國立交通大學

應用藝術研究所

博 士 論 文

中文色彩詞彙及語言色彩類別空間

Color Terms and Lexical Color Category Space in Mandarin

研 究 生：謝翠如

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摘要

色彩是萬物所呈現出來的鮮明視覺特徵，而語言則是高等認知功能的表現，探討複雜的色彩經驗如何由語言的方式傳達，遂成為可瞭解先天心智與文化相依性的重要學術議題之一。近半個世紀以來，由人類學、語言學、色彩科學及心理學等跨領域學者共同開啟了色彩知覺和語言互動的研究方向，此議題對於這些學門而言有著不同性質的重要意義：對心理學取向而言，色彩語言的研究成果提供關於大腦功能與文化對於知覺影響的解釋;而對於人類學及語言學者而言，色彩用語的複雜度或可視為社會成熟度的指標，跨文化間色彩用詞發展的共通性也揭示了人類語言演化的隱藏規律；而對色彩科學而言，以語言類別作為心理尺度的色彩度量方式具有較高層次的認知意義，可與傳統測色學當中以色彩區辨或視覺差異閾等較為基礎的色彩感覺單位互為參照，以補足採取不同認知層次的色彩感覺尺度於理論基礎及實務應用上的限制。

將色彩感覺以語言的方式編碼的行為（即色彩命名）源於人腦對於環境刺激以類別化的方式來處理的特性。色光是複雜而連續的刺激，色彩知覺的機制由從基礎的生理層次開始就以類別化的方式將資訊簡化、分類、進而完成迅速有效的辨識。語言色彩類別是整個色彩知覺當中對色彩經驗最概念化的表現，亦即我們會將某頻段的色光、一群可辨識出調子不同的相近色彩歸為同一類別，並以一個色彩詞彙涵蓋描述，例如紅色。在相關領域當中的一個核心爭議是：語言色彩類別的現象是先天且普遍的、還是會受到文化所規範？中文母語者心裡的「紅色」一詞所涵蓋的色彩範圍跟英語母語者心裡的“red”是一樣的嗎？此問題引起相當多論辯及實徵資料佐證，例如起始於柏克萊大學語言學系學者的基本色名研究、世界色彩語言調查(WCS)等。然而，過去相關文獻以中文為研究

對象的資料卻顯著不足，有鑑於此，本論文主旨為以中文母語者作為研究對象，探討中文語境下的色彩詞彙以及語言色彩類別的現象。

本論文重點有三，分別以實徵調查達成研究目的，重點一：瞭解中文色彩詞彙的使用現況：為達成此研究目的，執行一個189位中文母語者參與的色彩詞彙自由回想作業，取得約五千個色名樣本，並以敘述統計描述其重複性與多樣性。重點二：執行一個由36名中文母語者參與的色彩自由命名實驗，以121個在螢幕呈現、規律取樣的色彩為刺激，以色名、反應時間及信心分數三項為依變項，此實驗目的在於瞭解在中文色彩命名行為當中的反應特徵，以及經常被使用的色名。重點三：建立以中文母語者的語言色彩類別在標準色彩空間(CIE1931 x-y diagram)上的對應範圍，這部分的實驗為以12個中文基本色名作為選項、461個考慮色相、彩度與亮度並且規律取樣的螢幕色彩作為刺激，讓44位受試者進行選色實驗，研究結果可作為考量語意的色彩系統之建立參考，另外比較中文與其他語言的語言色彩類別範圍在分佈上的異同，可作為色彩用語研究的兩個傳統理論框架，「普遍主義」(Universalism)或「相對主義」(Relativism)的實徵證據。

根據本論文的三個系列研究結果可歸納出以下發現：1.在自由回想與自由命名實驗當中，有12個中文色彩詞彙具有高度的回溯率及重複性，包括紅、橘、黃、綠、藍、紫、黑、灰、白、咖啡、粉紅、桃紅等，這些詞彙符合相關文獻當中的11個基本色名的類別，其中粉紅與桃紅兩個色名雖屬同一類別、且也不符基本色名的「單詞」(monolexemic)之定律，但兩者在語言色彩類別空間的「焦點」(foci)位置明顯有區隔，在理論上或可視為中文之基本色名。2.自由命名結果顯示常用的中文色調修飾詞(tone modifier)包括亮、暗、淡、粉、淺、深、偏以及正。3.與英語色彩自由命名研究的結果相較之下，中文色彩命名的行為趨向於使用較多的複合色名、較少的基本色名及單詞色名，而且中文命名作業所需的反應時間較長，受試者對於色彩命名的平均信心度也較低。4.與同樣觀測條件的日語色彩類別範圍研究結果相較，本研究的藍色與綠色之定義範圍顯著異於日語研究結果，另外灰色與咖啡色的定義範圍在中文與日文也略有不同。5.由比較由自由命名以及12色名選色兩個實驗的結果顯示：受試者針對介於藍、綠及紫色類別範圍的刺激進行命名作業時，比其他刺激需要更長的反應時間，但是同樣範圍的刺

激在選色作業的反應時間卻是相對短的。這表示此三者的色彩類別的判斷難度會因作業要求而有所差異，在強迫選擇(force-choice)時的反應時間短、作業難度低，而且實驗結果的集中趨勢較高；而在自由命名作業之下的反應時間長、而且命名結果集中趨勢相對較低，由此現象可推論形容藍、綠至紫色調的中文色名在使用上較為複雜，其選擇或回溯時的難度較高。

整體而言，本論文以實徵調查及實驗的方式提供中文色彩語言研究領域的重要參考資料，包括整合兩種色名調查方法所得結果歸納現行的中文基本色名，這些色名不同於以往文獻中所使用的字辭典中英翻譯，與實際普遍的用語有所出入。另外本研究之結果也可作為跨語言色彩類別研究的中文參考資料，相對於其他世界語言、過去中文的實徵研究數量是相對稀少的。再者，本研究的發現也可作為中文與顏色彩類別研究的基礎框架，相對於英文的相關研究的系統與規模而言，中文在基本色名、次要色名(secondary color term)、以及色名演化結構等方面都尚有進一步探討的空間。

Color Terms and Lexical Color Category Space in Mandarin

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Abstract

The lexical color categorization is a critical function of color perception which involves sorting visual responses to lights into certain color categories and coding them with language. The issue of verbalizing color experience, or color naming, had drawn many attentions from visual psychologists, linguistic anthropologists, and color scientists. Some anthropologists suspected that the amount of color vocabulary circulated within a language could be taken as an idex to the technological and cultural complexity held by the speakers. Although some data were reported in the pioneering work of Berlin and Kay (1969), the developmental status of Mandarin, i.e., the sophistication and the differentiation of its color vocabularies, remains unclear. Besides the theoretical impact on linguistic anthropology, the behavior of naming color experiences is also considered a mirror reflecting the cognitive structure of inner structure of color space. English color naming is a well-discussed topic, and there were over a hundred of different languages in previous extensive color naming survey (WCS). However, there is still a considerable vacancy of empirical color naming data in the relevant domain. The current study aims at establishing the groundwork of lexical color terms and categories in Mandarin by collecting empirical data from native speakers. The objectives to be achieved in this research include: 1. to investigate synchronic Mandarin color lexicon and the popularity of frequent color vocabularies. 2. to acquire behavioral data of color naming. 3. to determine Mandarin basic color terms by analyzing results of the empirical survey. 4. to locate Mandarin speakers' foci and boundaries of known lexical color categories in a standardized chromaticity diagram. The empirical works in the study includes: 1. a free-recall survey of prevalent color terms involving 189 informants who are native Mandarin speakers. The collected data would help establishing the color lexicon in the current cultural context. 2. a free color naming experiment with written color terms and response times as dependent variables. It is supposed that these variables provide not only the simple popularity counts of color terms, but also an index to the psychological link between color categorization and naming. 3. a 12-terms color sorting experiment. There are 461 color stimuli varying in hue, saturation and brightness in this experiment and participants were asked to sort them into twelve color terms.The results of the three empirical works showed that 1. there are twelve Mandarin color terms that are consistently recalled and named, 紅(Hung), 橘(Ju), 黃(Huang), 綠(Lu), 藍(Lan), 紫(Zi), 黑(Hei), 灰(Hui), 白(Bai), 咖啡(Ka-fei), 粉紅(Feng-Hung) and 桃紅(Tao-hung). These terms correspond well to the eleven color categories found by linguistic anthropologists Berlin and Kay, and can be regarded as basic Mandarin color terms. 2. There are eight tone modifiers found to be frequently used in the free naming experiment,亮(bright),暗(dark), 淡(pale), 粉(powder), 淺(light), 深(deep), 偏(-ish), and 正(central, correct). 3. Compared to the results of English color naming study, Mandarin speakers use more compound color terms and fewer basic or monolexemic color terms. The response times of Mandarin color naming are longer, and participants' confidence scores are lower. 4. Comparing the current results with Japanese color sorting experiment in a similar viewing condition, one finds that the location of blue-green boundary is quite different in the two studies. To sum up, this study conducted an exploratory survey on modern Mandarin color terms and color naming, and obtained the experimental data for constructing the space of Mandarin lexical color categories. These results form a good complement to the empirical vacancy in the related fields in world language community, and also serve as the backbone for further studies.

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CHAPTER 1. INTRODUCTION

This chapter gives an overview of the general background and scope of this dissertation. Session 1.1 addresses the brief history, orientation and impact of cross-language color naming studies. Session 1.2 focuses on the scope, purpose and expected contribution of this dissertation. Session 1.3 gives the structure and completed works in the dissertation.

1.1 Backgrounds

Color is the most salient feature in the visible world. The ability of making good use of color information greatly enhance the chance of survival and the quality of life of human and animals alike. Color also carries the potential of arousing aesthetical emotions, and therefore plays a key role in visual art and modern display industry. Due to its significance in human life, color study has a long history and involves diverse research disciplines. Interests in color can be found in academic areas ranging from philosophy, visual arts, culture studies, to physics, psychology, and a good variety of industrial applications. The remarkable variety of color research was discussed in certain review works such as *Color For Science, Art and Technology* (Kurt, 1998). Among various perspectives of color related studies, an extraordinary research line regarding the verbalization of color perception is relevant to the present dissertation.

Some anthropologists suspected that the amount of color vocabulary circulated within a language could be positively related to the technological and cultural complexity held by the speakers (Berlin & Kay, 1969). Besides serving a probable index of cultural maturity, the behavior of naming the color experience is also considered a mirror reflecting the cognitive structure of inner color space, or even the fundamental mechanism of color vision.

There is a critical mechanism involving sorting visual responses of lights into certain color vocabulary, which is the lexical color categorization. This mechanism reveals the nature of information processing of human cognition. Fundamentally, the mind processes vast amount of continuously changing sensory data into more manageable discrete pieces of information, that is, to sort many similar or related events into a finite number of accessible categories. The categorization phenomenon is an information reduction procedure found in the whole cognitive system, and particularly underlies the process of color perception. We literally “see” colors in a categorical fashion. For instance, people lump various discriminable or indiscriminable bluish shades together into a single ‘blue’ category, and we also use linguistic labels, such as “blue” in English and “藍” in Chinese, to convey the visual quality of that whole color category. Common color terms like red, yellow, and green are also color categories in that they cover a set of color stimuli instead of referring to a specific monochromatic stimulus.

The study on color verbalization soon picked on a heated debate over whether color category is governed by color vision, which is supposed to be universal, or by language, which is relative and culture dependent. Will the concept of any color category be similar between different populations using different color terms, provided they share the same visual physiology?

Around half century ago, two linguistic anthropologists Brent Berlin and Paul Kay (hereafter B&K) were intrigued by the ease with which common color terms could be translated between languages form locales as diverse as Tahiti and Mesoamerica (Hardin & Matffi, 1997). This seems to be inconsistent with the culture relativity theory in which languages are thought to divide color space arbitrarily (e.g. Whorf), and shape the way their speakers perceive colors (Whorf, 1956). B&K afterwards conducted a cross-languages color naming survey on U.C. Berkley campus and published their empirical observation in *Basic Color Term* (Berlin & Kay, 1969). B&K proposed two general hypotheses about the naming of perceptual color categories: (1) there is a restricted universal inventory of naming of these categories; (2) a language adds basic color terms in a constrained order, interpreted as an evolutionary sequence. The universal and evolution features within their earlier findings were improved and confirmed by the subsequent World Color Survey (hereafter WCS) with a more comprehensive scope and systematic method.

In the rich history of color-vision research, color scientists dedicated themselves to psychophysical aspects of color, such as color matching and discriminating, adaption, and the measurement of thresholds, but seldom addressed the categorical structure or linguistic expression of color perception. However, since B&K and the followers initiated the investigation on the color categories and their naming in various human languages, the linguistic expressions of perceptual color categories are considered to interact with the introspective side of color vision. In the traditional domain of color-linguistic studies, the interaction between color perception and languages was framed into two fundamentally separate questions (Regier, Kay, Gilbert, & Ivry, in press): (1) Are semantic distinctions in languages determined by largely arbitrary linguistic convention? (2) Do semantic differences cause corresponding cognitive perceptual differences in speakers of different languages? In the past decades, many linguistic anthropologists and visual psychologists produced a considerable amount of evidence and arguments to answer the questions. Chapter 2 would track the research on these questions in detail.

There were over a hundred of different languages in previous extensive color naming survey. However, the status of Mandarin regarding color categories and the naming could not be fully clarified based on the existing data. Specifically, the latest WCS report started from 1970s and surveyed 110 different languages do not cover Mandarin. Dating back to 1960s, in the survey of 20-unrelated languages carried out by B&K (1969), the data that contributed by a restricted number of Mandarin informants was insufficient to affirmatively determine the evolutionary color naming stage to which Mandarin belongs. B&K then roughly treated Mandarin as an example of evolutionary Stage V, in that contains only six color terms, black, white, red, yellow, green, and blue, while Japanese, Korean and Cantonese were assigned into Stage VII which fully contains eleven basic color terms. Practically most native Mandarin speakers would find the terms in use are surely much more than the six terms that were concluded. A later duplicate survey in Mandarin color naming conducted by Taiwanese color researcher Lu Ching-Fu was motivated by this debatable discrepancy (Lu, 1997). In general, although Mandarin is a complex language used by more native speakers than any other language, there is a considerable vacancy of empirical color naming data in the relevant domain.

In addition to the theoretical impact of color categories and naming issue, knowledge about this issue could lay the groundwork in applied researches of color. It is known that one's color experience in color-science lab and in real life is qualitatively different. We process, memorize and communicate colors in categorical form with linguistic labels, while color vision research reports psychophysics data based on very basic discrimination response. Most color researches focused on the psychophysics of color, instead of the cognition of color. However, in the application of visual communication and visual design involving colors, the color knowledge at cognitive level would be necessary. A landmark color order system Natural Color System (NCS) was developed on the cognitive level of color perception (Sivik, 1997) .

1.2 Scope

The issue of language-dependent color naming had drawn many attentions from visual psychologists, linguistic anthropologists, and color scientists. However, previous studies did not collect enough observations from local native Mandarin speakers. Seeing that, this study aims at establishing the groundwork of Mandarin color categories and terms by collecting color naming data from native speakers who resident in one of the areas currently using Mandarin and traditional Chinese characters, Taiwan. This fundamental-orientated study holds specific objectives listed as below:

(1) Investigating synchronic Mandarin color lexicon and the popularity of frequent color

vocabularies.

(2) Acquiring behavioral data of color naming and establishing the cognitive model of color naming space.

(3) Locating Mandarin speakers' foci and boundaries of known major color categories in a standardized chromaticity diagram.

(4) Sieving out frequently-used secondary color terms and their chromaticity structure relative to basic color terms.

(5) Discussing the impact of color naming research on applied domain such as visual communication and color design.

The listed objectives in this dissertation were approached through empirical works involving methods of color lexicon survey, color naming and sorting experiments. Comparing with typical color naming works following B&K's paradigm, this study holds some methodological distinctions:

(1) Most of previous cross-language survey, including WCS, adopted reflective color stimuli such as color chips sampled form Munsell system, and the viewing conditions were not strictly controlled. Actually, the appearance of reflective color could drastically affected by multiple factors, e.g. lighting, or even more subtle factors like stimulus size or viewing distance. The color stimuli in the study are LCD-display and under well-controlled condition.

(2) In the previous anthropological survey, the foci color (the best example within a color category) was determined by simultaneously presenting many color samples to the viewers. This method is direct and efficient, but the juxtaposition would lead to color contextual effects like color assimilation or color contrast, which might alter the appearance of color samples. Instead, this study locates foci color through behavioral statistics, e.g. frequency count of sorting and naming, and response times (hereafter RTs).

(3) Color samples used in B&K and WCS were in the highest saturation level and varied along Munsell Hue and Value axis, i.e. perceptual dimension of hue and brightness. Colors of middle and low saturation were excluded in those works, while most colors in the real world should be in these shades. The stimuli in this study are evenly-sampled from the CIE1931 chromaticity diagram and cover several distinct luminance levels. The stimulus sampling was sweeping the available gamut of a typical LCD display. Thus the stimuli are a set of finely sampled colors varying along hue, saturation and brightness. Moreover, the results can be transformed to other color spaces or color appearance models.

1.3 Structure

The structure of this thesis is given in Table 1-1, which presents the major works surrounding each theme and how they are arranged into separate chapters. Chapter 2 gives an overall review of literature related to the current study. The first empirical work in Chapter 3 is a free-recall survey of prevalent color terms involving 189 informants who are native Mandarin speakers. The gathered data would help establishing color lexicon of current cultural context. Chapter 4 presents a free color naming experiment with written color terms and response times as dependent variables. It is supposed that these variables provide not only the simple popularity counts of color terms, but also an index to the psychological links between color categorization and naming. Chapter 5 is a 12-terms color sorting experiment. There are 461 color stimuli varying in hue, saturation and brightness in this experiment and participants were asked to sort them into twelve color terms corresponding to B&K's eleven basic color categories. The cross comparison with the current results and the results in previous studies would be given in Chapter 6. The last chapter also organizes the findings in the study. The further extension works and the links with application domain would be discussed too.

Table 1.1. Structure of the thesis

Structure of the thesis		
Theoretical grounds →	**Methods and experiments** →	**Results and discussion**
Chapter 2. Literature review	Chapter 3. Color Lexicon Survey in Mandarin	Chapter 6. General Discussion
2.1. Color discrimination versus color categorization 2.2. Cognitive linguistic debates: Universalist and relativist views 2.3. Color naming methods 2.4. Basic and Secondary color terms 2.5. World Language Survey (WCS) 2.6. Color naming in Mandarin	A Mandarin color terms survey with method of free-recall **Chapter 4. Mandarin Color Naming Space** A free color naming experiment **Chapter 5. Structural Formation of Main Color Categories** A 12-terms color sorting experiment	6.1. Comparing popularity ranking of color terms between studies 6.2. Comparing with other studies' free-naming results 6.3 Comparing free naming and sorting maps within this study 6.4. Future works

CHAPTER 2. LTERATURE REVIEW

This chapter introduces the theoretical background of the thesis. It briefly reviews various aspects of lexical color category discussed in the following disciplines: psychophysics, perceptual cognitive, linguistic psychology and anthropological linguistics. Also, the study of color naming in Mandarin will be reviewed.

