundaries are often between the two language systems. For example, the delimitation of the "blue green" boundary line by Spanish English bilinguals will be obviously affected by the classification of "azul/verde" in Spanish.

The second is unbalanced bilinguals, who rely more on the classification model of dominant languages. However, when the proficiency of the second language reaches a certain threshold, even without using the language, its color category will continue to affect the perceptual judgment.

These individual differences suggest that we must consider variables such as development trajectory and multilingual experience when exploring the relationship between language and cognition.

6. Conclusion

This paper reviews the influence of language on color perception from multiple perspectives, including theoretical framework, empirical evidence and regulatory factors. It can be concluded that language does affect human color cognition through color classification, discrimination and memory. The Sapir-Whorf hypothesis provides an important starting point for understanding this relationship, while interaction theory offers a more comprehensive framework by integrating biological and cultural factors. However, there is still room for improvement in this area. For

DOI: 10.54254/2753-7064/2025.HT25744

example, most existing studies focus on the static language effect, while the dynamic process of language affecting color perception has not been fully explored. In addition, the neural mechanism behind this relationship needs more accurate mapping. Future research can focus on the longitudinal study of the development of color perception and use advanced imaging technology to explore the neural mechanism. At the same time, future research can further focus on the color perception patterns of special groups (such as color blindness patients and early sign language users) to deepen the understanding of linguistic relativity. It will help to clarify the universality and particularity of the influence of language on color perception.

References

[1] Palmer, S. E. (1999). Color, consciousness, and the isomorphism constraint. Behavioral and Brain Sciences, 22(6), 923-943.
[2] Dougherty, R. F., Koch, V. M., Brewer, A. A., Fischer, B., Modersitzki, J., & Wandell, B. A. (2003). Visual field representations and locations of visual areas V1/2/3 in human visual cortex. Journal of vision, 3(10), 1-1.
[3] Berlin, B., & Kay, P. (1991). Basic color terms: Their universality and evolution. Univ of California Press.
[4] Kay, P., & Regier, T. (2003). Resolving the question of color naming universals. Proceedings of the National Academy of Sciences, 100(15), 9085-9089.
[5] Roberson, D., Davies, I., & Davidoff, J. (2000). Color categories are not universal: replications and new evidence from a stone-age culture. Journal of experimental psychology: General, 129(3), 369.
[6] Heider, E. R., & Olivier, D. C. (1972). The structure of the color space in naming and memory for two languages. Cognitive psychology, 3(2), 337-354.
[7] Martin, A., & Chao, L. L. (2001). Semantic memory and the brain: structure and processes. Current opinion in neurobiology, 11(2), 194-201.
[8] Mo, L., Xu, G., Kay, P., & Tan, L. H. (2011). Electrophysiological evidence for the left-lateralized effect of language on preattentive categorical perception of color. Proceedings of the National Academy of Sciences, 108(34), 14026-14030.
[9] Eckhardt, G. M., & Houston, M. J. (2002). Cultural paradoxes reflected in brand meaning: McDonald's in Shanghai, China. Journal of International Marketing, 10(2), 68-82.