Language and Culture Influence Color Cognition: Direct Language Effect or Indirect Language Effect?

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Date: 2018-12-23T00:00:00+00:00

Abstract

Debates on the influence of language and culture on color cognition center on direct language effects and indirect language effects. Direct language effect refers to the process where individuals first convert colors into color names during color encoding, and then complete recognition tasks by matching the retained color terms in memory with target color names. Color categorical perception is a result of linguistic strategies. Indirect language effect refers to language and culture shaping color perceptual representations, forming a warped color perceptual space that directs individuals toward language- and culture-defined boundaries of color categories. Even without the involvement of linguistic strategies, categorical effects still emerge. Color culture constitutes an important component of ethnic culture. Green and red hold significant meaning in the language and culture of the Uyghur and Han ethnic groups respectively. Using color similarity judgment, color categorization, and color recognition tasks, this study investigated the cognition of red and green among Uyghur and Han university students, exploring the influence and nature of language and culture on color cognition. Results showed that, compared with the Han group, the Uyghur group exhibited response advantages in green discrimination, categorization, and recognition, but response disadvantages in red cognition. Compared with color discrimination responses, both ethnic groups showed significantly longer response times in color recognition. The overall study demonstrates that the influence of language and culture on color cognition involves indirect language effects, with language and culture shaping individuals' color perceptual space.

Full Text

Language and Culture Influence Color Cognition: Direct or Indirect Language Effects?

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Abstract

The influence of language and culture on color cognition has been debated in terms of direct versus indirect language effects. Direct language effects posit that during color encoding, individuals first convert colors into color terms, and recognition is accomplished by matching retained color names in memory with target color names—the color category perception effect is thus a product of linguistic strategy. Indirect language effects propose that language and culture shape color perceptual representations, creating a distorted color perceptual space that guides individuals toward language- and culture-defined color category boundaries. Category effects emerge even without linguistic strategy involvement. Color culture constitutes an important component of ethnic culture. Green and red hold significant meaning in the languages and cultures of the Uyghur and Han peoples, respectively. Using color similarity judgment, color classification, and color recognition tasks, this study investigated color cognition of red and green among Uyghur and Han university students to examine the influence and nature of language and culture on color cognition. Results showed that compared with Han participants, Uyghur participants demonstrated a response advantage in discriminating, classifying, and recognizing green, but a response disadvantage in red cognition. Both groups showed significantly longer recognition response times compared with discrimination responses. The overall findings indicate that language and culture influence color cognition through indirect language effects, with language and culture shaping individuals' color perceptual spaces.

Keywords: Uyghur; Han; color cognition; direct language effect; indirect language effect

The relationship between language and cognition is highly complex. In the domain of color cognition, how do color terms relate to color perception? This question has generated debate between linguistic universalism and linguistic relativity. Linguistic universalism holds that human thought possesses universality and consistency, with thought preceding language. Color terms, as linguistic encodings of color, have universal semantic features and cognitive significance, and color terms and color cognition are independent of each other [?, ?]. Linguistic relativity argues that culture influences thought through language, with linguistic differences leading to cognitive differences. Different languages contain varying numbers of basic color terms, segment the continuous spectrum differently, and create different empirical classifications of color, resulting in differences in color cognition. To incorporate the strengths of both theories, an eclectic theory has emerged, proposing that color cognition includes both physical/physiological and cultural components, representing both biological and cultural events [?, ?]. Zhang Jijia, Fang Yanhong, and Xie Shushu (2012) proposed an interaction theory of color terms and color cognition, suggesting that factors influencing color cognition include physics, physiology, cognition, intelligence, language, and culture, operating at physical-physiological, cognitive-intellectual, and socio-cultural levels. The physical-physiological level provides the material foundation for color cognition, with the physical properties of color and the physiological structure of the human eye creating consistency in human color perception. Perceptual and memory processes and intelligence are key to color cognition, while language and culture are prerequisites for understanding color meaning. Different cognitive processes, intelligence levels, and linguistic and cultural factors can all cause differences in color cognition. When sensory and intellectual functions are normal, differences in color cognition are typically determined by language and culture.

Numerous studies have provided evidence for the influence of language and culture on color cognition, primarily through comparisons of color cognition among speakers of different languages and members of different ethnic groups. Color perception exhibits characteristics of categorical perception. When perceiving colors, individuals segment and categorize continuous spectra and name them using focal colors [?, ?]. Individuals show better perception and memory for colors from different categories than for those from the same category, even when their physical distance in the Munsell color system is identical. This phenomenon is known as the color category perception effect [?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?, ?]. Bornstein et al. (1976) selected yellow and blue (different categories) and dark green and light green (same category). Although the chromatic distance between yellow and blue was equal to that between dark green and light green, participants discriminated yellow and blue faster than they discriminated the two greens. However, due to the influence of language and culture, color category perception effects show different results. Kay and Kempton (1984) asked English speakers and Tarahumara speakers (an indigenous language) to make similarity judgments on colors at the blue-green boundary, determining whether target colors were more similar to blue or green. English has distinct terms for blue and green (blue and green), whereas Tarahumara uses a single color term for both blue and green. English speakers showed a clear color category perception effect for blue-green boundary colors, while Tarahumara speakers did not.

Davies, Corbett, Laws, McGurk, Moss, and Smith (1991) asked English, Russian, and Setswana speakers to classify colors. Setswana uses one word for both blue and green, English uses two words, and Russian not only distinguishes blue from green but also differentiates dark blue from light blue. Setswana speakers tended to group blue and green together, Russian speakers tended to separate dark blue from light blue, and Russian speakers showed greater Stroop interference for blue than English speakers, indicating greater discriminability for blue. Winawer et al. (2007) found that Russian speakers discriminated dark blue from light blue faster, showing a color category perception effect, while English speakers did not. Zhang Jijia, Liu Lihong, Chen Xi, and He Xiumei (2008) compared color similarity judgment, color classification, and color recognition between Naxi and Han participants. Although Naxi uses two words for blue and green, they are used interchangeably in practice, whereas Chinese makes a clear distinction. Naxi participants performed worse than Han participants on all three tasks. Zhang Jijia et al. used natural classification methods to study the conceptual structures of basic color terms among Han [?, ?], Yi, Bai, and Naxi [?, ?, ?, ?], Mosuo [?, ?, ?, ?], Lisu and Pumi [?, ?, ?, ?, ?], Mongolian [?, ?, ?, ?, ?], Oroqen [?, ?], and Japanese [?, ?, ?, ?, ?, ?] populations. They found that different ethnic groups showed both commonalities and differences in classifying basic color terms, with differences primarily caused by culture and language. Ethnic-specific color concepts influence the organization of color concepts in individuals' minds [?, ?]. Thus, numerous studies have demonstrated that language and culture influence color cognition.