2.1. Color discrimination versus color categorization

One of the core issues in the long history of color science is the inquiry of the functional unit of color perception. Human eyes perceive distinct hues in the visible radiant spectrum ranged from 400 to 700 nanometers, as Isaac Newton observed three centuries ago. Phenomenally, the apparent chromaticity quality derived from visible lights varies region by region instead of wavelength by wavelength. The attempt of segregating perceptual regions of color had been made intensively by classic color-scaling experiments (Boynton, 1975). Color coding involves multiple levels starting from the wavelength continuum to color discrimination, and to color categorization and finally the act of naming. Within this complex process of internal percept transformation, the discrimination and categorization are two different stages that serve different purposes and adopt different information processing strategies.

The discrimination capability is associated with how many different wavelengths observers can tell apart. The paradigm of color discrimination experiment is to juxtapose two spectral fields and alter one relative to another systematically across the spectrum to derive a JND ((just noticeable difference, or $\Delta\lambda$) function, which means the degree of wavelength change required to elicit a just noticeable differences in color as a function of the reference wavelength (Bornstein, 1990). With brightness and saturation controlled, there are approximately 120-150 JNDs among color-normal observers (Bornstein, 1990), or 200 distinguishable steps (Gouras, 1991a), across the visible spectrum. If considering other perceptual dimensions of brightness and saturation variation in the real world, human can theoretically discriminate millions of colors. Ecologically, the benefit of high resolution in color discrimination affects mainly the object recognition from chaotic and complicated background.

Another stream of processing chromatic light is categorization. This is an information reduction strategy that entails rapid coding of colors. There is evidence supporting the model of parallel processing of continuous and categorical (discrete) information in color perception (Bornstein & Korda, 1984). Studies on color categorizing questions concern whether observers perceive qualitative similarities of hues among spectral wavelengths (Bornstein, 1990). The illustration in Figure 2-1 gives three psychological levels of color encoding. The 'grain size' of color codes in these levels, the physical level of visible wavelength, the psychophysical level of color discriminations, and the linguistic-psychological level of color naming, are getting coarser and coarser in that order. Physically, the possible values of wavelengths combination across the visible spectrum are infinite. Psychophysically, the number of discriminable steps of chromatic stimuli are constrained by the visual system, especially for hue discrimination (Gouras, 1991a). The observer's color sensations only change when the stimulus light cuts across the division between two different wavelength regions; therefore the perceptual color space is virtually partitioned into distinct JND bands instead of a sensory continuum.

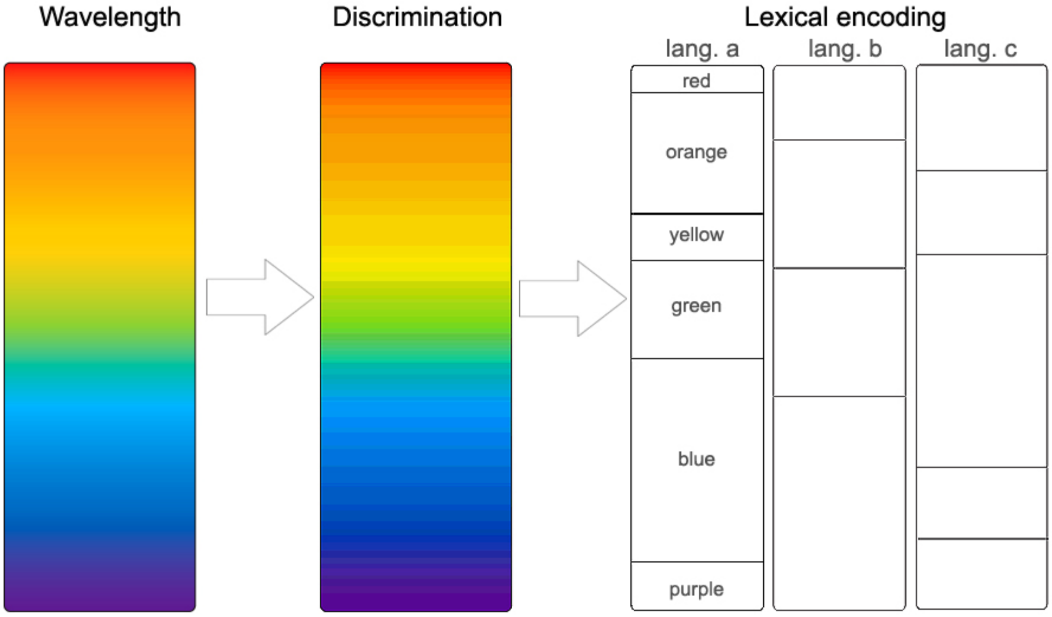


Figure 2-1. Color encoding levels from stimuli and discrimination to lexical encoding.

The categorical color perception at higher order cognitive level always links with the behavior of lexical color encoding, i.e., using verbal description to represent certain color shades. Language is a highly developed cognitive function affecting many aspects of human behaviors. In fact, the formation and the structure of color categories are tightly bounded with language. The color category is conceptually more abstract on the linguistic level than that on the discrimination level. Consequently, the quantity of distinguishable categories on the linguistic level is drastically reduced. The number of frequently used color terms depends on the linguistic evolution stage. In the well-developed stage, a language usually contains no less than 11 basic color terms (Berlin & Kay, 1969). The endeavor of mapping color terms across languages on the color space leads to the finding that the corresponding chromaticity range of the equivalent color terms may vary across different cultures.

Discriminable wavelengths are categorized into a group due to the fact that they appear perceptually similar and share a dominant hue quality. The categorization effect affects human performance in various tasks ranging from discrimination, recognition to memorization.

Between-category color discriminations are more accurate and efficient than equivalent within-category discriminations (Bornstein & Korda, 1984; Boynton, Fargo, Olson, & Smallman, 1989; Goldstein, Davidoff, & Roberson, 2009). Color categorization is also found to enhance the performance in recognition tasks (Dale, 1969; Goldstein, et al., 2009; Kimball & Dale, 1972; Ostergaard & Davidoff, 1985). This categorical effect is also apparent in color memorization (Boynton, et al., 1989; Heider, 1972; Seliger, 2002; Uchikawa & Shinoda, 1996). The fundamentality of categorical color perception is supported by empirical evidence of early infant vision studies (Bornstein, 1985; Bornstein & Kessen, 1976) and recent neurophysiological studies (Franklin, Drivonikou, Bevis, et al., 2008; Holmes, Franklin, Clifford, & Davies, 2009; Roux, Lubrano, Lauwers-Cances, Mascott, & Demonet, 2006). Categorization of color seems to be an innate function, that is, a universal cognitive phenomenon shared by all human beings. However, these findings apparently oppose a language dominancy viewpoint proposed by anthropological linguist Benjamin Lee Whorf (Whorf, 1956). The following session discusses the major debate over color terminology.

2.2. Cognitive linguistic debates: Universalist and relativist views

The regular pattern of sorting continuous lights into discrete categories has provokes researchers' interest on pondering the relations between world and brain, language and perception. Lexical color category and its implication became an important issue in anthropological linguistics and cognitive science, and induced a controversy lasting for half of a century (Jameson & D'Andrade, 1997; Regier & Kay, 2009; Regier, et al., in press). This is a classic debate on the relation between perception and language. Two opposing stances in linguistic anthropology— universalist and relativist— engaged in this intense debate regarding the dominant hierarchy of thought and language (Dedrick, 1998; Kay & Regier, 2006; Regier, et al., in press).

At one pole of the debate is the universalist stance, which holds that there is a universal repertoire of thought of the world. The universalist view holds that language is a limited semantic palette shaped and restricted by human cognition. The range of color categories are projected from the universal color foci and therefore located in similar positions in color space across world languages. The first systematic cross-culture color naming survey provides consistent evidence for this view. Berlin and Kay established a pioneering theory of basic color terms by conducting this anthropological survey; they proposed 11 common color terms that are widely used across cultures (Berlin & Kay, 1969). The universal color terms in English are black, white, red, green, yellow, blue, orange, purple, pink, brown and grey. The sequence is based on the developmental order of the terms. This universalist view of the usage of color terms, involving a belief in profound common ground that connects human cultures and minds, has been observed in various types of studies, including cross-culture surveys (Goldstein, et al., 2009; Lin, Luo, MacDonald, & Tarrant, 2001a; Kay & Regier, 2007; Lindsey & Brown, 2006; Lu, 1997; Regier, Kay, & Cook, 2005) , free color-naming tasks (Guest & Van Laar, 2000; Lin, et al., 2001a; Sturges & Whitfield, 1997), developmental studies (Bernasek & Haude, 1993; Bornstein, 1985; Karpf, Gross, & Small, 1974; Pitchford & Mullen, 2002), and psychophysics and physiological experiments (Boynton & Gordon, 1965; Boynton, Maclaury, & Uchikawa, 1989; Boynton & Olson, 1990; Boynton, Schafer, & Neun, 1964; Holmes, et al., 2009; Ingling, Scheibner, & Boynton, 1970; Roux, et al., 2006; Sakurai, Ayama, & Kumagai, 2003; Sturges & Whitfield, 1997), despite the continued existence of opposing, relativist arguments (Dedrick, 1998; Ozgen, 2002; Roberson, Davies, & Davidoff, 2000) .

In contrast, the relativist view denies the universal foci theory and argues that language shapes thought. The relativist view holds that the human perception of the world is shaped by the semantic categories of the native language, which means the content of mental categories is defined by cultural conventions and would vary across languages. This view is often associated with anthropologist Whorf who hypothesized that language organizes attributes of the world and that linguistic organization in turn influences perception (Whorf, 1956). According to this view, color categories are defined at their boundaries by local language conventions and the corresponding range of a given color category may vary widely across cultures (Roberson, et al., 2000) .

Over the years, the dominant view has swung back and forth between these two poles. The latest authoritative review addressing this issue gives a compromised solution (Regier & Kay, 2009). It concludes that Whorf, the representation of the relativist view, was half right, in two different ways: (1) Language influences color perception partially in the right half of the visual field due to the left hemisphere's dominance for language (Franklin, Drivonikou, Bevis, et al., 2008; Franklin, Drivonikou, Clifford, et al., 2008). (2) Color naming across languages is shaped by both universal and language-specific forces. Generally, the landmark basic terms, red, yellow, green and blue, behave more universal than other basic color terms.

Besides the traditional frames of universalist versus relativist, there is another theory intends to explain the phenomenal pattern of cross-languages color naming. It proposed that color naming reflects optimal or near-optimal divisions of the irregularly shaped perceptual color space (Jameson & D'Andrade, 1997; Regier, Kay, & Khetarpal, 2007). This hypothesis seems to be supported by tests of the hidden consensus of WCS (world color survey) (Regier, et al., 2007) .

2.3. Color naming methods

Color naming is a frequently used paradigm in related studies. The observers participating color naming experiment may be exposed to chromatic stimuli and were asked to name (or identify to group) the spectral light to derive color-naming functions, that is the percentage of times basic color names are applied to different wavelength. Boynton and Gordan found only four color terms – red, yellow, green and blue – and their combinations are sufficient to describe the perceptual color space exhaustively. These color terms thus were considered as the psychological color elements: unique red, unique yellow, unique green and unique blue (Boynton & Gordon, 1965). The usage of other color terms such as purple or orange was inconsistent among participants and was considered to be less reliable. It suggests that there are only four basic color labels were regularly and satisfactorily needed when observers were to partition color spectrum.

As reviewed previously, the thought and language of colors has been under extensive investigations. Color terminology and its primary mechanism of categorical color perception are heated topics in part because color is a salient visual feature in most human cultures. Additionally, the 'thought' of color can be scientifically defined in the chromaticity space through standard measurement techniques. In other words, the appropriate experimental survey can convert the color semantics from the linguistic domain to the physical domain. The color naming method is widely applied to make attempts to gauge the chromaticity range that corresponds to color term. Color naming method was adopted from the early applied investigation of signal lights (Halsey, 1959a; Halsey, 1959b), to theoretical issues of visual psychophysics, such as precisely verifying the psychologically primary hues (Sternheim & Boynton, 1969) and characterizing the Bezold Brücke hue shift (Boynton & Gordon, 1965).

In addition to color naming method, free naming and color sorting task are often used in lexical color studies. The free naming method is good for collecting a large, diverse amount of color name data (e.g. Grant, 1980; Guest & Van Laar, 2000; H., et al., 2001a; Lu, 1997; Sturges & Whitfield, 1995, 1997) , while the sorting method focuses on the corresponding chromaticity range of the color terms in question (e.g. Lin, Luo, MacDonald, & Tarrant, 2001c; Lu Ching-Fu, 1997; Shinoda, Uchikawa, & Ikeda, 1993). In a typical sorting task, also called the constrained method in some studies,(e.g. Lin, et al., 2001c) observers are given a set of color terms (traditionally, Berlin and Kay's 11 color terms) as options for sorting the presented color stimuli. This method employs forced-choice tasks and systematic stimulus sampling, which can efficiently bridge each color term and its corresponding area in the chromaticity coordinate. Both free color naming and color sorting tasks would be adopted in the experiments of this thesis.

Besides those task-orientated naming methods, in psycholinguistic researches, the free-recall method without involving any stimuli and naming or matching task is considered to be the most faithful representation of the reference relationships that are peculiar to a given language (Lenneberg, 1967).

2.4. Basic and Secondary color terms

Basic color terms

Every culture or language has indefinitely diverse expressions that denote the perceptual experience of colors. A patch of color is capable of arousing various associations and descriptions. For instance, a simple blue stimulus could elicit the expressions such as watercolor blue, bright blue, turquoise, light sapphire, the color of clear sunny sky…. and so on. However, psychologists and anthropological linguists have long operated with a concept of basic color terms which include simple forms like black, white, red, and green. A basic color term is thought to exhibit the following four features.

(1) It is *monolexemic*: that is, basic color terms are simplex lexemes; they are lexemes whose meanings are not determinable from the meanings of internal components. (Casson, 1997; Conklin, 1962).

(2) Its *signification* is not included in that of any other color term. For example the term scarlet in English or 赤(chi) in Chinese can be replaced by red or 紅(Hong) for most people.

(3) It is *general*. Its application must not be restricted to a narrow class of object. It should be general if it applied to diverse classes of objects and its meaning is not subsumable under the meaning of another term.

(4) It is psychologically *salient*. It should be readily elicitable, occurs in the idiolects of most speakers, and is used consistently by individuals and with a high degree of consensus

among individuals.

Within the eleven well-tested basic color terms, the uniqueness and affirmed psychophysical foundation of four terms: red, yellow, green and blue are known as the *Landmark* basic color terms in related studies. The rest orange, purple, pink, brown, grey are other basic color terms.

Secondary color terms

Secondary color terms, or non-basic color terms, are defined as all color expressions excluding basic color terms. It by definition includes simplex and complex lexemes (Casson, 1997; Casson, 1994). English terms such scarlet, indigo, rose, emerald and turquoise are simplex lexemes, yellowish orange, light green, orange-red, wine-red and bright pinkish violet are complex lexemes; the above color terms are secondary color terms.

However, in the empirical survey of current study, the huge amount of secondary color terms are further classified into sub-classes such as simplex (monolexemic secondary color terms), complex (polylexemes) and other forms with specific combination pattern, in order to finely organize and analyze the obtained data.

2.5. World Language Survey (WCS)

The WCS is a massive study started in 1976 and carried out by University of California at Berkeley, International Computer Science Institute, Berkeley and University of Chicago. It was designed for two major purposes: to assess the general hypotheses advanced by B&K against a broader empirical basis, and to deepen the knowledge regarding universals, variation, and historical development in basic color-term systems (Hardin & Matffi, 1997). The methods and some initial results of the WCS are reported in Kay, Berlin, and Merrifield (1991). A large number of comparable data on naming ranges and focal choices for basic color terms was collected on 110 languages, but the survey did not cover Mandarin. A methodological departure of the WCS from the method used by B&K was that chip-naming judgments were obtained on individual chip presentations, rather than the full array of stimuli. Judgments of best example (foci color) were obtained in the same way as in the original study, by requesting selection of the chip or chips that best represent each basic color word of the native language from an array of 330 color patches, representing 40 equally spaced Munsell hues at 8 levels of lightness (at maximum saturation plus 10 levels of lightness of neutral colors black, grey, white). The WCS stimuli and the denotation of stimuli are shown in Figure 2-2.

All of the WCS data and detailed method is open to public for comparative studies (available in http://www.icsi.berkeley.edu/wcs/data.html). The valuable information would be a footstone of comprehending color terminology in all languages.

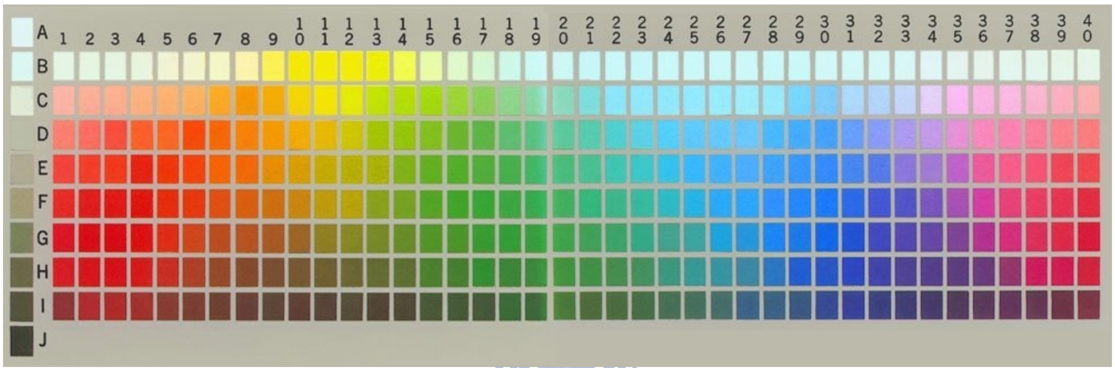


Figure 2.2. Stimulus array used in WCS

2.6. Color naming in Mandarin

The linguistic class that Mandarin belongs to is Sino-Tibetan, Han Chinese. It was originated from northern China and spoken widely by Modern Chinese around the world. Mandarin is the official language in China, Taiwan, Hong Kong and Macaw. The early color term study conducted by B&K classified Mandarin as a language in the developmental Stage V, which holds six color terms, white, black, red, yellow, green and blue. The foci color of these terms can be found in the origin data plot shown in Figure 2-3 (Berlin & Kay, 1969) .

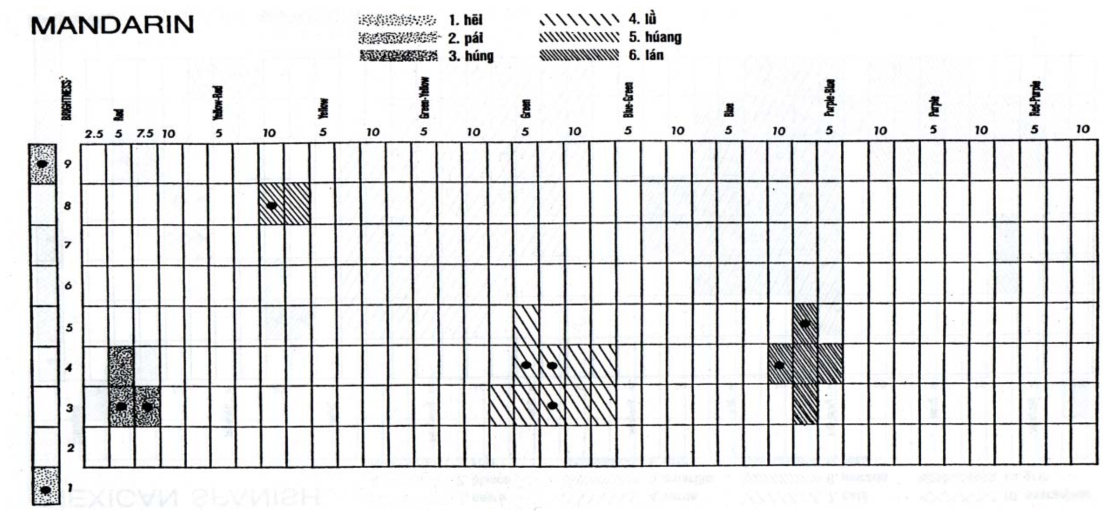


Figure 2.3 Foci color data gained form Mandarin informants (Berlin & Kay, 1969).

However, this conclusion remains controversial for local color researchers. A study conducted in 1990s refuted this finding and made an attempt to provide evidence of a greater variety of color terms in use (Lu, 1997). Actually, B&K left many open questions for the development of color terms in Mandarin. In their report on cross-language survey *Basic color terms, their universality and evolution*, Mandarin was treated as one of the “problematical cases” (in the section 2.5, p41-42). One of the unsolved issues was whether grey is a basic or a tertiary term, due to the inconsistency of the data collected from limited number of non-native speakers. Although B&K tentatively treated Mandarin as Stage V at that time and planned to obtain more data for this language in further research, the later WCS did not cover this language, either. Fortunately a few recent studies did recruit native speakers to address the variety and the range of Mandarin color terms and, thus, provided some reference base for the current study. The comparison of current results with these studies would be given in Chapter 6.

In addition to the empirical and theoretical vacancy of Mandarin color terms, the appropriate translation between English color terms and Mandarin color terms is another thorny problem in the present study, due to the wide variance in Mandarin color terms across regions, times and speakers. There is currently no consensus on the convention of color terms in contemporary Mandarin. Therefore, it is inappropriate to assign basic color names simply by following an existing dictionary. Additionally, the definitions of color terms in Chinese are more ambiguous than in English. There are diverse wording choices to describe the same color category. For example, the brown category can be conveyed by distinct terms like 咖啡 *Ka-fei* (the phonic translation of coffee), 棕 *Tsong* (palm fiber, coir) or 褐 *He* (tan). Similarly, multiple color categories can be expressed with identical color terms. The ancient polysemous term 青 *Ching* can refer to blue, green and sometimes purple and black. Though there are some studies concerning the usage of basic Mandarin color terms (Lin, et al., 2001a, 2001c; Lu, 1997), the translations were unfortunately not consistent, particularly for non-landmark basic terms. The term pink can be translated in two different ways: 粉紅 *Fenhong* (Lin, et al., 2001a) and 桃 *Tao* (Lu, 1997). Brown can be both 棕 *Tsong* (Lin, et al., 2001a) and 褐 *He* (Lu, 1997), and orange can be 橘 Ju (Lin, et al., 2001a) and 橙 Cheng (Lu, 1997).

CHAPTER 3. COLOR LEXICON SURVEY IN MANDARIN

This chapter presents the local survey of color lexicon with the method of free-recall task. The whole survey was designed to compare with the similar survey conducted in 1990s, but with modified procedure. The purpose and methodological details is given in Section 3.1 and 3.2. The statistical results are summarized in Section 3.3.

3.1. Purpose

The free-recall survey was conducted for the purpose of obtaining the data of color vocabulary which is *synchronic* (present linguistic phenomenon without concerning the factor of time, contrast of *diachronic*). Specifically, the obtained data would be the representation of these aspects: (1) popular color terms currently in use by native Mandarin speakers resident in Taiwan, (2) The popularity rank of those color terms, and (3) the diversity of those color terms. A similar survey employed systematic anthropological paradigm was conducted and published in the 1990s (Lu, 1997). The current results would be compared with that in the work and another Japanese study in Chapter 6. A historical change and cultural difference of the popularity of color terms can be expected in that comparison.

In addition to the purpose of surveying color term lexicon, another purpose of this experiment is to the collect conventional Mandarin color terms that would serve as options in the later color sorting experiments in Chapter 5 i.e., 12-terms sorting experiment. There is no consistent translation of Mandarin color terms in previous studies. To solve this problem, the color terms in Chinese Mandarin written form that were to be used in the sorting experiment and future works involving Mandarin color terms would be filtered by this survey. Only the terms that emerged most frequently from the free-recall task were employed.

3.2. Method

This survey was executed without any reference resources in order to elicit the most intuitive and tangible color terms currently in use. There were totally 189 informants performed this free-recall task. The voluntary participants are native Mandarin speakers aged 16-45, education level spanned from high school to PhD, opportunity sampled from undergraduates, postgraduates, engineers, businesses, labors, designers, public officials, home makers, academic researchers, school staffs and teachers. The percentage of visual arts or design professionals was under 10%. The informants were provided with a blank sheet, and a pencil or pen. The task instruction was to "write down color terms/ vocabularies you frequently use, hear and read." After the frequent terms recalling was done, the author encouraged the informant to freely recall color terms as many as he/she could and also write them down on the sheet. The informants were allowed to use any written forms in Chinese as long as the written color terms are recognizable to the researcher. Most informants used traditional Chinese characters, and simplified characters and notional phonetic alphabet were occasionally used. There was no time limit for informants, but they were invited to recall color terms as hard as possible. The recalling task typically took 5-20 minutes. The whole data collection works started from May 2009 to Feb. 2010, and each informant performed the task individually with the instruction of the researcher.

3.3. Results

There were 5102 color terms produced by 189 informants. Several types of color terms were considered to be insufficient for representing both the frequency and diversity of color terms, thus were removing form the raw data. One of the discarded type is those that uses common tone-modified adjectives, e.g. light red, dark red, bright red, vivid red and so on. Another discarded type is a compound of any two or more common color terms, e.g. red-yellow, blue-purple and so on. Although those color terms are valid for describing real color experience, all of them can be classified or decomposed into known color categories.

Moreover, some other terms were also excluded if they were judged to be inadequate in describing the perceptual quality of a simple color, e.g. transparency, fluorescence, neon and so on. Some terms referring to a certain series of colors, e.g. rainbow, candies, sunset, autumn leaves and so on, were eliminated, too. A few unrecognizable color terms were screened out as well. After filtering out those color terms, there are 4961 color terms left, containing 2493 items that were of frequent use and 2468 items that were recalled less consistently.

3.3.1 Descriptive overview

The descriptive statistics of the results are given in Table 3-1. The informants were able to produce 26.25 valid color terms on average, but the individual difference is noticeable in the performance of the later task that solicits more color terms. For the task of recalling terms in frequent use, the central tendency indexes and the STD is relatively small. For visualizing the distribution of the counts of collected terms, Figure 3-1 shows the histograms of the frequency counts of total amount (a), frequent use (b) and extended color terms (c). The results of Gaussian curve fitting capturing these three distributions are presented as well. In the case of frequent use (c) there is a peak at the value of 12, while in the case of extends (b), the curve appears to be leaning leftwards. The distortion of total frequency count (a) roughly fits a normal distribution model but leaves a long right-side tail. In general, these descriptive statistics indicate the capacity of color lexicon produced from the sampled population. There is a significant individual difference in the amount of less frequent terms.

Table 3.1 Descriptive statistics of the color term recall

	Count	Mean	Mode	Median	STD	Max	Min
Total	4961	26.25	20	25	10.7	58	8
Frequent use	2493	13.19	12	12	3.69	26	6
Extends	2468	13.05	8	10	9.12	42	2

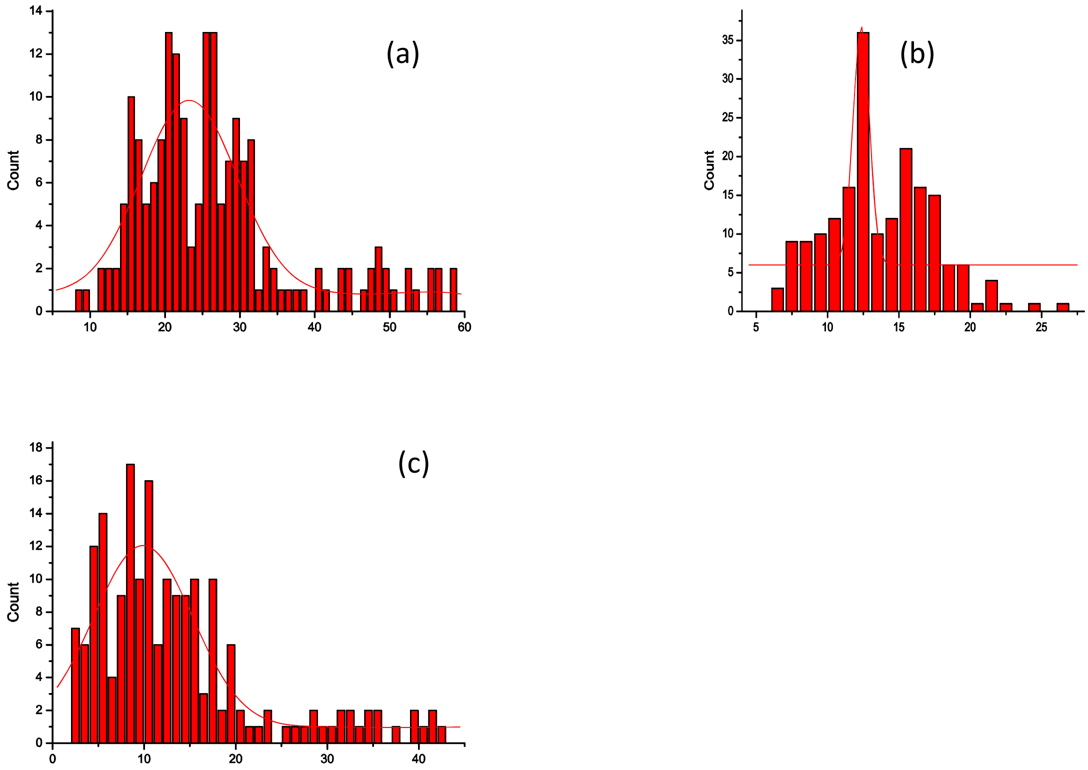


Figure 3.1. Histograms of frequency count of total amount (a), frequent use (b) and the extends (c).

3.3.2 Classification of the collected color terms

The free recall survey gathered a great quantity of color terms with an extraordinary diversity. These samples include the basic color terms representing common color categories mentioned by previous lexical color category related studies. Also, equipped with the flexibility and complexity that Chinese language holds, the informants produced a lot of ornate color expressions. These various color terms were classified into different types in a hierarchical manner as Figure 3-2 shows. The chart presents the organization of Mandarin color terms classification. The numbers are the proportion of each class relative to the total amount (4961) of collected terms, and some block stands for subclasses. The classifying method was extended from some of the previous color naming studies with different tasks, e.g. Guest's free-naming experiment (Guest & Van Laar, 2000).

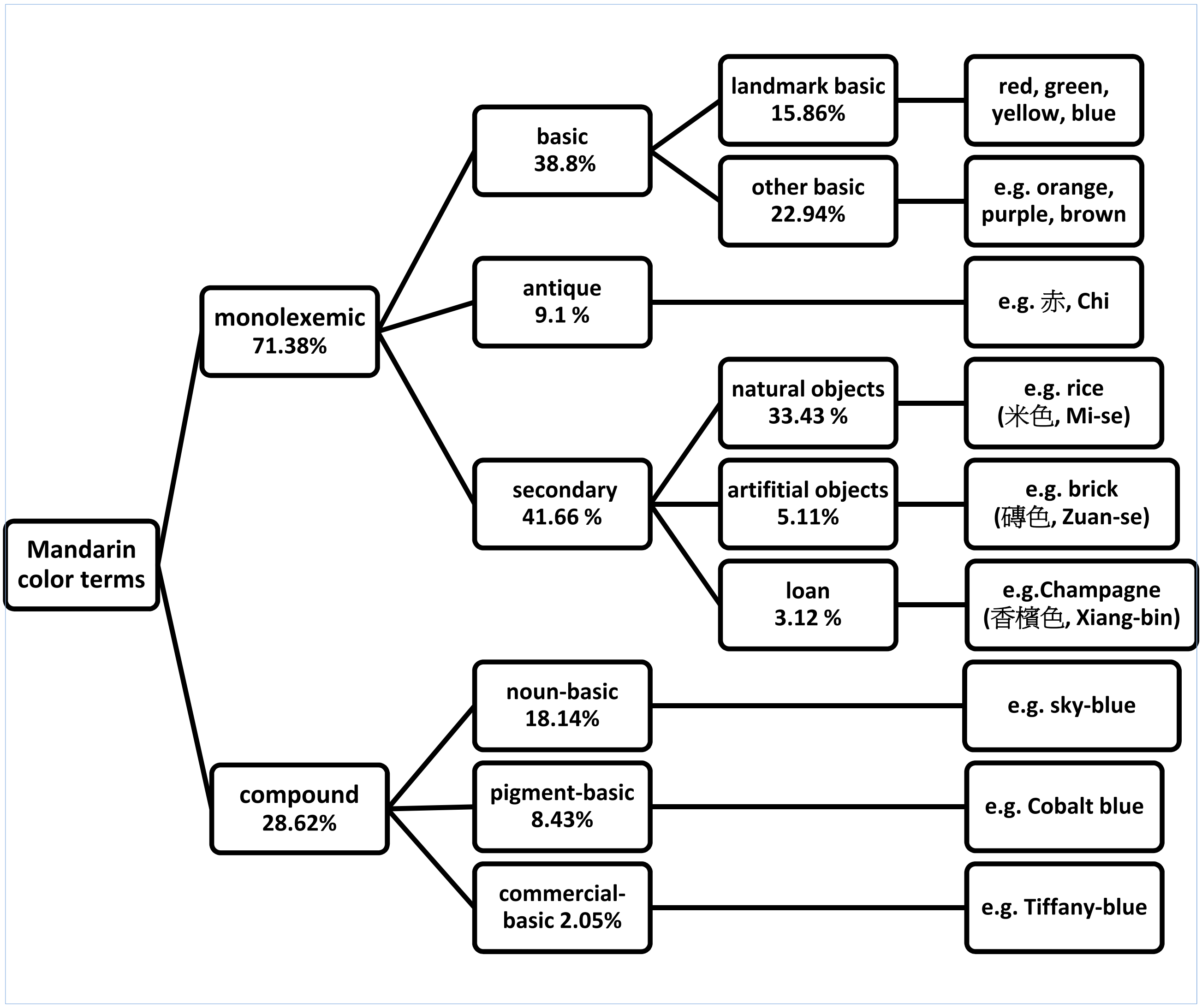


Figure 3.2. A hierarchical classification of Mandarin color terms based on the collected data in the recalling study.

The collected terms were first sorted into either monolexemic or compound classes. The criterion of the monolexemic color term is that it uses only single color vocabulary or noun, or lexeme in the linguistic term. Actually, the participants in many previous color naming studies were constrained with using only monolexemic color terms to generate response (Sturges & Whitfield, 1995, 1997). Some terms contain two or more Chinese characters but indicate a single color category are considered belonging to this class, e.g. 咖啡色(brown) or 紫羅蘭色 (violet). The compound color terms are defined as those consisting of two or more monolexemic color terms, or terms with the adjective. However, if the modifier of the compound is used to describe different shades of same color category, examples in Mandarin are 深, 淺, 濃, 淡, 亮, 暗, (deep, light, dense, pole, bright, dark), that compound is discarded. The subclasses under the monolexemic and compound are defined by the criteria of basic-or-not and origin. There are four subclasses under the monolexemic class:

(1) The basic color term (38.8%): includes four landmark basic terms red, green, yellow and blue, and 7 other basic terms, black, white, grey, purple, pink, orange and brown.

(2) The antique color term (9.1%): includes color terms that are found in classic Chinese literature or used by ancient Chinese. Some of them are still in use in more formal occasions or in idiomatic phrases. For instance 赤 Chi and 朱 Zhu represent red, and 青 Ching represents blue, green or black.

(3) The secondary color term (58.4%): by definition this class should contains all the color terms except for the basic color terms. But in current context the class is defined as monolexemic color terms except for basic and antique color terms. These terms can be further distinguished as deriving from either natural or artificial materials. The color terms in this subclass demonstrates many culture signatures compared to the previous reports of secondary color terms in English. For instance, the term 茶 Cha(tea) represents a reddish dark brown and could be similar to walnut in English, and 藕 Ou (lotus root) represents a unique shade of pale, pinkish grey. Some man-made materials, e.g. 磚 Zhan (brick), represent brownish red or orange. Also there are many secondary color terms that were transliterated from foreign languages and do not have local origins, such as 咖啡(café) and 香檳(champagne). They represent the general brown category and a glimmering light yellow respectively.

The sub-classification of compound color terms is rather challenging since their variability is larger than that in monolexemic class. But they are all comprised of a modifier of various origins and one common basic color terms. There are four distinguishable subclasses:

(1) Noun-basic color terms (18.14%): includes compound terms consisting of a noun referring to a specific object and a basic color terms, e.g. sky-blue, tomato-red,

lake-green, grass-green, ivory-white, wine-red and so on. Many of these terms are modified with common objects thus can be directly translated into English without much distortion. Such terms can convey more specific color quality than a single basic, or a single secondary color term.