However, how do language and culture influence color cognition? Is the influence of language and culture on color cognition a direct language effect or an indirect language effect? These questions have not been adequately addressed. Proponents of direct language effects argue that individuals adopt linguistic strategies when encoding colors, first converting colors into color terms and then matching retained color names in memory with target color names during recognition. Language only temporarily influences color memory without fundamentally altering color perception; language serves merely as a recognition strategy [?, ?, ?, ?, ?, ?, ?, ?]. Proponents of indirect language effects argue that color perceptual representations are formed through language learning, with language and culture shaping the color perceptual space. Due to language's influence, discrimination near category boundaries improves relative to within-category discrimination, creating a "distortion" in color perceptual space that causes color perception to be bounded by linguistic categories. Even without linguistic strategy involvement, color category perception effects still emerge. In short, direct language effects refer to the immediate influence of language on color cognition, while indirect language effects refer to persistent changes in color space resulting from language and cultural influence, occurring before the experiment. Since most previous studies used color stimuli that were largely nameable and tasks that involved memory components, it was difficult to escape the influence of linguistic strategies, making it impossible to distinguish between direct and indirect language effects.

Currently, only a few studies have attempted to differentiate direct and indirect language effects. Özgen and Davies (2003) found that color category perception still emerged when target and distractor stimuli were presented simultaneously. In this case, there was no memory demand, and although stimuli were nameable, direct visual comparison seemed more likely. In visual search, color category perception effects were also found: target detection was much faster when target and distractor stimuli belonged to different categories than when they belonged to the same category. Because target stimuli appeared too quickly to be named, the effect should occur at the pre-attentive stage of early vision [?, ?, ?, ?, ?, ?, ?, ?]. Özgen and Davies (2003) conducted a series of color perception experiments. Experiment 1 used a color similarity judgment task in which participants learned blue or green categories over three days, finding that color discrimination performance gradually improved and showed transfer effects to the other color, indicating that color discrimination ability can be improved through practice or training. Subsequently, three experiments tested whether newly formed color categories also showed category perception effects, the time course of category perception formation, and whether category perception effects were based on hue or brightness classification. Using focal colors of blue and green as boundary points, the researchers divided blue and green into two color categories each: one category closer to yellow-green (or blue-purple) and another closer to the blue-green boundary. Colors were presented randomly, and participants were required to master the classification criteria based on feedback after each similarity judgment. Color category perception effects were still found, indicating that participants could "abandon" existing color classification standards and acquire new ones. Since the color stimuli used were difficult to name, the influence of linguistic strategies was largely eliminated, supporting the indirect language effect view. However, the study involved transfer between two colors, making it difficult to exclude interference between colors.

Pilling and Davies (2004) compared English speakers and Ndonga speakers in color classification, color comparison, and color visual search tasks. Ndonga lacks terms for orange, pink, and purple. Results showed that in classification, colors with similar names were more likely to be grouped together than those with dissimilar names. In color comparison (selecting the different color among three), when the different color was not lexicalized in both languages, participants chose the color that was isolated in their language. In visual search (searching for a target color among distractors), the target color was either among distractors from different categories (between-category) or from the same category (within-category). Results showed that British participants paid a greater cost in reaction speed than Ndonga participants when within-category distractors were present. Winawer et al. (2007) asked English and Russian speakers to discriminate blues of different lightness while performing linguistic interference tasks and spatial interference tasks. They found that Russian speakers showed a color classification advantage when discriminating colors belonging to different linguistic categories in Russian. This classification advantage was disrupted by linguistic tasks but not by spatial tasks or combined linguistic-spatial tasks. For more difficult discriminations, linguistic interference effects were greater, while

English speakers showed no effects. Since the study used blues with minimal memory components, it provided evidence for indirect language effects. However, the study focused primarily on color similarity judgment with a single task and varied the lightness of blues. Although each blue was difficult to name, it could not be ruled out that Russian participants used linguistic strategies based on pragmatic labels, dividing blues into "dark blue" and "light blue."

Xie Shushu, Zhang Jijia, He Xiumei, Lin Na, and Xiao Erping (2008) used color similarity judgment and color recognition tasks with black and white color blocks that varied only in lightness while maintaining constant hue and saturation. They examined differences in black and white cognition among Yi, Bai, Naxi, and Han university students, finding that the four ethnic groups differed in discrimination and recognition speed for black and white blocks, matching their respective black and white cultures: the Yi people favor black and dislike white, the Bai favor white and dislike black, the Naxi favor white but do not dislike black, and the Han hold contradictory attitudes toward black and white. Since the black and white blocks only varied in lightness and could not be named, direct language effects were largely eliminated, providing evidence for indirect language effects. Differences among the four groups were larger in recognition tasks than in perceptual similarity judgment tasks, suggesting that participants might have used linguistic strategies during recognition—that is, direct language effects existed. Therefore, they argued that the influence of language and culture on color perception involves both indirect and direct effects.

The relationship between color terms and color cognition has been extensively documented. Modern researchers tend to accept the interaction view of color terms and color cognition [**?**, **?**]. However, whether the influence of language and culture on color cognition reflects memory strategies or changes in perceptual space remains debated. Previous studies have struggled to escape the influence of linguistic labels or memory strategies, making it difficult to separate direct and indirect language effects. Zhang Jijia et al. (2008) attempted to address the direct versus indirect language effect question through black and white cognition, but their study only used color similarity judgment and color recognition tasks, and black and white are not strictly chromatic colors. In summary, further research on this issue is necessary, as it concerns the fundamental nature of how language influences color cognition.

Color preference is a direct manifestation of ethnic culture. An ethnic group' s color culture is directly connected to its production and lifestyle, natural worldview, religious views, folk consciousness, and aesthetic concepts. The Uyghur people have a special affection for green, viewing it as a symbol of life. Uyghur culture is typical oasis culture with strong characteristics of grassland nomadic culture. Uyghur ancestors lived on grasslands, where grass, trees, forests, and lakes were all green, leading to a "totemic" worship of green [**?**, **?**]. The *Qur' an* considers green "the soil of humanity and the source of nature." Islam views green as symbolizing peace and tranquility. Green is extensively used in religious architecture such as mosques, arches, and mazars [**?**, **?**]. The Islamic flag is also green. Uyghur clothing embodies oasis culture; for example, embroidered caps in Turpan, Hami, and Kashgar use dark green as the base color. Uyghur residential architecture also reflects oasis culture [?, ?]. These dwellings adapt to the natural environment of different regions in Xinjiang and share common features: courtyard layouts highlight a desire for plants and greenery, while roofs and wall backgrounds are primarily blue or green, decorated with patterns of lakes, rivers, and various plants. Walls feature colorful tapestries with floral and plant motifs. Thus, the love for green is a cultural unconscious accumulated over thousands of years in Uyghur culture, representing a unique cultural connotation that distinguishes them from other ethnic groups.

Although the Han people also like green, using it to symbolize spring, youth, peace, freshness, environmental protection, hope, and safety, green in Chinese culture carries connotations of "low status" and "inferiority." The Tang Dynasty official system stipulated that sixth-rank officials wore dark green, seventh-rank officials wore light green, eighth-rank officials wore dark cyan, and ninth-rank officials wore light cyan. Wearing a green headscarf was a symbol of lowliness. During the Yuan, Ming, and Qing dynasties, people in "despised professions" such as prostitutes and musicians generally wore cyan and green clothing. In the Yuan and Ming dynasties, men from prostitute families were required to wear green headscarves, which later evolved into the expression "wearing a green hat" to mean a man' s wife is having an affair [?, ?]. This is completely different from Uyghur cognition of green.

Han working women typically wear black clothing, but brides must wear bright red wedding dresses. Compared with green, the Han people have a stronger preference for red. In Chinese culture, red symbolizes power and status, smoothness and success, respect and popularity, and bravery, perseverance, and sincerity. The positive semantic range of "red" in Chinese is broader than that of red in Uyghur, where the cultural representation of red is more limited to its original visual sensation [?, ?].

Given the different cultural backgrounds of Uyghur and Han preferences for green and red, this study compares whether Uyghur and Han cognition of green and red differs. By using different tasks to separate factors influencing color cognition, we examine whether language and culture affect cognition through indirect language effects. In perceptual similarity judgment, individuals only need to compare simultaneously presented perceptual information with minimal conceptual involvement. Classification and recognition tasks present target and comparison color blocks sequentially, requiring participants to remember one or two target color blocks before classifying or recognizing one or two color blocks. If Uyghur and Han participants show cognitive differences for green and red across perceptual similarity judgment, classification, and recognition tasks, this would demonstrate that language and culture indeed influence color cognition. By strictly controlling the nameability of colors, the possibility of participants using linguistic strategies can be excluded.

Experiment 1: Similarity Judgment of Red and Green Color Blocks by Uyghur and Han University Students

Participants

Thirty-one Uyghur undergraduate students from Xinjiang Normal University (7 male, 24 female; mean age = 21.36 years) participated. Their native language was Uyghur, and they were proficient in Chinese, able to communicate and read fluently in Chinese. Thirty-one Han undergraduate students (6 male, 25 female; mean age = 20.74 years) from the same university also participated. All were local to Xinjiang, native Chinese speakers, and did not speak Uyghur. All participants had normal or corrected-to-normal vision and no color blindness or weakness.

Design

A 2 (ethnicity: Uyghur/Han) × 2 (color: green/red) mixed design was used, with ethnicity as a between-subjects variable and color as a within-subjects variable. The dependent variables were response time and error rate for similarity judgments of red and green color blocks.

Materials

Using green (RGB: 0, 255, 0) and red (RGB: 255, 0, 0) as central points, vertical demarcation lines were drawn on the RGB chromatogram, dividing red and green into left and right color groups. At lightness-saturation levels of 240–120, nine adjacent color blocks were selected from each side of the demarcation line (18 each for red and green). According to the CIE1976Lab* color system [?, ?, ?, ?], color block chromaticity was based on central color chromaticity (a_green = 80, a_red = 0), varying with a progression coefficient of 2. Pre-experiment evaluation confirmed that all blocks belonged to red or green categories. Left green block chromaticities were 78, 76, 74, 72, 70, 68, 66, 64, 62; right green block chromaticities were 82, 84, 86, 88, 90, 92, 94, 96, 98; left red block chromaticities were 238, 236, 234, 232, 230, 228, 226, 224, 222; right red block chromaticities were 2, 4, 6, 8, 10, 12, 14, 16, 18. The fifth block in each group served as the standard color. Color blocks were 127 × 86 pixels. Using the block combination "green-left 6–green-left 5–green-right 1" as an example: green-left and green-right indicate the region names, 1 represents colors near the central green, and 6 represents colors far from central green. Green-left 5 is the standard color for the left green region. The distance between green-left 1 and the green-left standard color equals the distance between the green-right standard color and green-right 1. Through balanced combinations of red and green blocks, 256 color block combinations were created. Each combination contained one standard block, one same-side block, and one opposite-side block, with the distance between the standard block and the same-side block being smaller than that between the standard block and the opposite-side block. To provide visual rest, filler combinations primarily featuring black-white-gray were created using the same method.