(2) Pigment-basic color terms (8.43%): includes compound terms used in the context of painting, glazing or dyeing industry, and the specialized modifier in front of the basic term is related to the chemical or cultural origin, e.g. 鈷藍 (cobalt-blue), 藤黃 (gamboges yellow), 土耳其藍, (Turnkey-blue), 洋紅(Western-red), 普魯士藍 (Prussian-blue). Some terms originated from the pigments of Chinese painting but many others are loanwords or translated ones.

(3) Commercial-basic color terms (2.05%) : These are compound terms comprised of the name of a celebrated brand or well-known commercial image, including four consensus terms Tiffany blue, Ferrari red, Kitty pink, and Hermes orange. These terms were rarely recalled, but to whom exposed to these commercial images, they are precisely linked to that very unique color shade representing the whole image of the brand or the product series.

The above classification principles are set for clarifying the common composition of Mandarin color terms. Two terms fits the characteristics of compound but stands for the color category. They are pink, i.e., Fen-Hong (粉紅, directly translated as powder-red) and Tao-Hong (桃紅, directly translated as peach-blossom-red), which are classified into monolexemic class due to the shortage of a simplex lexeme representing pink in Mandarin. Also, the sub-divided types under the monolexemic class are not mutually exclusive. Specifically the antique are overlap with the secondary type.

3.3.3 Popularity of the monolexemic color terms

Table 3-2 summarizes the rank order and the frequency counts of all collected monolexemic terms.

Table 3.2. Rank list derived from monolexemic Chinese color terms.

R k.	Ct	Ch.	Ph.Trans .	English	Freq. use		Extends		Subclass
					ct	%	ct	%	
1	18	紅	Hong	red	182	97.3	5	2.67	Landmark basic
2	18	藍	Lan	Blue	184	99.4	1	.54	Landmark basic
3	18	紫	Zi	Purple	176	95.6	8	4.35	Other basic
4	18	綠	Lu	Green	178	97.8	4	2.20	Landmark basic
5	17	橘	Ju	Orange/tangerin	174	97.2	5	2.79	Other basic
6	17	黃	Huang	Yellow	169	94.9	9	5.06	Landmark basic
7	17	粉紅	Fenhong	Light pink	145	82.8	30	17.1	Compound/Other basic
8	16	咖啡	Ka-Fei	Brown/Coffee	123	75.9	39	24.0	Other basic
9	15	橙	Cheng	Orange	105	66.0	54	33.9	Other basic
1	15	褐	He	Brown/tan	94	59.8	63	40.1	Secondary-natural /Other basic
1	14	灰	hui	Gray/ash	126	85.1	22	14.8	Other basic
1	13	桃紅	Taohong	Dark pink	107	78.1	30	21.9	Compound/Other basic
1	13	棕	tsong	Brown/palm	88	65.6	46	34.3	Secondary-natural /Other basic
1	13	靛	Dian	deep blue/indigo	62	47.3	69	52.6	Secondary- artificial
1	11	青	Ching	Green/Blue/black	55	47.4	61	52.5	Antique
1	10	膚	Fu	Skin	89	84.7	16	15.2	Secondary- natural
1	93	金	Jin	Gold	51	54.8	42	45.1	Secondary- natural
1	89	米	Mi	Rice / Beige	64	71.9	25	28.0	Secondary- natural
1	88	茶	Cha	Tea	52	59.0	36	40.9	Secondary- natural
2	85	赤	Chi	Red	7	8.24	78	91.7	Antique
2	84	銀	Yin	Silver	56	66.6	28	33.3	Secondary- natural
2	51	紫羅蘭	Zilolan	Violet	2	3.92	49	96.0	Secondary- loan
2	39	黑	Hei	Black	39	100.	0	.00	Landmark basic
2	38	卡其	Ka-qi	Khaki	32	84.2	6	15.7	Secondary- artificial
2	36	駝	Tuo	Camel	17	47.2	19	52.7	Secondary- natural
2	35	白	Bai	White	35	100.	0	.00	Landmark basic
2	34	杏	Xing	Apricot	15	44.1	19	55.8	Secondary- natural
2	32	橄欖	Ganlan	Olive	12	37.5	20	62.5	Secondary- natural
2	32	土	Tu	Soil / Earth	14	43.7	18	56.2	Secondary- natural
3	30	玫瑰	Meigui	Rose	11	36.6	19	63.3	Secondary- natural
3	29	磚	Zhuan	Brick	20	68.9	9	31.0	Secondary- artificial
3	28	藕	Ou	Lotus root	18	64.2	10	35.7	Secondary- natural
3	26	香檳	Xiangbin	Champagne	12	46.1	14	53.8	Secondary- artificial/loan
3	25	朱	Zhu	Red/ Cinnabar	4	16.0	21	84.0	Antique/Secondary- artificial
3	24	小麥	Xiaomai	wheat	9	37.5	15	62.5	Secondary- natural

3	23	芋	Yu	Taro	10	43.4	13	56.5	Secondary- natural
3	20	墨	Mo	Ink/black	8	40.0	12	60.0	Antique/Secondary- artificial
3	18	奶油	Nai-you	Cream	6	33.3	12	66.6	Secondary- natural
3	13	翡翠	Fei-cui	Emerald	1	7.69	12	92.3	Secondary- natural
4	10	古銅	Gutong	Bronze	3	30.0	7	70.0	Secondary- natural
4	9	玄	Xuan	Dark/Black	0	.00	9	100.	Antique
4	8	珊瑚	Shanhu	Coral	2	25.0	6	75.0	Secondary- natural
4	7	碧	Bi	Jasper	1	14.2	6	85.7	Antique/ Secondary- natural
4	7	赭	Zhe	Sienna/ocher	0	.00	7	100.	Antique/ Secondary- natural
4	6	珍珠	Zhenzhu	Pearl	1	16.6	5	83.3	Secondary- natural
4	2	紺	Gan	Dark purple	0	.00	2	100.	Antique/ Secondary- natural

The circulation and distribution of monolexemic color terms are the most representative information for probing the color lexicon within a language. Table II provides the statistical results of collected monolexemic terms. The columns from top left to right are the ranking order, denoted as Rk., the frequency count (Ct.) of each, the color terms in written Chinese (Ch.), in phonic transliteration (Ph.Trans.), in English, the frequency counts (ct) and percentage (%) of the term recalled in the prior task regarding color terms in frequent use (Freq. use), the same data in later task of recalling more extends, and the last column denotes the subclass each term belongs to, some terms are qualified for more than one subclass. For visualizing the quantity and proportion of the monolexemic terms, the histogram shown in Figure 3-3 represents the frequency count of each recalled monolexemic color term, with black and white fill to distinguish either the term was mentioned in the frequent use task or the extends task. The total count of each term are positively correlated to that count in the frequent use task (Pearson correlation coefficient=0.95). The level of 100%, 75%, 50% and 25% threshold are marked with horizontal dash-lines.

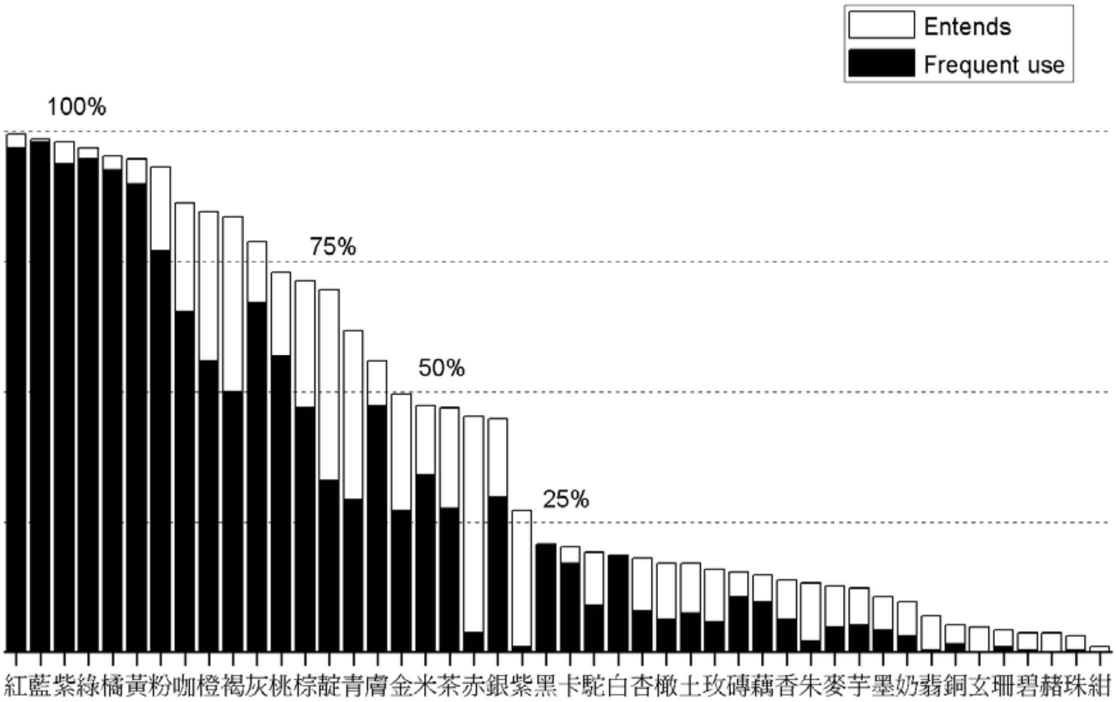


Figure 3.3. The frequency count histogram of monolexemic color terms.

In general, the results shown in above table and histogram reveal the popularity and the degree of consensus of the collected monolexemic color terms. The top 15 terms encompass B&K's universal color categories, though some overlapping terms in the same categories are evident. For instance, the term 8th, 10th and 13th all refer to brown category, and 7th and 12th can stand for pink category, and 5th and 9th for orange category. These rank order data provide the base for selecting proper Chinese translations in subsequent color-term-sorting experiments. Black and white were not frequently recalled as they ranked in the 23th and the 26th respectively, perhaps due to many informants account these two achromatic terms.

The more popular terms are distinct color concepts featuring in hue identity, e.g., red, blue, purple, green, orange and so on, and all these are frequently used in modern society and are legible in both colloquial and writing. The count of terms decreases with its distinctiveness in color appearance, but those less frequently recalled terms can represent a delicate tone by using a specific object as a metaphor. There is a plunge between the 22^{th} and the 23^{th}, all terms from there on were counted fewer than 25%, and half of the collected monolexemic terms are below this level.

It is worth noting that many different terms refer to a same brown category. The informants produced multiple secondary terms, e.g. 咖啡(coffee), 褐(Tan), 棕(Palm), 茶(Tea), 駝(Camel), 土(Soil/Earth), that are linked to colors of brown category. However, from the current recalling data, it is difficult to tell whether these could indicate different shades within brown category, or they are just different individual idioms for describing a similar color range. This question would be clarified in the free-naming experiment presented in Chapter 4.

CHAPTER 4. MANDARIN COLOR NAMEING SPACE

This chapter presents a naming work and the derived color naming space. The color naming task with systematic arrangement of stimuli was able to confirm the structure of internal cognitive space of color in previous study employing English speakers as participants (Guest & Van Laar, 2000). Due to the linguistic differences between English and Mandarin, the categorical color space derived from the behavioral data of naming task was expected be different. The purpose and methodology of the experiment is described in Section 3.1 and 3.2. The results are given in Section 3.3.

4.1. Purpose

The research work presented in this chapter is based on the observation of a free color naming task. Color naming used to be considered an unrespectable psychophysical technique in the scientific field of color research (Boynton, 1997), even though B&K's landmark report on the universality of color naming results had impressed many color vision scientists. However, in 1960s Boynton and his fellows applied this method to investigate theoretical issues such as verifying the psychological primary hues (Sternheim & Boynton, 1969) and characterizing the Bezold Brüke hue shift (Boynton & Gordon, 1965). Subsequently color naming was widely adopted in various paradigms such as chromatic adaptation (e.g. Jacobs & Gaylord, 1967), developmental studies (e.g. Dale, 1969; Kimball & Dale, 1972), and categorical color perception, (e.g. Bonnardel, 2006; Guest & Van Laar, 2000; Regier, et al., 2007; Roberson, et al., 2000). The boundaries of lexical color categories do not comply with the perceptual distance determined in approximately uniform color spaces such as Munsell, CIELUV and OSA. (e.g. Guest & Van Laar, 2000, 2002; Sturges & Whitfield, 1995, 1997)

The purpose of free color naming scheme in current work is twofold. The first is to investigate the lexical color categories in color naming space within Mandarin speakers. Language is a common way for communicating color experience, but the lexical color categories in color naming to not equal to the perceptual distance determined in known approximate uniform color spaces. The categorical structure of color naming space has been intensively examined (Guest & Van Laar, 2000, 2002; Lammens, 1994), but these studies are conducted with English speakers. The factor of culture difference cannot be ruled out completely in the theoretical issues of color naming. The linguistic coding style and task difficulty in Mandarin could be different from that in the English literature.

Another purpose is to collect the secondary color terms and tone modifiers in frequent use, such as light, dark, and vivid. The free-recall survey reported in Chapter 3 had collected large amount of secondary color terms with high diversity, but the purpose of that survey is qualitatively different with the present work, as these are two distinct cognitive tasks. The color terms acquired in the free- recall task were elicited from the participants' long term memory and depended heavily on individuals' color literacy, while those in this work were elicited under the pressure of naming specific color stimuli adequately. The researcher thus expected such method would collect empirical data of color modifiers in common use and their corresponding chromaticity ranges.

4.2 Method

Participants

There are 36 trichromates screened with Ishihara test participated in the experiment. All participants are native Mandarin speakers capable of using spoken and written Chinese, background sampled from graduate, undergraduates and staff on campus, aged from 19-36, 19 females and 17 males, and few of them had took part in the previous free-recall task. All participants are naive to the purpose of the study, and have no formal training in color science.

Stimuli

There are 121 evenly sampled stimuli sweeping the 50 cd/m^2 level of CIE x-y diagram within the available gamut constrained by the display media. Sampling interval on x and y axis is 0.25, to produced a regular and evenly spaced sample space as that plotted in Figure

4.1. The peak white of the screen (x=0.319, y= 0.335), was defined as the reference white in the study. Although the CIE x-y diagram is not a perceptually-uniform color space, the chromaticity coordinates can be transformed into that of various approximately uniform color spaces, e.g. Musell (Boynton, et al., 1989; Sturges & Whitfield, 1995) or LUV(Guest & Van Laar, 2000), or the latest CIECAM2000 color appearance model, and the results can be compared with that in related studies. The results would be directly compared with some important studies adopting CIE x-y diagram as well, such as the survey of Japanese lexical color categories (Shinoda, et al., 1993) .

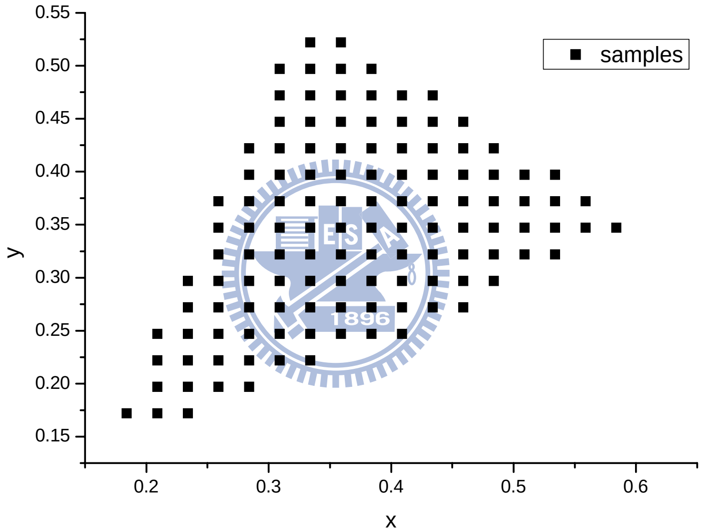


Figure 4.1 Stimuli plotted on CIE x-y diagram at 50 cd/m^2 luminance level.

Apparatus

Stimuli were presented and controlled by an ASUS F6E 13.3" laptop. The output uniformity and stability check of the LCD was carried out according to a standardised procedure. A well-calibrated PhotoResearch™ PR-650 SpectraScan spectroradiometer was used to repeatedly measure the center output of the LCD. The measuring distance was 355mm, and the sample size was 10cm^2, covering the whole field of the spectroradiometer lens. The measuring geometry followed the recommendations of PhotoResearch, Inc. The adopted standard observer model was CIE1931, and the reference white selected was D65. The mean output intensity was 235.8cd/m^2 (STD=3.28, maximum value=241 cd/m^2 (+2.11%), with a minimum value of 229cd/m^2 (-2.96%)). A look-up table was generated by the standard measuring procedure, and a Matlab interpolation function was used to produce all color stimuli. The mean errors of all stimuli in chromaticity were also checked by the spectroradiometer; these were 4.42cd/m^2 in L, 0.006 in *x* and 0.004 in *y*.

The stimulus was displayed in a square, sized 2° by 2° visual angle at the required viewing distance of 50cm. Each stimulus was displayed in the exact center of the monitor. The background of the stimulus square was set at 50cd/m^2 to produce an equal-luminance scene. In addition to the stimulus square, there was a thin black border surrounding the square and a white thin border surrounding the black border. Both the inner black and outer white borders were 0.2° wide. The double border design provides the viewing condition with the reference white and the lowest L level of the display medium. Additionally, the border reduces the L contrast effect between the stimulus and the background, and keeps the viewer's attention on the stimuli.

Procedure

The experimental procedure was identical to that of the previous studies on the structure of color naming space (Guest & Van Laar, 2000). The naming work was conducted in a chamber without illumination except for the display screen. The observers were presented with the stimuli and then asked to freely name the color on a trial. The researcher instructed the observer to give the name that could be used to describe that color to others acceptably. The observers were stressed to respond as fast as possible, and they were also aware of that the response times (hereafter RTs) were recorded. Further, following the production of a name, the observers were asked to give a confidence rating along a scale of one to five. This rating corresponded to the confidence level that the observer would name the same name if it were present again. There are totally 121 naming trials presented in random order, and the researcher was present in the experiment chamber throughout all trials. The initial 20 trials were for practice only and the results were discarded. The average time for each observer to accomplish the experiment is 40 minutes.

4.3 Results

4.3.1. Classification methods

The free naming experiment had produced 4356 color terms in total, and these terms would be sorted into different classes for further investigation. The classification method follows that used in two previous free-naming studies (Guest & Van Laar, 2000; Lin, Luo, MacDonald, & Tarrant, 2001), with slight necessary modifications in accordance with the quality of the current data. The organized structure of the classification method is shown in Figure 4-2. The hierarchical chart presents the classification of each sub-class and abbreviation, the percent occurrence to total amount, and examples in each of the sub-class. Similar to the hierarchical principle of classification method in free-recall survey presented in Chapter 3, all the color terms were first divided into monolexemic and compound terms, the monolexemic class also contains sub-classes like landmark basic(LB), other basic(OB), secondary (S) and antique (A) color terms. The characteristics of the compound class are qualitatively different from that in the previous free-recall survey. In the free-recall, it was forbidden to produce compound terms composing of common basic color terms and common color modifier, due to the purpose of the free-recall task was to elicit the largest diversity of color expressions. However, the usage of color terms was not contained in the current free-naming work. In view of the variety of the produced polylexemic terms, the compound class is further divided into five forms of sub-classes: basic-basic (BB), secondary-basic (SB), modifier-basic (MB), modifier-secondary (MS), and complex (C). The first four are composed of two lexemes, while the complex sub-class of three or more lexemes.

This classification chart gives a general profile of the usage of Mandarin color terms.

The most noticeable discrepancy between the current data and that of English speakers is the ratio of monolexemic and compound. In other free naming studies, the occurrence percentage of monolexemic and compound is 65.7% and 34.4% respectively (Guest & Van Laar, 2000), while that in this study is 40.9% and 59.1%.

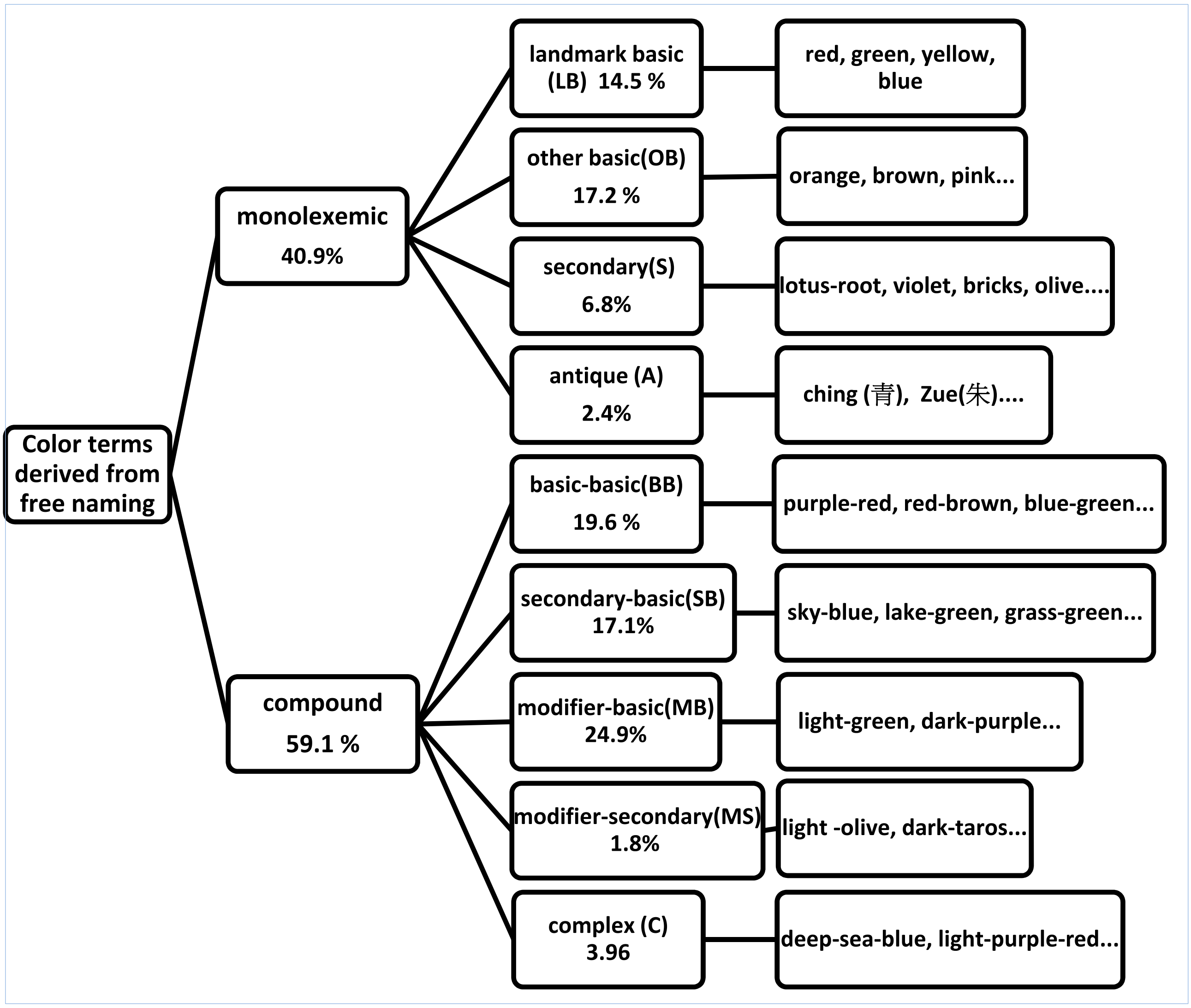
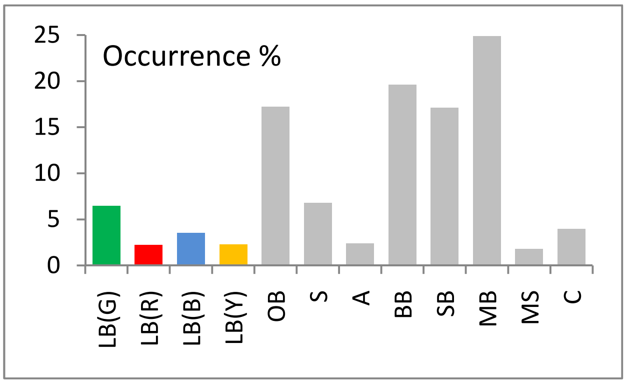
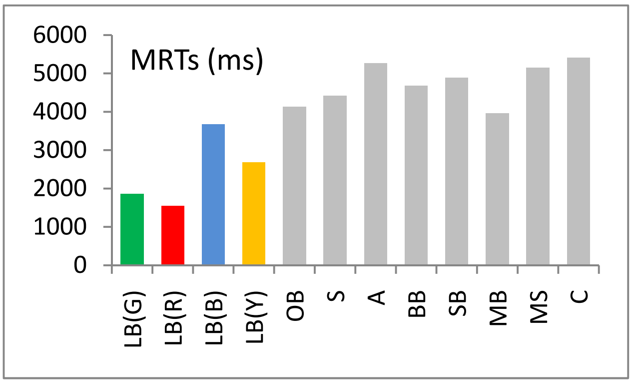


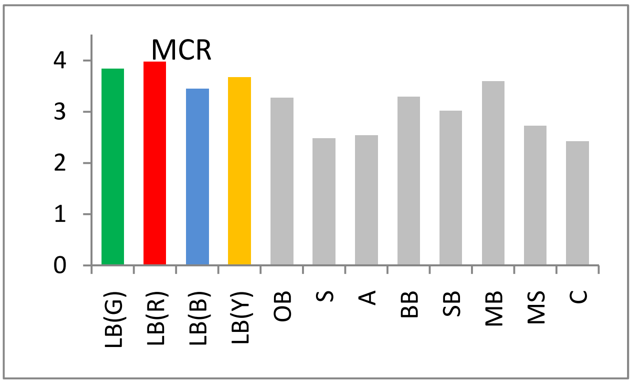
Figure 4.2. The structure of classified color terms

4.3.2. The characteristics of different classes

The four histograms in Figure 4-3 give a statistical overview of the collected data. The first top histogram presents the occurrence rate of each sub-class. The researcher noticed the landmark basic terms, namely the LB class members red, green, yellow and blue do not behave uniformly, thus need to be singled out and marked separately. The second histogram shows the mean response time (ms) of the classes. Within the LB class green and red responses result in the shortest RTs, but the RTs for blue and yellow are longer. The RTs in LB are generally shorter than that in other classes. In the compound classes, the MB (modifier-basic) class shows a relatively short RTs, indicate the combination of the common modifier and basic terms are easier to retrieve than other forms of compound.







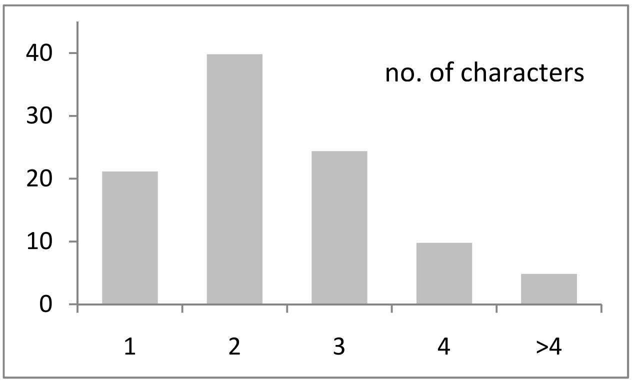


Figure 4.3. From histogram of top to bottom: occurrence (%), mean response times, mean confidence rating, and numbers of Chinese characters of collected data. More details are given in the text.

The third histogram is the results of mean confidence rating (MCR), which is an evaluation score of each naming trial given by participants them self. RTs and CR are both sensitive indexes to task difficulty in color naming research. The MCR of the LB class is higher than the other complex forms of color terms, and red responses gained the highest MCR. The bottom histogram shows the frequency distribution of the color terms composed of one to more than four Chinese characters. The number of composing characters is a simple but effective index reflecting the complexity of color term peculiar to Chinese Mandarin. From the current results, the two-character color terms are in majority.

The detailed descriptive statistics of the collected data are summarized in Table 4-1, including the examples of color terms and the mean response time (MRTs), mean confidence rating (MCR), and the occurrence rate of each class. The sub-classes of color terms in each row correspond to that in Figure 4-2. Only the color terms that were named more frequently (frequency count more than 87, i.e. over 2% occurrence to total amount) would appear as examples in the column of Mandarin and English translations. Notice that the column of MB (modifier-basic) class only listed the modifiers. The color terms shown in this table were reported with relatively higher consistency and frequency during the free naming experiment. There is no color term surpassing 2% occurrence threshold (87 repetition times) in the MS (modifier-secondary) class as this form of color term is rarely used by Mandarin speakers.

Also the C (complex) class contains no item of high consensus. There are 39 color terms (for the MB class researcher counted the frequency of modifiers in order to bring out the modifier terms in common used) standing out when screened by the 2% occurrence consistency and frequency threshold. These terms provide valuable information about color idioms in current use.

Table 4.1. Statistic summary of collected terms (each occurrence percentage over 2%)

Class	Mandarin	Eng. Translation	MRTs (SD)	MCR (SD)	%
LB	綠	Lu (Green)	1854 (894.31)	3.84 (0.96)	6.48%
	紅	Hong (red)	1541 (903.57)	3.98(0.80)	2.21%
	藍	Lan (blue)	3672 (1521.49)	3.45 (0.69)	3.53%
	黃	Huang (yellow)	2683 (1178.03)	3.67 (0.73)	2.28%
OB	橘，咖啡，粉紅，桃紅，灰，橙，紫，褐，棕	(refer to Table 3-2)	4126 (1347.69)	3.27 (1.14)	17.2%
S	藕	Ou (Lotus root)	4419 (1559.13)	2.48 (1.0)	6.8%
A	青	Ching (blue, green, black)	5263 (2305.42)	2.54 (0.77)	2.4%
BB	藍綠，藍紫，灰綠，藍灰，橘紅，黃褐，紫紅，黃綠，橙黃	blue-green, blue-purple, grey-green, blue-grey, orange-red, yellow-brown purple-red, yellow-green orange-yellow	4673 (1724.60)	3.29 (0.95)	19.6%
SB	橄欖綠，草綠，芋紫，天藍，墨綠，土黃，葡萄紫	Olive-green, grass-green, taros-purple, sky-blue, ink-green, earth-yellow, grape-purple	4889 (1648.1)	3.02 (1.13)	17.1%
MB	亮，暗，淡，粉，淺，深，偏，正	Bright, dark, pale, powder, light, deep, -ish, central/correct	3960 (1578.29)	3.60 (1.03)	24.9%
MS			5142 (1910.88)	2.73 (1.27)	1.8%
C			5406 (1259.93)	2.42 (1.09)	3.96%

There are diverse and larger amount of color terms recalled in previous free-recall survey, but in the task-orientated naming work only 39 color terms or modifiers are repeatedly used. The pattern of these terms is described as following:

(a) The LB class: this class contains the perceptually unique hue, the most familiar and salient basic color categories, red, green, blue and yellow. It thus results in relatively short RTs and high CR compared with other classes. The green and red responses are more confident and rapid than that of blue and yellow. The usage of the term blue results in the longest RTs, lowest CR and least consensus (as in the Figure 4.4 in next section), which is a point worthy of further study in itself.

(b) The OB class: contains terms representing the rest of B&K's basic color categories except for black and white. The brightness of the stimuli was constrained at 50cd/m^2. The terms for describing color categories of purple and grey are 紫(Zi) and 灰(hui) respectively. However, similar to the phenomenon in free-recall survey, there are three different terms, 咖啡(Ka-fei), 褐(He) and 棕(Zong), were used for representing brown category. Likewise, the pink category was divided into 粉紅(Fen-Hong)or 粉(Fen), and 桃紅(Tao-Hong), and orange category can be both 橘(Ju) or 橙(Cheng). Among these terms, 咖啡, 粉紅 and 橘 are the most frequently recalled and used terms corresponding to brown, pink and orange categories in both survey. However, these terms are translated inconsistently in Chinese-English dictionaries and in previous studies regarding Mandarin color terms (Lin, et al., 2001; Lu, 1997). It is therefore necessary to determine whether these terms are synonyms denoting the same color categories, or these are sub-categories used to represent different shades within or between major categories. The S class: There is a remarkable discrepancy of number of the collected secondary color terms in free-recall and free-naming works. There is only one term 藕(Ou, lotus root), a shade of pale grayish pink, surpassed 2% occurrence. Other terms overlapping with those in the free-recall task such as 磚(Zhan, brick), 卡其(Ka-qi, khaki) or 土(Tu, soil) were sparsely reported. One possibility is that the stimuli for naming are limited, while many secondary terms cover the brightness range beyond the 50 cd/m^2 level , such as 膚(Fu, skin) or 米(Mi, rice) are used for representing very light warm colors. Another reason is the secondary color terms are rarely used alone in the task-oriented naming experiment. Many secondary terms were used as hue-modifiers in front of basic colors terms, such as sea-blue, olive-green or grape-purple. This sort of color terms are classified as the SB class, which results in higher occurrence rate (17.1%) than S class (6.8%).

(c) The A class: contains color terms appeared in ancient classical Chinese literature or pigments of Chinese painting, such as 青(Ching), a widely applied color term representing the colors from green to blue, sometime even covers purple and black. This word was unsurprisingly mentioned for over 2% occurrence rate in the experiment, mainly used for naming stimuli of bluish green or light green. In contrast to the color terms in Chinese vernacular, a single antique color terms are rarely used in everyday color reference. But some of them served as hue-modifier in the naming task, such 朱紅 (Zhu-Hong, bright red).

(d) The BB class: accounts for 19.6% occurrence, which is a very common pattern of compound color terms. This sort of color terms is composed of two basic color terms in order to describe the ambiguous shades locating between two color categories. However, due to the flexibility of Chinese grammar, the syntax of this type is somewhat controversial since the precedent basic term is difficult to tell its functional identity as a noun or a hue modifier. For example, 藍綠 could means blue-green or bluish green in English. Currently the researcher treats these as simple compound nouns. The combinations of two basic terms seem to be constrained in some conventional rules and perceptually-logical order, instead of arbitrarily piecing any two terms together. One of the obvious rules is the composed color terms are neighboring in the hue circle, such blue-green and orange-red. Terms like yellow-red or green-purple were never found. Secondly, there are idioms with specific combination order using for describing the color located between two color categories. For example, the color between yellow and orange would be always named as 橘黃 (orange-yellow) but never named as 黃橘 (yellow-orange). Generally, red, yellow green are mostly placed as the second noun.

(e) The SB class: contains the compound terms composed of a secondary color term or noun with a basic color terms. The frequently occurred terms including olive-green, grass-green, sky-blue, taros-purple, ink-green, soil-yellow and grape purple. It is remarkable that there is larger diversity in the usage of secondary terms or nouns for describing colors in green, blue and purple categories.

(f) The MB class: this sort of compound terms is composed of a tone modifier and a basic color term. The front modifier could modify the perceptual dimensions of hue, brightness or saturation of the main color term. The frequently used modifiers including 亮(bright), 暗(dark), 淺(light), 深(deep), 淡(pale), 粉(powder), 偏(-ish) and 正(canonical/correct). The first two correspond to the brightness of the color, while the third and the fourth are more related to the saturation level. The modifier 淡(pale) is usually used to describe a lighter tone than 淺(light), and 粉(powder/whitewash) is a unique Mandarin color modifier used to describe light, clean colors with opaque quality. The color terms modified by 粉 are always associated with feminine or childishness. The modifier 偏(-ish) is used to modify the hue of a color, such 綠偏黃 or 偏黃綠(yellowish green), which is in contrast to 正(canonical/correct). The modifier 正 is always used as a stimulus approximates the focal color of a color categories, especially in the cases of landmark basic terms.

(g) The MS class: is a type of combination of modifier and a secondary color term. This sort of compound terms resulted in a low occurrence rate of 1.8%, which is lower than that in the English naming study(Guest & Van Laar, 2000).

(h) The C class: includes complex composition of more than two color terms and modifiers, such as 淺藍綠 (light blue-green) or 偏黃橄欖綠 (yellowish olive green). There is no term surpassed 2% consensus level in this class. This sort of color terms appear more frequently than the Antique and MS classes (3.96%, 2.4% 1.8% respectively), and more than the rate (1.4%) of the same type of polylexemic terms observed in the English naming study (Guest & Van Laar, 2000). However, the low value of CR and consistency along with longer RTs of this class suggest that this type of complex color terms is an unstable color expression. This form of terms is usually found in the responses to stimuli located between two or three main color categories with low saturation.