Procedure

The experiment was programmed using E-prime 2.0 software and presented on a 17-inch IBM monitor with a resolution of 1024 × 768 pixels. The experiment was divided into red and green sections, each including practice and formal experimental phases. Participants sat in front of the computer with their index fingers on the F and J keys. Three color blocks were presented simultaneously on the screen, with the standard block at the top and two comparison blocks below. Participants were required to judge as quickly and accurately as possible which lower block was more similar to the upper standard block, pressing F for the left block and J for the right block. Each comparison block appeared equally often on the left and right sides. If no response was made within 3000 ms, a blank screen appeared for 1000 ms before the next trial began. The experimental flow is shown in Figure 1 [Figure 1: see original paper]. Materials were presented randomly. Participants completed eight practice trials using non-experimental materials before the formal experiment.

Results and Analysis

For response time analysis, data from incorrect responses were first deleted, followed by data below 300 ms, above 2500 ms, and beyond M ± 2.5 SD, accounting for 3.13% of trials. Results are shown in Figures 2 [Figure 2: see original paper] and 3 [Figure 3: see original paper].

ANOVA on response times revealed only a significant interaction between ethnicity and color, $F(1, 60) = 23.26$, $p < 0.001$, $^2 = 0.28$. Simple effects analysis showed that Uyghur participants judged green significantly faster than Han participants, $p < 0.05$, $d = 0.52$, 95% CI = [-144.31, -2.20]; Uyghur participants judged red significantly slower than Han participants, $p < 0.05$, $d = 0.56$, 95% CI = [7.99, 179.50]. Uyghur participants judged green significantly faster than red, $p < 0.01$, $d = 0.70$, 95% CI = [-126.67, -39.65]; Han participants judged red significantly faster than green, $p < 0.001$, $d = 0.87$, 95% CI = [43.93, 123.75]. No main effects were significant, $ps > 0.05$.

ANOVA on error rates showed a significant main effect of color, $F(1, 60) = 264.62$, $p < 0.001$, $^2 = 0.82$, 95% CI = [0.13, 0.16], and a significant interaction between color and ethnicity, $F(1, 60) = 5.36$, $p < 0.05$, $^2 = 0.08$. Simple effects analysis indicated no significant difference between the two groups in error rates for green judgments, $p > 0.05$, but a significant difference for red judgments, $p < 0.05$, $d = 0.87$, 95% CI = [0.01, 0.09], with Han participants showing significantly lower error rates than Uyghur participants.

Experiment 1 demonstrated significant differences between Uyghur and Han students in perceptual similarity judgments of green and red: Han participants judged red faster and more accurately than green, while Uyghur participants judged green faster than red. These findings indicate that linguistic and cultural differences affect discrimination of green and red between the two ethnic groups.

Experiment 2: Classification of Red and Green Color Blocks by Uyghur and Han University Students

In classification tasks, if participants change their responses to a color as classification trials increase, this demonstrates that individuals can learn new color categories through experience, meaning learning can alter color perceptual space and that color cognition is not genetically fixed or immutable. If participants do not change their responses to a color, this indicates stable classification criteria unaffected by classification labels, suggesting that classification is based on existing color perceptual space without using linguistic strategies. The influence of language and culture on color cognition occurs before the cognitive task.

Participants

Thirty-three Uyghur undergraduate students from Xinjiang Normal University (14 male, 19 female; mean age = 21.45 years) participated. Their native language was Uyghur, and they were proficient in Chinese. Thirty-three Han undergraduate students (12 male, 21 female; mean age = 20.75 years) from Xinjiang, native Chinese speakers who did not speak Uyghur, also participated. All had normal or corrected-to-normal vision and no color blindness or weakness. None had participated in Experiment 1.

Design

A 2 (ethnicity: Uyghur/Han) $\times$ 2 (color: green/red) mixed design was used, with ethnicity as a between-subjects variable and color as a within-subjects variable. Dependent variables were response time and error rate for classifying red and green color blocks.

Materials and Procedure

Materials and apparatus were identical to Experiment 1. The green and red spectral regions were each divided into two color categories using the focal color as the boundary. The instructions were: "Please learn to divide a series of stimuli into two groups, left and right." Participants were first shown the standard color blocks for the left and right groups of the same color: green-left 5 and green-right 5 for green, red-left 5 and red-right 5 for red. After memorizing these, participants pressed the space bar, the two standard blocks disappeared and did not reappear. Following a 1000 ms blank screen, a series of target color blocks appeared randomly in the center of the screen. Participants judged whether each target block belonged to the "left" or "right" group, pressing F or J with their left or right index fingers. After each response, the computer provided accuracy feedback before presenting the next target block. Materials were presented in a pseudo-random sequence ensuring that the same block did not appear consecutively. Each block was repeated four times. The experiment was divided into green and red sections, with participants making 128 responses for each color. The experimental flow is shown in Figure 4 [Figure 4: see original paper].

Results and Analysis

For response time analysis, data from incorrect responses were first deleted, followed by data below 300 ms, above 2500 ms, and beyond M $\pm$ 2.5 SD, accounting for 4.73% of trials. Results are shown in Figures 5 [Figure 5: see original paper] and 6 [Figure 6: see original paper].

ANOVA on response times revealed a significant main effect of color, $F(1, 60) = 48.25$, $p < 0.001$, $^2 = 0.45$, 95% CI = [21.35, 59.31], and a significant interaction between ethnicity and color, $F(1, 60) = 102.90$, $p < 0.001$, $^2 = 0.63$. Simple effects analysis showed that Uyghur participants classified green significantly faster than Han participants, $p < 0.05$, $d = 0.87$, 95% CI = [-121.23, -9.98]; Uyghur participants classified red significantly slower than Han participants, $p < 0.05$, $d = 0.17$, 95% CI = [3.34, 101.06]. Uyghur participants classified green significantly faster than red, $p < 0.001$, $d = 0.78$, 95% CI = [-24.61, -12.53]; Han participants classified red significantly faster than green, $p < 0.001$, $d = 0.87$, 95% CI = [76.30, 122.17].