4.3.3. The structure of color naming map

A color naming map shown in Figure 4.4 was derived by labeling the color sample with the most consensual term (the mode) of each stimulus. The stimuli plotted on the diagram are marked with colored bubbles along with the term in traditional Chinese characters. The color of the bubbles is the host color category the stimulus was consistently named into. The size of the bubbles represents the size of the mode, i.e., the consistency of the naming results. Some bubbles are filled with two colors, representing the BB class, namely the combination of two basic colors. The larger bobbles are distributed around the peripheral districts, which are zones of higher chromaticity purity. The consensual terms correspond to nine color categories, red, orange, yellow, green, blue, purple, pink, brown and grey, and the location of the centroid of like terms could be considered as the foci color of each category. However, the size of mode of these terms is quite hue-dependent. The colors 紅(red), 綠(green), 橘(orange) and 灰(gray) resulted in larger sizes of mode, while that of 藍(blue), 黃(yellow), 桃紅(pink), 紫(purple), and 咖啡(brown) are smaller. The larger mode indicates a given stimulus matches the focal color of a category better among different observers, and the chromaticity location of the stimulus can be viewed as the best exemplar of the category. However, the less consistently named categories, such as 藍(blue) and 紫(purple), could be attributed to two reasons. The first is the fixed luminance level and constrained chromaticity range of the stimuli could not capture and represent the foci color. The later color sorting experiment covering a wide range of luminance levels would examine this possibility.

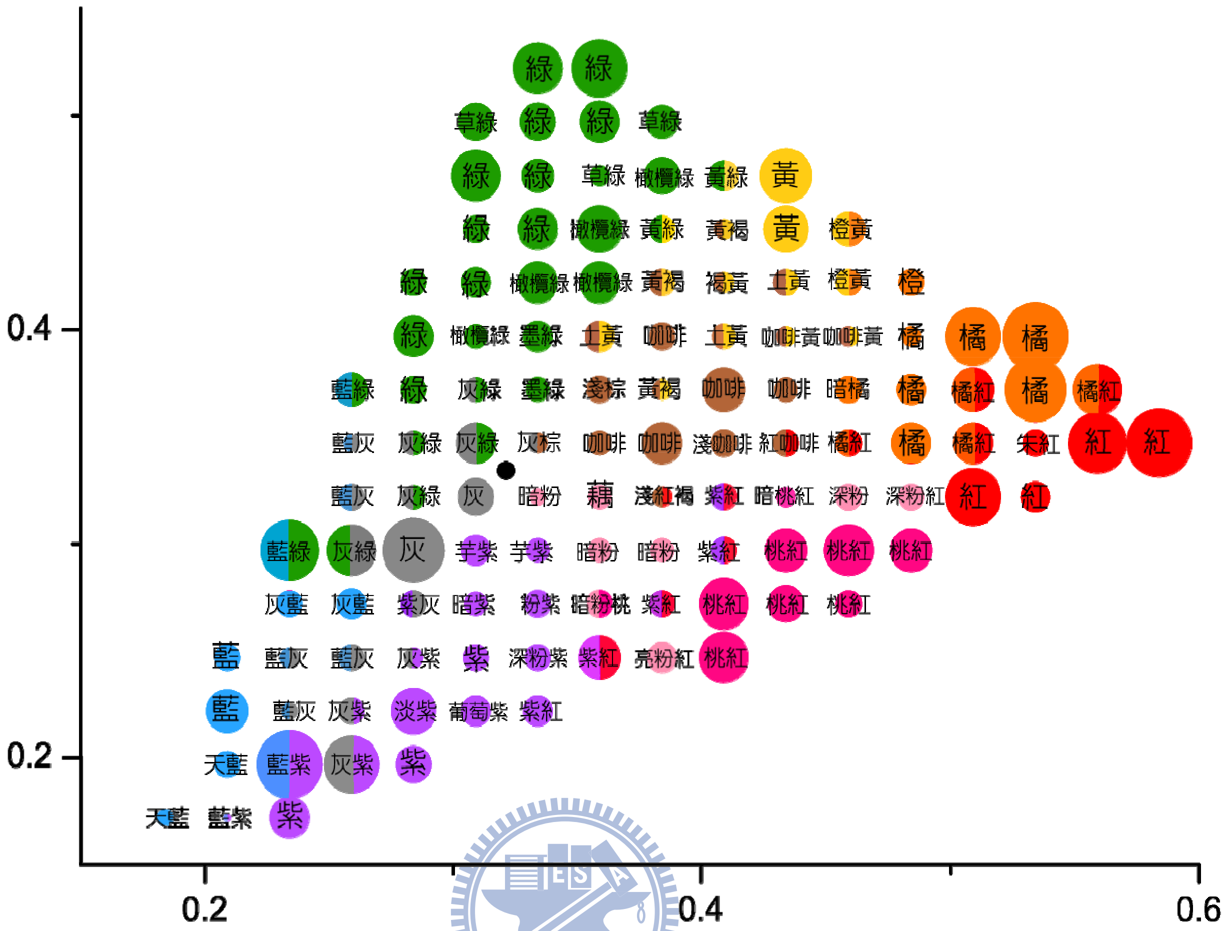
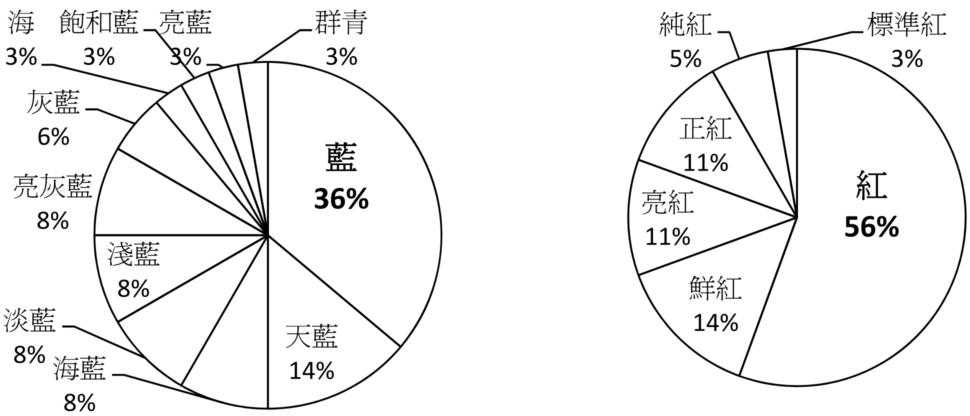


Figure 4 .4. The color naming map derived from the results of color naming experiment. Each color bubble represents the location of the stimulus, and the color of the bubbles is the host color category defined by the mode of the collected terms. The size of the bubble represents the size of the mode. The black dot within the triangle of stimulus points is the reference white of the screen.

The other plausible reason to explain the low consistency of certain hues is that observers might hold richer vocabulary to express the appearance of these colors. The pie charts in Figure 4-5 present the different varieties of color names between the stimuli of larger modes (right two charts, red and orange) and that of smaller modes (left two charts, blue and brown). The left two pie charts show the composition of different color terms that were used to express the focal blue and brown stimuli. The right two charts are the cases of red and orange. Some hues tend to arouse association with objects in natural scenes. The simple square stimuli filled with typical blue color would elicit the naming responses not simply "blue", but sky-blue, sea-blue and so on. Similarly, observers name brown stimuli not only "brown", but also khaki, deep skin, warm palm and so on. The naming for green and purple also involves diverse secondary color terms as hue modifiers. The naming of typical red stimulus shown in the chart is relatively straightforward. In addition to the simple naming with "red", other terms are "red" modified with modifiers such as bright, vivid, pure, and stander and so on.

As presented in previous session, the confidence and response time statistics are better for all landmark colors than the other classes of color terms. This result is consistent with the result of the English color naming study (Guest & Van Laar, 2000) . That study also collapsed the measures of consistency, RTs and confidence rating into a unitary "nameability", a single index representing the ease of naming colors. The concurrent study chooses to represent these data separately lest compromising the acuity of the original measures. Figure 4-6 show the unsmoothed contour map of mean confidence rating. The darkness of the fill between contour line is the level of confidence. The darker an area is, the higher the confidence rating. The distribution of dark and light zones roughly matches the size of mode presented in Figure 4-4. The match, however, is less consistent with the pattern of RT contour map plotted in Figure 4-7.



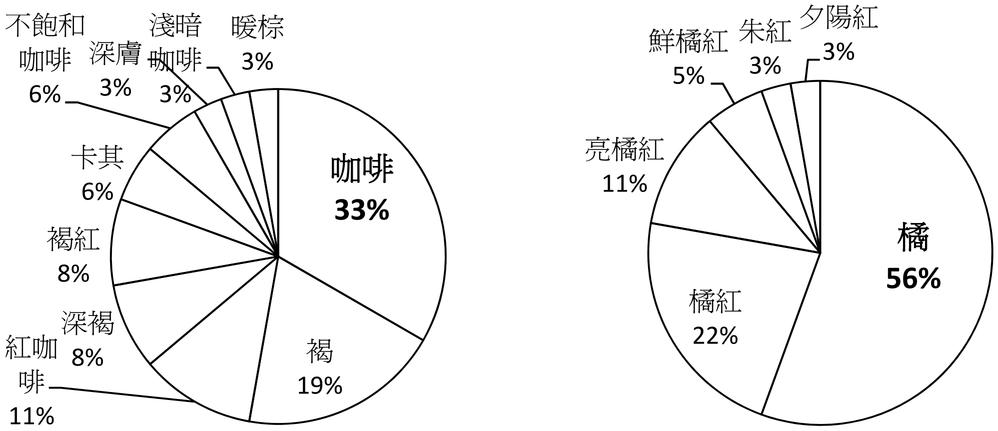


Figure 4.5. The naming of the typical stimulus of blue, brown, red and orang.

The central zone of the triangle gamut gained the lowest confidence due to its location at the joint of all color categories with low saturation. The names given for this zone are brown, grey, pale or compound terms like dark pink, dull pink and so on. This area constitutes the most ambiguous part of the color space, and it is not surprising that the longest RT zone in Figure 4-7 overlaps with it. However, the area giving rise to the longest RTs is not only found in the ambiguous central zone, but also in the joint areas between blue-green and blue-gray, and partial areas of typical blue and purple. This is not because that these hues are hard to determine their host categories, instead, it is the rich vocabulary and associative potentials of these shades that prolongs the processing and decision of the naming. The results of sorting experiment (to be presented in Chapter 5) without involving naming behavior would support this argument.

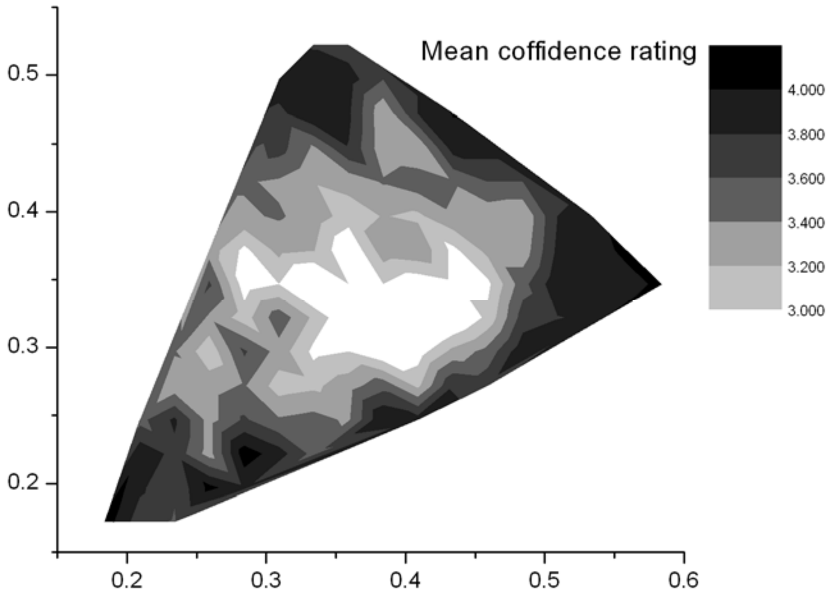


Figure 4.6. The contour map of mean confidence rating.

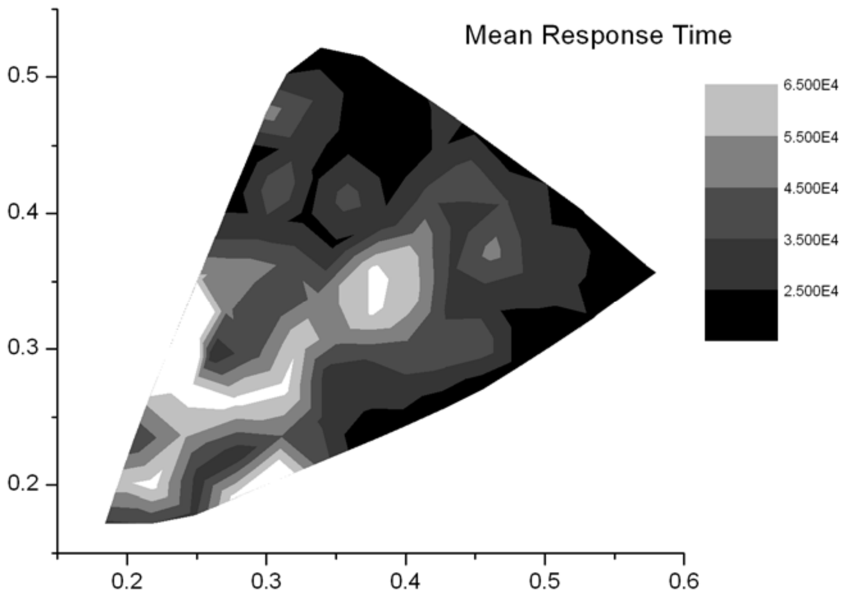


Figure 4.7. The contour map of mean response time (ms).

CHAPTER 5. STRUCTURAL FORMATION OF LEXICAL COLOR CATEGORIES

This chapter presents a twelve-color-term sorting experiment, and the derived color category space. The results of this work can be the foundation of establishing the chromaticity structure of color categories of Mandarin. The purpose is given in Section5.1, and methodology of the experiment is described in Section 5.2. The results are given in Section 3.3.

5.1 Purpose

This experiment uses a sorting experiment to specify basic color terms in the CIE1931 x-y chromaticity diagram. To fully depict the categorical formation of colors on the color space, stimuli were square sampling that vary across six different luminance (L) surfaces and vary in three perceptual dimensions: lightness, saturation and hue. The effect of stimuli luminance and purity, which are related to perceptual dimensions of lightness and saturation, are examined for their potential interactions with color naming and categorization (Guest & Van Laar, 2000; Jameson & D'Andrade, 1997; Shinoda, et al., 1993).

The general purpose of this experiment is to construct the formation of color categories in Mandarin. Besides measuring the sorting frequency, the response latency also reveals the category robustness in participants' mental model. The dependent variables are sorting items and response time (RT), which are submitted to serve indexes of central tendency (mode) and task difficulty, respectively. Similar measurements are sometimes collapsed to be unitary indexes such as 'codability' or 'nameability,' which typically represent the observers' consensus and dispersion (Guest & Van Laar, 2000; Lin, et al., 2001a; Sturges & Whitfield, 1997; Zollinger, 1988).

5.2 Method

Experiment design

The sorting work is the force-choice task. Participants view the color stimulus under controlled viewing conditions, and then sort it into one of the given twelve color categories. There are twelve color categories to choose from, and these are labeled with traditional Chinese characters, that is, the original complex form instead of the Chinese simplified character. The traditional characters and phonetic transcriptions of these color terms are 紅 *Hong* (red), 橘 *Ju* (orange), 黃 *Huang* (yellow), 綠 *Lu* (green), 藍 *Lan* (blue), 紫 *Zi* (purple), 粉紅 *Fen-Hong* (light pink), 桃紅 *Tao-Hong* (dark pink), 咖啡 *Ka-Fei* (brown), 灰 *Hui* (gray), 白 Bai (white) and 黑 *Hei* (black). As discussed in previous chapters, both synonymous and polysemous color terms are common in Mandarin. Moreover, the idioms of Mandarin color vocabulary vary across regions, times and speakers. Thus, the color terms used in the experiment were determined by a pretest on current popular color vocabulary rather than by arbitrary assignment. A ranking of Mandarin color term frequency counts was obtained in the free-recall survey, as listed in Table 3-2 in chapter 3. The most frequently used Chinese color terms corresponding to color categories of red, orange, yellow, green, blue, purple, pink, brown, gray were selected as semantic labels in the sorting color task. Two terms, 粉紅 and 桃紅, which both correspond to the English color term 'pink' in related studies,(Lin, et al., 2001a; Lin, Luo, MacDonald, & Tarrant, 2001b; Lin, et al., 2001c; Lu, 1997) are both included because the authors assume that the two terms actually denote two distinct color categories according to cultural convention. This argument can be examined by the present color sorting experiment. In the free recall survey, black (黑 *Hei*) and white (白 Bai) were seldom counted as 'color' terms, but they still were adopted as options in the sorting experiment as well. Consequently, a total of 12 Mandarin color terms, 紅, 橘, 黃, 綠, 藍, 紫, 桃紅, 粉紅, 咖啡, 灰, 黑, 白,serve as semantic labels for representing basic color categories. These are denoted in the study as R, O, Y, G, B, P, pk, dpk, Br, Gr, W, and Bk.

Participants

Forty-four participants (some of whom also participated in the free recall survey) screened with the Ishihara color vision test took part in the experiment. All are native Mandarin speakers ages 20 to 34, with 25 females and 19 males. Participants are undergraduates or postgraduate students at Chiao-Tung University, and their participation satisfied a course requirement. Participants have no formal training in color science, and were not aware of the purpose or methodology of the study.

Stimuli

Six sets of colors were generated, corresponding to six different L levels: 5, 10, 25, 50, 100 and 170cd/m^2. Stimuli of the same L surface were evenly sampled along x- and y-axes in the CIE1931 x-y diagram. At each L surface, the sampling interval is 0.025 units, sweeping along the x- and y-axes to produce a regular and equal sampling of points within the gamut of display media. Six stimulus sets contain unequal amounts of colors—67, 89, 99, 121, 64, and 21, respectively—and these amounts depend on the availability of LCD colors at different L levels. There are 461 distinct stimuli in total. The top figure in Figure 5-1 shows all stimuli in the L-x-y space, and the bottom figure is the separated plots of all stimuli at each L level. The widest color gamut constrained by the display media was measured at a level of approximately 50cd/m^2 and is denoted with three large, solid triangles in the figure. Another solid triangle in the center of the 50cd/m^2 surface presents the peak white (x=0.319, y= 0.335, defined as the reference white in the study) of the display.