ANOVA on error rates revealed a significant main effect of color, $F(1, 60) = 50.56$, $p < 0.001$, $^2 = 0.46$, 95% CI = [0.07, 0.14], and a significant interaction between ethnicity and color, $F(1, 60) = 19.66$, $p < 0.001$, $^2 = 0.25$. Simple effects analysis showed that Uyghur participants had significantly lower error rates for green classification than Han participants, $p < 0.01$, $d = 0.79$, 95% CI = [-0.14, -0.03]; Uyghur participants had significantly higher error rates for red classification than Han participants, $p < 0.05$, $d = 0.87$, 95% CI = [0.004, 0.08]. The difference in error rates between red and green classification was not significant for Uyghur participants, $p > 0.05$, but Han participants had significantly higher error rates for green than for red classification, $p < 0.001$, $d = 0.14$, 95% CI = [0.13, 0.21].

Mean response times for repeated classification of red and green blocks are shown in Figure 7 [Figure 7: see original paper]. One-way ANOVA showed that for Uyghur participants, F for green(3, 120) = 0.10, $p > 0.05$, and F for red(3, 120) = 0.77, $p > 0.05$; for Han participants, F for green(3, 120) = 0.25, $p > 0.05$, and F for red(3, 120) = 0.20, $p > 0.05$. Neither Uyghur nor Han participants showed repetition effects for red or green blocks.

Experiment 2 showed that compared with green, Uyghur participants classified red significantly slower; Han participants classified red significantly faster with lower error rates. Compared with Han participants, Uyghur participants classified green significantly faster with lower error rates; compared with Uyghur participants, Han participants classified red significantly faster with lower error rates. Moreover, after four classification repetitions, participants' response speeds did not significantly improve, indicating that no new color labels were formed during the experiment and that classification was based on existing color perceptual space.

Experiment 3: Recognition of Red and Green Color Blocks by Uyghur and Han University Students

Participants

Thirty-one Uyghur undergraduate students from Xinjiang Normal University (15 male, 16 female; mean age = 21.68 years) and 31 Han undergraduate students (13 male, 18 female; mean age = 21.12 years) participated. All Uyghur participants were native Uyghur speakers proficient in Chinese; all Han participants were native Chinese speakers from Xinjiang who did not speak Uyghur. All had normal or corrected-to-normal vision and no color blindness. None had participated in Experiments 1 or 2.

Design and Materials

A 2 (ethnicity: Uyghur/Han) × 2 (color: green/red) mixed design was used, with ethnicity as a between-subjects variable and color as a within-subjects variable. Dependent variables were response time and error rate for recognizing red and green colors.

Some color blocks from Experiment 1 were selected as experimental materials. Ten blocks each for red and green were chosen, including two standard blocks and two adjacent blocks on each side of the standard.

Procedure

A standard color block was first presented in the center of the screen for 5 s before disappearing. Then two two-digit or three-digit addition problems appeared as distractor tasks. After completing these, participants pressed the space bar (maximum response time = 10 s). Two comparison color blocks then appeared, and participants judged as quickly and accurately as possible which block had appeared previously: press F for the left block or J for the right block. In each trial, the standard block was the same as those used in Experiments 1 and 2, and comparison blocks were adjacent to the standard block. Each block appeared equally often on the left and right. Participants made 32 responses each for red and green. Materials were presented randomly. The experimental procedure is shown in Figure 8 [Figure 8: see original paper]. Participants completed eight practice trials using non-experimental materials before the formal experiment.

Results and Analysis

For response time analysis, data from incorrect responses were first deleted, followed by data below 300 ms, above 2500 ms, and beyond M ± 2.5 SD, accounting for 4.41% of trials. Results are shown in Figures 9 [Figure 9: see original paper] and 10 [Figure 10: see original paper].

ANOVA on response times revealed no significant main effect of ethnicity, $F(1, 60) = 0.14$, $p > 0.05$; a significant main effect of color, $F(1, 60) = 6.77$, $p = 0.012$, $^2 = 0.11$, 95% CI = [4.06, 116.35]; and a significant interaction between ethnicity and color, $F(1, 60) = 58.74$, $p < 0.001$, $^2 = 0.50$. Simple effects analysis showed that Uyghur participants recognized green significantly faster than Han participants, $p < 0.01$, $d = 0.85$, 95% CI = [-243.72, -58.86]; Uyghur participants recognized red significantly slower than Han participants, $p < 0.001$, $d = 0.08$, 95% CI = [97.07, 261.96]. Uyghur participants recognized green significantly faster than red, $p < 0.01$, $d = 0.55$, 95% CI = [-182.46, -36.05]; Han participants recognized red significantly faster than green, $p < 0.001$, $d = 0.44$, 95% CI = [172.44, 270.66].

ANOVA on error rates revealed a significant main effect of ethnicity, $F(1, 60) = 23.53$, $p < 0.001$, $^2 = 0.28$, 95% CI = [0.04, 0.10], with Uyghur participants showing significantly higher error rates than Han participants; a significant main effect of color, $F(1, 60) = 19.88$, $p < 0.001$, $^2 = 0.25$, 95% CI = [0.02, 0.06], with both groups showing higher error rates for green than for red recognition; and a significant interaction between ethnicity and color, $F(1, 60) = 8.14$, $p < 0.01$, $^2 = 0.12$. Simple effects analysis showed that Uyghur participants had significantly higher error rates for green recognition than Han participants, $p < 0.01$, $d = 0.68$, 95% CI = [0.02, 0.16], with a difference of 9.09%; Uyghur participants also had significantly higher error rates for red recognition than Han participants, $p < 0.001$, $d = 0.05$, 95% CI = [0.12, 0.27], with a difference of 19.43%. The difference between red and green recognition error rates was not significant for Uyghur participants, $p > 0.05$, but Han participants had significantly higher error rates for green than for red recognition, $p < 0.001$, $d = 0.96$, 95% CI = [0.08, 0.18].

Experiment 3 showed that Uyghur participants recognized green more easily than red, as evidenced by shorter response times; Han participants recognized red more easily than green, as evidenced by shorter response times and lower error rates. Uyghur participants recognized green significantly faster than Han participants, while Han participants recognized red significantly faster than Uyghur participants with lower error rates. These results indicate that different languages and cultures influence color recognition.

Post-Hoc Analysis Across Three Experiments

To examine task effects on red-green color cognition, a 2 (ethnicity: Uyghur/Han) × 2 (color: red/green) × 3 (experimental task: perceptual similarity judgment/color classification/color recognition) ANOVA was conducted. Experimental task and ethnicity were between-subjects variables; color was a within-subjects variable.