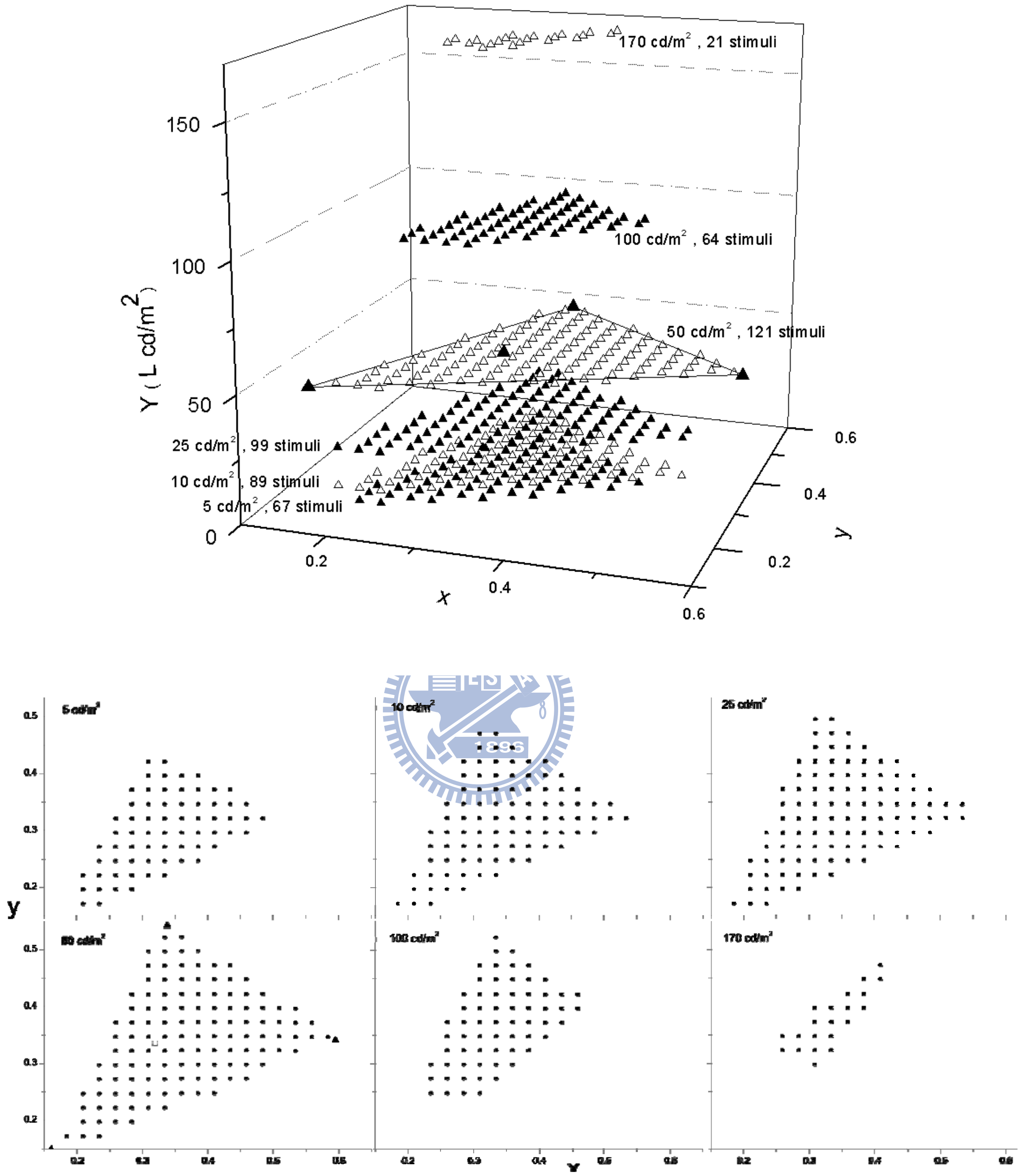


Figure 5.1. Stimuli plotted on the CIE1931 L-x-y color space (top). Six sets of stimuli in distinct L levels were evenly spaced on x-y surfaces. The widest color gamut was measured at 50cd/m^2, and this gamut is denoted with solid triangles and their links. The center triangle represents the peak white (reference white) of the LCD monitor. The separated stimulus plots of each L level are as the bottom figure.

Apparatus

Stimuli were presented and controlled by an ASUS F6E 13.3" laptop. Each stimulus was displayed in the exact center of the monitor. The output uniformity stability check of the LCD was carried out according to a standardised procedure. A well-calibrated PhotoResearch™ PR-650 SpectraScan spectroradiometer was used to repeatedly measure the center output of the LCD. The measuring distance was 355mm, and the sample size was $10cm^2$, covering the whole field of the spectroradiometer lens. The measuring geometry followed the recommendations of PhotoResearch, Inc. The adopted standard observer model was CIE1931, and the reference white selected was D65. The mean output intensity was $235.8cd/m^2$ (STD=3.28, maximum value=241 cd/m^2 (+2.11%), with a minimum value of $229cd/m^2$ (-2.96%)). A look-up table was generated by the standard measuring procedure, and the Matlab interpolation function was used to produce all color stimuli. The mean errors of all stimuli in chromaticity were also checked by the spectroradiometer; these were $4.42cd/m^2$ in L, 0.006 in *x* and 0.004 in *y*. The mean L error increases with the L level of stimuli. The mean errors of the stimulus sets of 5 cd/m^2 and 10 cd/m^2 are 0.38 and 0.76, respectively.

The stimulus was displayed in a square, sized 2° by 2° visual angle at the required viewing distance of 50cm. The background of the stimulus square was set at $60cd/m^2$, the average L of all stimuli. In addition to the stimulus square, there was a thin black border surrounding the square and a white thin border surrounding the black border. Both the inner black and outer white borders were 0.2° wide. The double border design provides the viewing condition with reference white and lowest L level of the display medium. Additionally, the border reduces the L contrast effect between the stimulus and the background, and concentrates the viewer's attention on the stimuli.

Procedure

The experiment was conducted in a darkened room, with the only light source from the LCD. The viewing distance was set at 50cm. The viewing distance and position were kept constant by an adjustable chin rest table with head fixer. There were a total of 461 trials.

Participants were instructed to sort each stimulus into one of the given color categories. A custom keyboard with 12 tags of Mandarin color vocabulary was used to input the sorting results. The initial 40 trials were for practice and were not recorded. The practiced observers were familiar with the position of color terms on the keyboard and were able to produce rapid and accurate sorting actions. All stimuli were presented in random succession. During the experiment, the observers could use a pause key and a resume key to break and restart the experiment. The flow of the experiment was controlled by Presentation® (Neurobehavioral System, Inc.).

5.3 Results

5.3.1. Zone map of color categories

The participants have produced 20,284 color category judgments via the force-choice sorting task. These judgments are submitted to render color zone maps connecting semantics with perception. Table 5-1 provides a descriptive overview of categorical sorting results in conditions of different L levels. In this table, the rank order for the sum of frequency counts is G (green), Br (brown), P (purple), B (blue), O (orange), Y (yellow), Gr (gray), R (red), Pk (pink), Dpk (deep pink), Bk (black) and W (white). There were very few unreasonable judgments—precisely two votes for Bk in 170 and one in 100cd/m^2 conditions, and one for W in 5 and 10 cd/m^2. These should be ignored because they may easily have been keyboard input errors. The input key for Bk was close to the key for W.

Table 5.1. The descriptive overview of categorical sorting results in different L level conditions

	R	O	Y	G	B	P	Pk	Dpk	Br	Gr	W	Bk
5 cd/m^2	88	23	12	671	336	578	9	19	805	104	1	**304**
10 cd/m^2	203	47	34	1089	367	791	34	43	**982**	**235**	1	90
25 cd/m^2	**348**	437	39	1143	399	**794**	38	140	798	211	0	9
50 cd/m^2	248	**786**	265	**1459**	**464**	680	297	**415**	497	213	0	0
100 cd/m^2	15	284	**331**	1077	329	224	**301**	17	101	127	9	1
170 cd/m^2	4	20	300	255	124	23	87	2	22	39	**46**	2

sum	906	1597	981	5694	2019	3090	766	634	3205	929	57	406

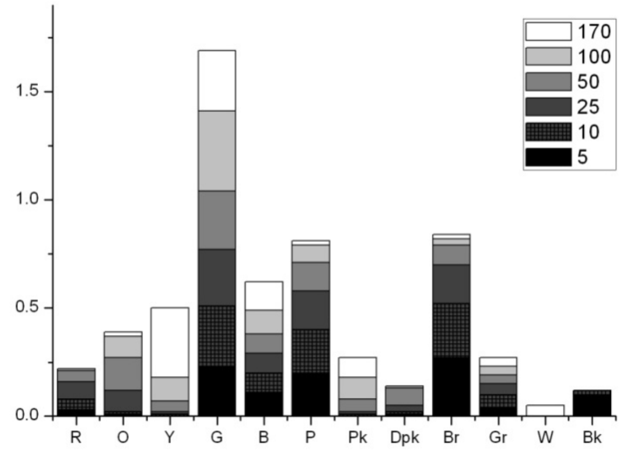


Figure 5.2. The stack histogram for presenting normalized frequency distribution of each condition. The x-axis shows the color categories, and the y-axis shows the (accumulated) ratio. The various filled grey levels are used to denote six luminance conditions.

A cross-L comparison of the normalized frequency distribution is shown on the stack histogram in Figure 5-2. The x-axis lists the given color categories, while y-axis presents the ratio of original counts to stimulus numbers of each condition, with various grey-level fills to differentiate the six L levels. The histogram presents a rough structure of the frequency distribution across color categories and L levels. The green, blue and grey categories give relatively even frequency ratios, implying that these three color concepts are luminance invariant; that is, they exist in all L conditions. In contrast, the other color categories are perceived at a limited number of L levels. Red, purple and brown are more frequently perceived in medium to low L conditions, orange and deep pink are recognized in middle L conditions and yellow and pink are apparent in high L conditions. It is particularly noteworthy that the chosen color terms (except for the achromatic terms) are often referred to as 'hue' terms, suggesting that these should be more or less independent from luminance and saturation. However, some 'hue' terms, such as yellow and deep pink, seems to be typical of specific luminance levels. This luminance-dependent phenomenon in color category sorting has been addressed(Shinoda, et al., 1993), and will be discussed further in the following section.

The interaction between the L condition and the recognized color category is illustrated in Figure 5-3. The upper six x-y chromaticity diagrams with colored circles represent the demarcated color zones in six L conditions. The coordinates of each circle's center correspond to those of the stimulus. The colors of the circles intuitively symbolize the category that gained maximum votes, the mode, except for the light grey in the L170 condition symbolizes white. In addition, the circle sizes correspond to the maximum number of judgments in order to better visualize the degree of consensus under each stimulus condition. Generally, larger circles symbolize the focal color of the category spread over the peripheral districts of high purity in colorimetry, whereas the smaller circles are found in the common border between distinct color zones and in the central area of low purity surrounding the reference white W.

The composition of color zones appears to be diverse across the six L conditions. In the lowest L condition (5cd/m^2), there are only five perceptually dominant categories: green, blue, brown, purple and black. As luminance levels increase, the other color categories gradually become apparent. Specifically, red and grey become recognizable from L=10, orange and deep pink from L=25 and pink and yellow from L=50. Certain color categories become less apparent in higher L conditions; specifically, red, deep pink and brown are seldom identified from L=100. In the highest L condition (170cd/m^2), only yellow, pink, blue, green and white remain visible. These results suggest that a common concept of color, labeled with a specific color term, is not merely an idea of a hue independent from brightness and saturation information. The results suggest that some color (hue) terms, such as red, yellow, pink and others are strongly associated with luminance.

The lower diagram in Figure 5-3 combines the above six diagrams. It reveals the spatial changes of color category compositions along with L level conditions. The color of the open circle also represents the mode of color sorting, and the size of the circle corresponds to the L level. The largest outer circles denote color zones designated in L=170, and the inner smaller circles that decrease in size denote gradually decreasing L conditions. The color consistency of the concentric circles is an index of the degree of luminance dependency in the sorting results. Stimuli located around the borders between categories appear more ambiguous, and naturally are designated into different categories when luminance changes. The top and lower-left corner of the gamut triangle, demarcated as green, blue and partial purple, show strong consistency across all L levels. However, color zones in the area from the center to lower-right corner of the triangle are strongly influenced by luminance conditions. It is important to note the superseding pattern of some groups in that area, such as a warm color group (yellow, orange and brown) and another group (pink, deep pink and purple). Members in these two groups seem to displace each other as the luminance conditions change. It is remarkable that the brown category overlaps a large range of color categories according to the fluctuation of luminance. A stimulus fixed in a chromaticity coordinate is recognized as brown in lower L but would be called yellow, orange or even pink as the L gets higher. In addition, the gray category also demonstrates a similar but weaker effect; it can substitute for many other colors as the luminance condition changes. This effect is related to the so-called ‘wild-card’ phenomenon.(Greenfeld, 1986)

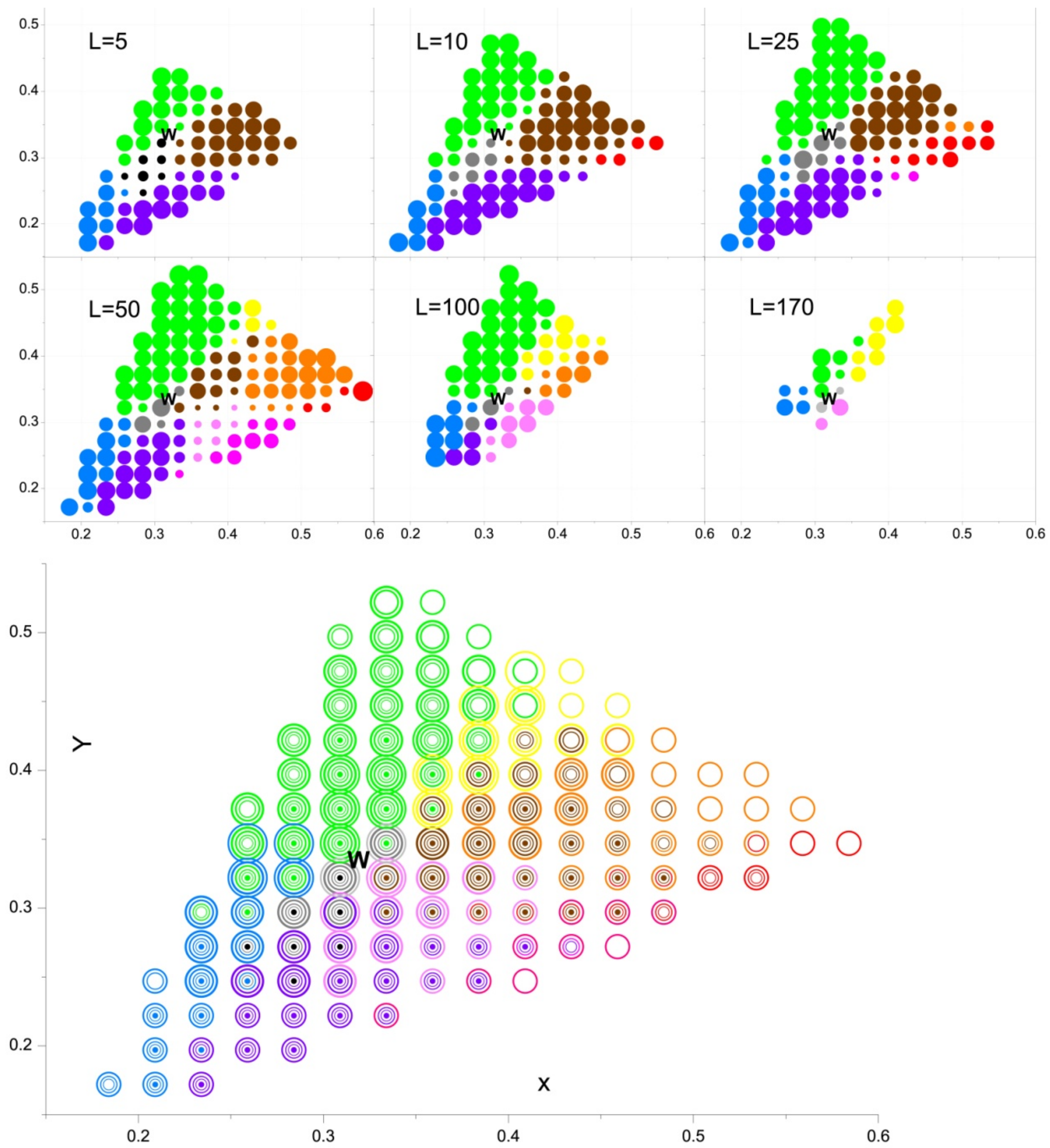


Figure 5.3. Upper six x-y diagrams of different L levels using circle color and size to present color category and mode size, respectively. The lower diagram combines all results and differentiates the modes of six conditions with open circles that decrease in size. The larger outer circle represents the mode of the 170cd/m^2 condition, and the smallest circle represents the mode of the 5cd/m^2 condition.

The particularized formation within each color category's luminance condition is presented in Figures 5-4 to 5-7. Each figure contains 6×3 (the number of L levels by the number of color categories) diagrams of smoothed-out contour maps, and all diagrams share the equivalent x-y unit and scale. The contour-smoothing algorithm was provided by

OriginPro 8.0 by OriginLab. The denotation of the conditions (cd/m^2 - color category name) is shown in top-left corner of each diagram. The small black dot in the midlle of diagram marks the position of reference white. Different fills of grey level between contour lines represent the frequency ratio of the observers' judgments. Zones filled with black indicate that these obtained over 90% of the votes for the corresponding color terms, which means they are focal zones with the least controversy. The other grey fills gradually increase in lightness according to their respective percentage of votes, with a decreasing interval of 10%. Consequently, the darker the zone fill, the higher the frequency, and the more representative the stimulus. The darkest grey fill indicates 80%-90% votes, while the lightest fill (white) indicates 10-20% votes. A frequency ratio below 10% is ignored and filled with slash lines to mark the gamut. These countour line maps reflect the noticeable transformation of each color zone involving luminance variation. Each color category shows distinct pattern of emergence, congregation and lapse on the color space.

Figure 5-4 presents zones of red, orange and yellow categories that show prominent lumiance-dependent features in their distribution. The red is recognizable below 50cd/m^2, and its focal zone (the zone with highest ratio) is relatively small, reaching only 70-80% ratio level. The covered area completely overlaps with the brown zone in 5cd/m^2, although the probability of seeing red at this L level is quite low. The orange zone is also designated at restricted luminance levels, mainly in 50 and 100cd/m^2. The formation of the orange contour map reveals a very concentrated pattern; it contains a recognizable focal zone of over 90% in 50cd/m^2 level, and then the zone diminishes drastically in 100 and 25cd/m^2 levels. The range of orange and brown categories also overlap considerably, and brown also overlaps with yellow. The yellow zone is recognizable in conditions above 50cd/m^2, and the focal zone of over 90% can be found in 100 and 170cd/m^2 level. The first three color categories discussed thus far contain colors of long wavelength range. Their territories are all luminance-dependent, and overlap with the brown zone in low luminance conditions. This result is consistent with the familiar perception that so-called warm colors (red, orange and yellow) would shift into brown as they become darker.