ANOVA on response times revealed no significant main effect of ethnicity, $F(1,$

180) = 0.54, $p > 0.05$; a significant main effect of color, $F(1, 180) = 24.03$, $p < 0.001$, $^2 = 0.12$; a significant main effect of experimental task, $F(2, 180) = 110.56$, $p < 0.001$, $^2 = 0.55$, with classification showing the shortest response times, similarity judgment intermediate, and recognition the longest; and a significant interaction between ethnicity and color, $F(1, 180) = 115.82$, $p < 0.001$, $^2 = 0.39$. Simple effects analysis showed that Uyghur participants were significantly faster than Han participants in perceptual similarity judgment, classification, and recognition of green, while Han participants were significantly faster than Uyghur participants in all three tasks for red. The interaction between color and experimental task was significant, $F(2, 180) = 3.98$, $p < 0.05$, $^2 = 0.04$. The three-way interaction between ethnicity, color, and experimental task was significant, $F(1, 180) = 10.74$, $p < 0.001$, $^2 = 0.11$. This primarily manifested as both Uyghur and Han participants showing shortest response times in classification, with Uyghur participants showing a smaller difference between red and green classification (only 19 ms) but larger differences in similarity judgment (83 ms) and recognition (110 ms).

ANOVA on error rates revealed a significant main effect of ethnicity, $F(1, 180) = 6.53$, $p < 0.05$, $^2 = 0.04$; a significant main effect of color, $F(1, 180) = 222.75$, $p < 0.001$, $^2 = 0.55$; a significant main effect of experimental task, $F(2, 180) = 31.16$, $p < 0.001$, $^2 = 0.26$; and a significant interaction between ethnicity and color, $F(1, 180) = 30.44$, $p < 0.001$, $^2 = 0.15$. Simple effects analysis found that Uyghur participants had significantly higher error rates for red cognition than for green, $p < 0.001$, $d = 0.63$, 95% CI = [0.04, 0.08], while Han participants had significantly higher error rates for green cognition than for red, $p < 0.001$, $d = 0.29$, 95% CI = [0.11, 0.15]. The interaction between ethnicity and experimental task was significant, $F(2, 180) = 4.71$, $p < 0.01$, $^2 = 0.05$. The interaction between color and experimental task was significant, $F(2, 184) = 97.47$, $p < 0.001$, $^2 = 0.52$. Simple effects analysis found that in classification and recognition tasks, Uyghur participants showed no significant difference in error rates between red and green judgments; in similarity judgment, Uyghur participants showed significantly higher error rates for green than for red. The three-way interaction between ethnicity, color, and experimental task was significant, $F(2, 180) = 4.86$, $p < 0.05$, $^2 = 0.04$. Simple effects analysis showed that in similarity judgment, the difference in green judgment error rates between Uyghur and Han participants was not significant, $p > 0.05$, but Uyghur participants had significantly higher error rates for red judgment than Han participants, $p < 0.05$. In classification, Uyghur participants had higher error rates for red classification than Han participants, $p < 0.05$, but lower error rates for green classification, $p < 0.001$. In recognition, Uyghur participants had significantly higher error rates for both red and green recognition than Han participants, $p < 0.001$.

All three experiments found significant differences between Uyghur and Han participants in green and red cognition. Uyghur participants showed shorter response times for green discrimination, classification, and recognition, while Han participants showed shorter response times and lower error rates for red discrimination, classification, and recognition. Uyghur participants demonstrated superior green cognition compared to red cognition and compared to Han participants' green cognition; Han participants demonstrated superior red cognition compared to green cognition and compared to Uyghur participants'red cognition. These differences in green and red cognition between Uyghur and Han participants were consistent with the two ethnic groups' cultural differences regarding green and red and showed cross-task stability.

General Discussion

6.1 On the Influence of Language and Culture on Uyghur and Han Students' Cognition of Red and Green

Ethnic groups are distinguished through religion, customs, language, and other factors [?, ?]. Parsons argued that language and religion are fundamental elements of ethnic cultural identity [?, ?]. After long religious evolution, Islam has profoundly influenced Uyghur psychology [?, ?, ?, ?]. Muhammad identified water, green leaves, and beautiful faces as three wonderful things. Followers of Islam advocate green [?, ?]. Green is the symbolic color of Islam and a marker of Muslim identity [?, ?]. Muslims' love for green is centrally expressed in architecture, which has deep historical and cultural roots. The Arabian Peninsula, the cradle of Islam, is mostly desert with occasional oases. Muslims therefore view green as the source of life, making green an important component of ethnic cognition that influences ethnic cognitive orientation [?, ?, ?, ?].

Every color carries cultural imagery in different ethnic cultures, revealing the "cultural information" displayed by color terms [?, ?]. Red is a revered color in Han culture, originating from ancient sun worship. The blazing sun is red like fire, giving people feelings of warmth and light. When looking directly at the sun, awe arises spontaneously, and the sun becomes an object of worship, making red the "color of celebration" [?, ?]. In Han life, major celebratory events are rendered with red [?, ?]. "Red" is also called "chi" and "zhu." "Chi" is one of the five primary colors, corresponding to fire in the five elements. "Zhu red" represents high status, so the residences of high officials and nobles are called "zhu men." Red provides the strongest visual stimulation among all colors, easily exciting the brain and creating feelings of pleasure [?, ?]. Red also easily evokes associations with blood, carrying meanings of danger and violence, and is therefore commonly used as a warning color. From the color of blood, associations with revolution and conflict also arise. "Red" is synonymous with "dan," representing loyalty, as in the idiom "danxin bixue" (loyal heart, jade-green blood) and the poem "Retain a loyal heart to illuminate the history books" (Wen Tianxiang, "Passing by Lingdingyang"). Red also symbolizes thriving, renewal, hope, and light, with connotations of popularity, recognition, and prosperity, such as "hongren" (popular person) and "zouhong" (becoming popular) [?, ?]. Red also symbolizes profit, such as "hongbao" (red envelope) and "hongli" (dividend) [?, ?]. Han people describe prosperity as "honghuo" [?, ?] and bustling places as "hongchen" (the world of mortals). Red is also associated with women, such as "hongyan" (beautiful face) and "hongzhuang" (red makeup). Red is also used in emotional descriptions, such as describing good health and complexion as "hongguang manmian" (face glowing red). Red also signifies solemnity, warmth, and formality, such as rolling out the red carpet to show grandeur and welcome [?, ?]. Thus, red has deep historical roots in Han culture and profound psychological effects on people.

In summary, green and red carry different cultural meanings in Uyghur and Han cultures. To accept their ethnic culture, individuals must attend to colors relevant to their ethnic culture and language, forming sensitivity to certain colors. This color preference and sensitivity forms a cultural unconscious. In this study, Han participants were faster and more accurate than Uyghur participants in discriminating, classifying, and recognizing red, while Uyghur participants were faster than Han participants in discriminating, classifying, and recognizing green. These results align with Han and Uyghur attitudes toward red and green. The findings are consistent with Xie Shushu et al. (2008), who found that Yi, Bai, Naxi, and Han university students differed in discriminating and recognizing black and white blocks of varying lightness, with differences matching each group' s black and white culture. Therefore, language and culture shape color perceptual representations, forming consistent color perceptual spaces, and individuals cognize colors based on their ethnic color perceptual space, leading to color cognition differences between ethnic groups with different languages and cultures [?, ?].

In Experiment 1, both groups showed significantly higher error rates for green than for red perception, which relates to the arousal level and emotional response that red and green elicit in the brain. Red produces higher arousal than green and can also elicit pleasant emotions [?, ?], thereby improving perceptual clarity and reducing errors. In Experiment 3, Uyghur participants showed significantly higher error rates for green recognition than Han participants, possibly related to the addition problems. Research shows that Uyghur students generally perform lower in science and mathematics than Han students [?, ?]. Likely, the addition problems caused greater interference for Uyghur than Han participants, consuming more cognitive resources and making memory for the presented color blocks more blurred.

6.2 Direct and Indirect Language Effects in Color Cognition

Experiment 1 found significant differences between Uyghur and Han participants in discriminating red and green blocks, demonstrating not only that language and culture influence color perception but also that this influence constitutes an indirect language effect. Do direct language effects also exist? Experiments 2 and 3 used color classification and recognition tasks, both involving memory components and potentially involving linguistic labels and strategies—that is, participants might unconsciously use native language terms to name colors. Most previous research used two color categories, such as blue-green or red-purple pairs, or within a single language used different linguistic labels for the same category, such as Russian' s two terms for blue [?, ?, ?, ?, ?, ?, ?]. In these studies, it was mostly impossible to exclude the influence of linguistic labels on color cognition because participants inevitably used linguistic strategies to complete cognitive tasks. Therefore, building on Özgen and Davies (2002) and Xie Shushu et al. (2008), this study divided a single color (red or green) into two parts using the focal color as the center and selected different blocks by varying chromaticity. Because each block was difficult to name in either Chinese or Uyghur, and it was even difficult to use memory strategies based on lightness or saturation differences, the influence of linguistic labels on color cognition was cleverly excluded, largely eliminating direct language effects. This view was further supported in Experiment 2. In Experiment 2, experimental materials were repeated four times. Logically, as repetition increased, response times for color classification should shorten. According to Özgen and Davies (2003), color classification can be learned through experience. If participants used linguistic strategies in color classification, such as naming green as "dark green" or "light green" and red as "dark red" or "light red," then as pictures were repeated, color names would be repeatedly activated and response times would become increasingly shorter, showing repetition effects. However, neither Uyghur nor Han participants showed repetition effects in color classification, indicating that classification was based on existing color perceptual space. This color perceptual space was formed before participants engaged in the cognitive tasks—that is, before the experiment, the color perceptual spaces of the two ethnic groups were already different, proving that language and culture shape individuals' color perceptual space. This demonstrates that, at least within the scope of this study, the influence of language and culture on color cognition is primarily indirect.

Compared with color classification, both Uyghur and Han participants showed significantly longer response times and higher error rates in color recognition. This results from differences in cognitive processing between the two tasks. In Experiment 2, participants needed to perceive two target color blocks, form mental representations, and when a classification block appeared, perceive one block while simultaneously comparing it with the two previously formed representations before making a classification. In Experiment 3, participants first perceived one target block, formed a representation, and when recognition blocks appeared, perceived two blocks while comparing them with the previously formed representation before making a recognition judgment. The response time differences between the two tasks partly reflect that classification requires online perception of one block and comparison with two previous representations, while recognition requires online perception of two blocks and comparison with one previous representation, making response times longer. Additionally, the recognition task included a distractor task: after forming a representation of the target block, participants had to solve two math problems, which occupied cognitive resources, blurred the representation of the target block, increased comparison difficulty, and lengthened response times. The response time differences between tasks likely reflect differences in cognitive processes.

Although this study confirms the existence of indirect language effects, this does not negate direct language effects. The focus of this paper was to demonstrate indirect language effects, so experimental tasks were designed to avoid direct language effects. Much research has proven the existence of direct language effects because the superiority of between-category over within-category color perception involves linguistic strategies. Additionally, Zhang Jijia et al. (2018) found that because Chinese has more collocational expressions and similar color associations for "red" and "purple," pragmatic relationships did not affect color perception but did affect color classification and recognition. This indicates that color associations arising from pragmatic relationships play an important regulatory role in cognition, with memory encoding playing a direct role, meaning linguistic strategies are at work. Furthermore, Experiment 3' s response times were significantly longer than Experiment 1' s, also suggesting that participants used some linguistic strategy to aid memory in tasks involving memory components. However, experimental evidence for indirect language effects is scarce. This study confirms the existence of indirect language effects. Therefore, at minimum, we can say that language influences color cognition through both direct and indirect effects.

6.3 The Relationship Between Color Perception and Color Preference

Influenced by history and culture, different ethnic groups have different color preferences. For example, the Yi favor black, the Bai favor white, the Naxi favor white but not black, the Han favor red and yellow but hold contradictory attitudes toward white and black [?, ?], and the Mongolian favor white and blue but dislike black [?, ?]. Are the different cognitions of green and red between Uyghur and Han people caused by differences in color perception and memory abilities or by differences in color preferences? We argue that although these experimental effects are related to color preferences, they are essentially cognitive in nature. The experimental effects result from different cognitive abilities for green and red between the two ethnic groups. Ontogenetically, ancestral ethnic color preferences lead to higher presentation frequencies of preferred colors in ethnic life, which in turn leads to higher perceptual frequencies for preferred colors in individuals' lives, improving sensitivity to preferred colors and enhancing cognitive abilities for them. On the other hand, color preference is also an important component of ethnic culture. Elders' positive attitudes toward certain colors influence later generations, creating similar color preferences that motivate individuals to more actively cognize preferred colors, increasing perceptual frequency and thereby enhancing cognitive abilities for those colors. Therefore, although the relationship between ethnic color preferences and ethnic color cognition abilities is complex, the direct cause of ethnic differences in color cognition in experiments is color perception and memory ability. Ethnic color preference differences are the cause, while ethnic color cognition ability differences are the factors that directly operate in experiments.

Popper (1967) proposed the theory of "three worlds," suggesting that all things in the world can be distinguished into World 1 (the physical world), World 2 (the world of consciousness or spirit), and World 3 (the world of objective thought content) [?, ?]. Shen Jiaxuan (2008) also proposed a "three worlds" theory, arguing that the physical world, mental world, and linguistic world are three parallel worlds. The linguistic world does not directly correspond to the physical world; their parallelism is manifested through language, with the physical world as the foundation and the mental world playing a mediating role. The mental world is responsible for connecting, transforming, and transitioning between the physical and linguistic worlds [?, ?]. Zhang Jijia, Xie Shushu, and He Xiumei (2008) proposed a "three spaces" theory, suggesting that space is divided into physical space, cognitive space, and linguistic space, with physical space determining cognitive space and cognitive space interacting with linguistic space. Zhang Jijia, Lin Qikun, and Chen Xiqian (2014) further revised this model, proposing that feedback exists between linguistic space and physical space. Language use activates physical space, prompting the brain to generate cognitive space representations consistent with physical space. As Socrates said, not all things belong to everyone equally at the same time, and things are not directly related to individuals [?, ?]. This explains why physically identical green or red colors are perceived differently by Uyghur and Han people. Influenced by language and culture, the color worlds in the eyes of Uyghur and Han people are very different. As Wittgenstein (1999) stated: "The limits of my language mean the limits of my world." Language reflects the world; language is an attribute, part, and condition of culture, but language does not directly reflect the world—language reflects the external world through cognition. These perspectives can well explain why speakers of different languages have different color cognitions, because the feedback from linguistic space to physical space differs.

In summary, language and culture influence color cognition through indirect language effects. Language and culture can change individuals' color perceptual spaces, influencing and even determining color cognition.

Conclusions

1. Compared with Han students, Uyghur students show a response advantage in discriminating, classifying, and recognizing green, and a response disadvantage in discriminating, classifying, and recognizing red.
2. The influence of language on color cognition involves indirect language effects. Language and culture shape individuals' color perceptual spaces.

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Language and Culture Influence Cognition: Effects of Indirect or Direct Language

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Abstract

The relationship between language and color cognition is key to understanding language and cognition. With the arguments between linguistic relevance and linguistic universal hypotheses, researchers prefer the eclectic theory that color cognition includes physics, perception, and culture-related properties. Given these theories and various investigations, interaction theory between color terms and color cognition has been proposed. One argument suggests that color perception should be influenced by language and culture, given the normal sense organs and level of intelligence.

Numerous types of studies have proven that language and culture play a role in color cognition, but how such a role is performed remains to be fully understood. Discussions on the essential mechanism of this effect remain lacking, and whether this effect is a direct or indirect effect (i.e., language strategies or cognition structure changes) continues to be unclear. According to the literature, the color category perception effect proposes that people are more likely to distinguish colors from different colors than those that landed in the same area. Thus, two categories of color were used as materials in past research, which made it difficult to distinguish between the direct and indirect effects. Accordingly, this paper employed just one category color, which was further divided into two different categories. Color culture is import to a nation. Thus, green is vital to Uygur culture, with red as the counterpart for the Han culture. In relation to this, the present study designed a perceptual task (Experiment 1) as well as classification and recognition tasks containing memory (Experiments 2 and 3), in order to explore the effect of language and culture on color cognition for the Uygur and Han nationalities.

Focal colors of red (RGB: 0, 255, 0) and green (RGB: 255, 0, 0) were selected as base points, and a vertical demarcation line was drawn on the RGB chromatography. On each side of the line, nine different stimuli in the same lightness saturation level (240–120) but with different chromaticities were selected. In Experiment 1, three colors (two from the same side of green or red and another from the other side) constitute one set of experimental material. Participants were asked to judge as quickly and as accurately as possible whether the left or the right color block looked more similar to the middle one, and press the corresponding button on a response box. A total of 62 college students participated in the experiment (31 of Han nationality and 31 of Uygur nationality). In Experiment 2, the materials and the participants (in terms of number and categories) were identical to those in Experiment 1. Participants were instructed to remember the colors and identify as quickly and as accurately as possible whether the following colors belong to the left or to the right of the color pair, and then press the corresponding button on a response box.

In Experiment 3, 62 participants from the two nationalities who were using identical materials were asked to judge as quickly and as accurately as possible whether the left or the right color looked more similar to the standard one, and then press the corresponding button on the response box.

Results showed significant differences in the perception, classification, and recognition tasks between the Uygur and Han nationalities. Compared with the Han nationality, the Uygur nationality had the advantage in distinguishing, classifying, and even recognizing green, but suffered a disadvantage when processing the color red. For the perception task, the two groups both spent a long time in the classification and recognition tasks. Accordingly, we believe that language and cultural differences in terms of perceiving the green and red colors affect color cognition and that such an effect is indirect, that is, language and culture can influence the color perception structure.

Keywords: Uyghur nationality; Han nationality; color cognition; direct language effect; indirect language effect

Note: Figure translations are in progress. See original paper for figures.