Another cluster of color category zones—green, blue and purple—is shown in Figure 5-5. Apparently, viewers were able to percieve these three colors across all six luminance levels, except that purple was infrequently indentified in 170cd/m^2 condition. The green category might be considered as a unique color concept that is particularly easy to define, given its large focal zone of over 90% votes and sharp border. Its dense peripheral contour lines reflect a steep fall in frequency ratio. The loaction of the focal zone remains constant, rather than shifting with luminance changes. Moreover, the overlapping area between the green zone and neighboring purple, green and brown zones is very limited in size. A similar pattern of contour lines can be found in the blue zone, although its covered range is much narrower than that of the green zone. The purple category is also a easy-to-identify color, as revealed in the concentrated pattern in the map, typically in conditions below 50cd/m^2.

However, the perceptual definition of purple seems not as distinct as that of blue or green. In the darker conditions, its zone overlaps patially with those of brown and red, while in lighter conditions it overlaps with deep pink and pink. Generally, when compared with the previously discussed warm color cluster and the other color categories, the three colors in Figure 5-5 demonstrate the notable characteristic of being preceptable across every L level. Furthermore, the overlapping zone between these and neighboring colors is relatively small, especially for the green and blue zones. All of these observed features suggest that the psychological quality of these colors is more universal, stable and less ambiguous when compared with other colors in the study.

Figure 5-7 shows the contour map of the achromatic categories of gray, white and black. The Gray zone distributes around the lower-left area in all luminance situations, close to the intersection of the blue, purple, green and brown zones. It also appears more clearly in the middle luminance levels, and switches to black in the lowest luminance conditions. The term of white was used only in 170cd/m^2 condition, and its zone encircles the W point. White and black categories gained very low votes, perhapes due to the fact that observers were provided with thin outlines of white and black for reference with each stimulus. Literally, gray and black should be neutral color concepts that do not involve any hue information. However, the results show gray as a category that represents the ‘cold’ cluster of colors, typically blue and purple, in very low saturation conditions, and black corresponds to cold colors in very low saturation and luminance conditions. The actual neutral exemplar in any luminance level should be located around the reference white point, just as in the white zone. Based on the present results, the ideal neutral point lies on the border between the brown and gray/black zones.

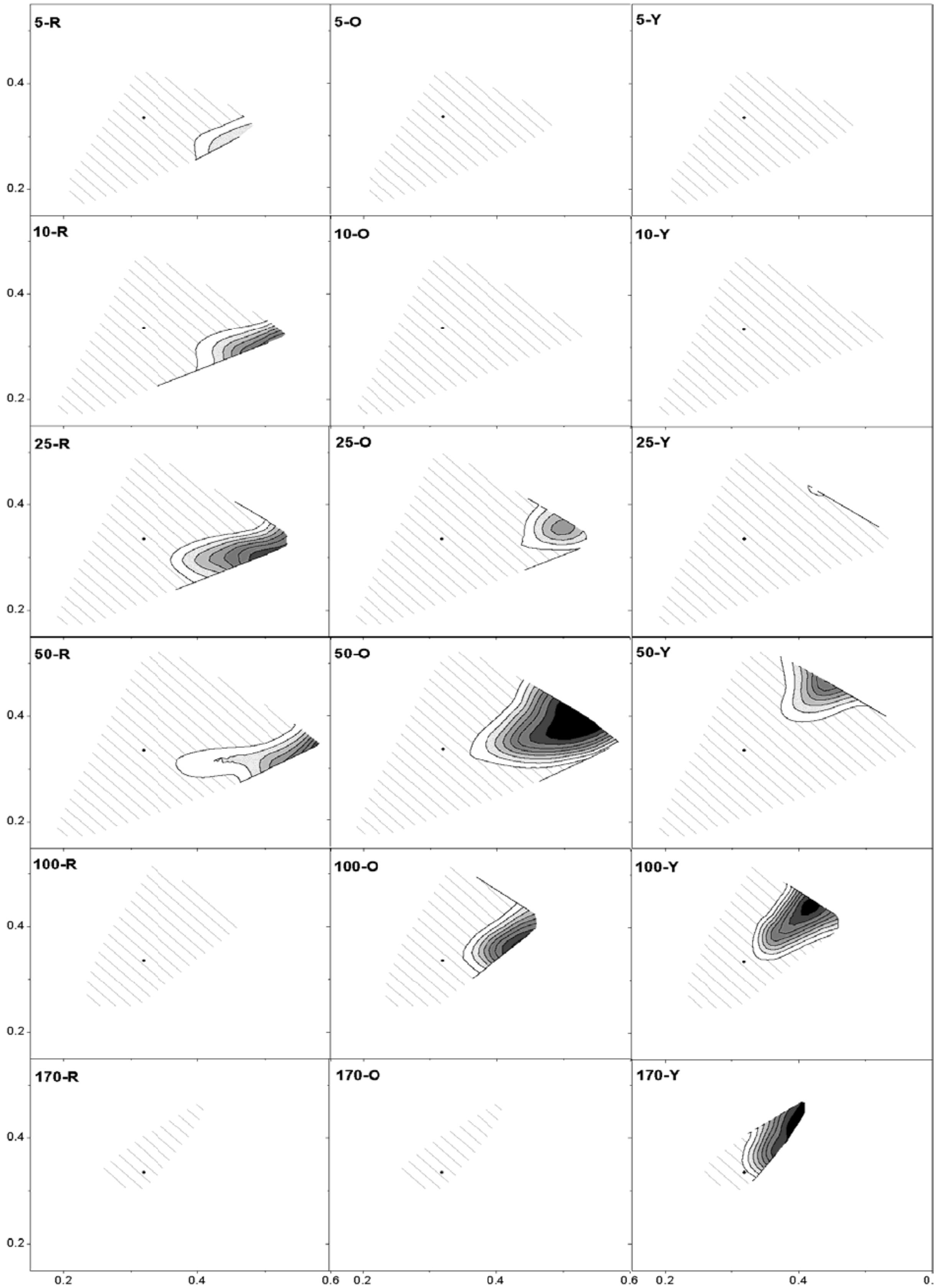


Figure 5.4. Contour line map showing the formation of red, orange and yellow. A detailed description is in the text.

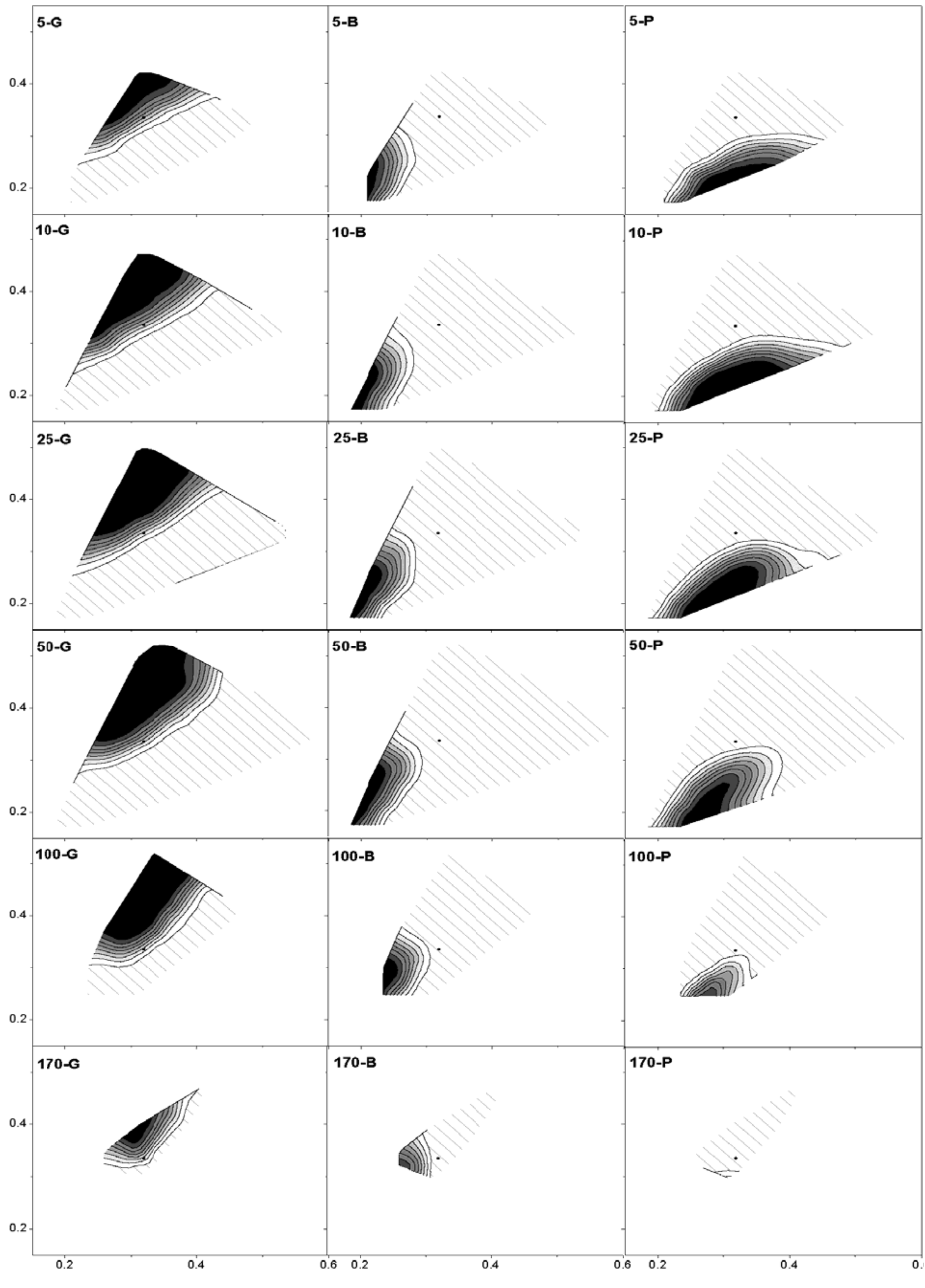


Figure 5.5. Contour line map showing the formation of green, blue and purple. A detailed description is in the text.

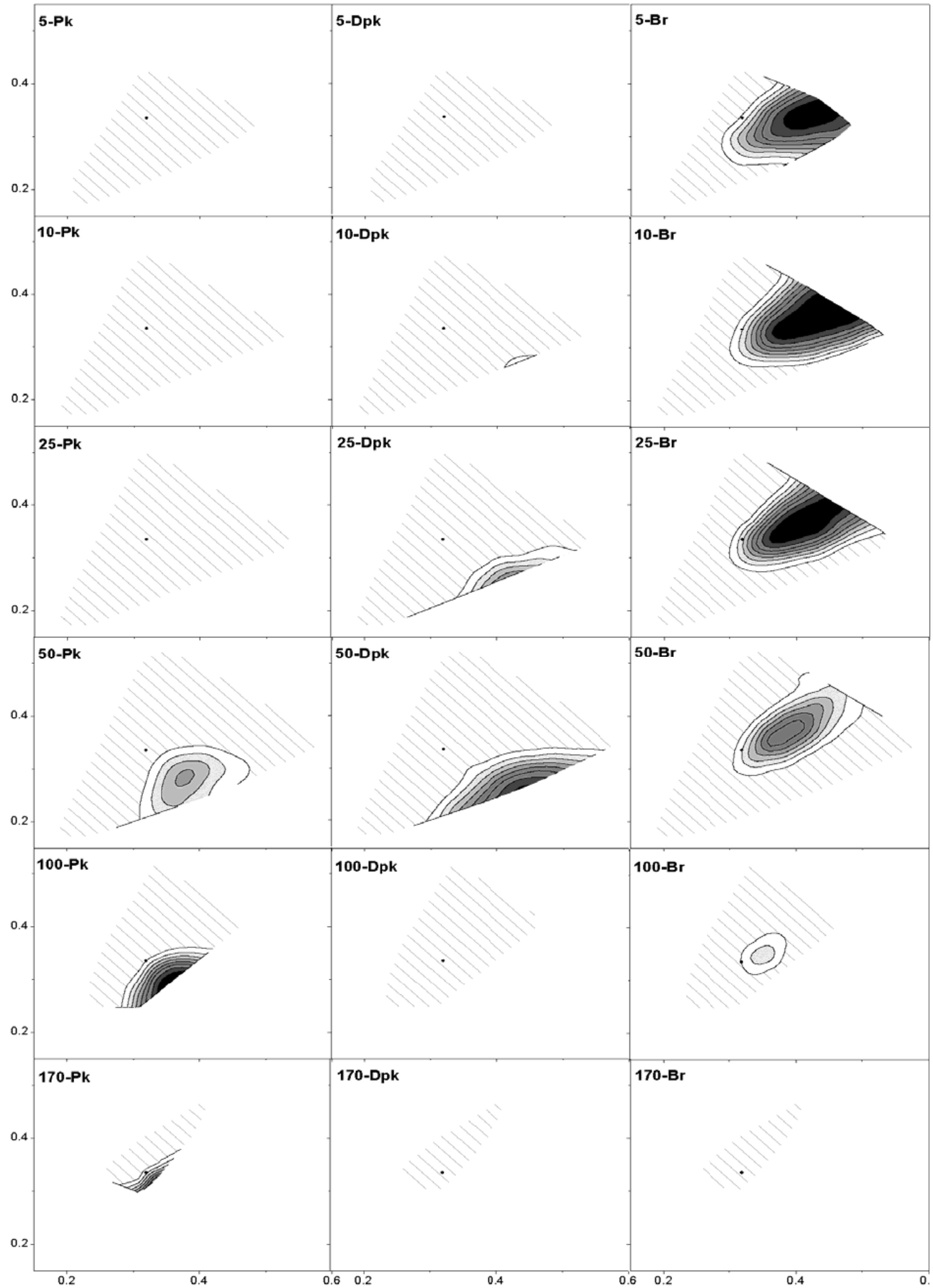


Figure 5.6. Contour line map showing the formation of pink, deep pink and brown. A detailed description is in the text.

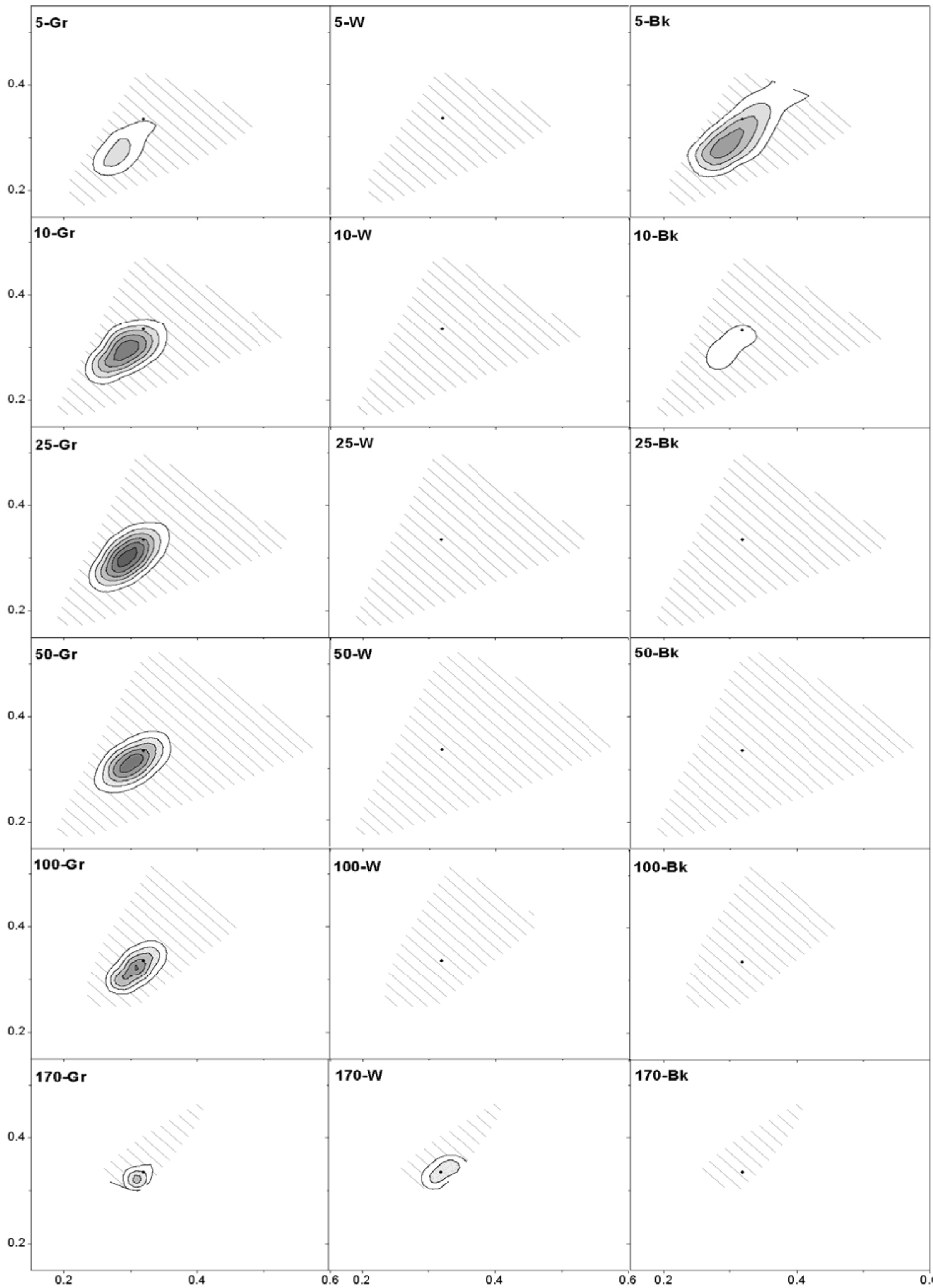


Figure 5.7. Contour line map showing the formation of gray, white and black. A detailed description is in the text.

5.3.2. Response times and the boundary definition

With the constrained option of 12 color terms, the perceptual regions corresponding to the main color categories on the CIE x-y diagram were carefully mapped out, as shown in all previous figures. However, the regions defined in those figures, such as the distinct color zones seen in Figure 5-3, were based on one single statistic; namely, the quantity of votes for a certain color term. Another way to help define the boundary between color territories is to take into account the task difficulty measure. In the study, the RTs in each sorting trial are rendered as dependent factors relative to the ease in making a color category judgment. It is assumed that the more ambiguous the color, the longer it takes to discriminate and sort the color into one of the given categories. The RTs were also considered important in the related studies.(Guest & Van Laar, 2000, 2002; Sturges & Whitfield, 1997) While the size of the mode is an index of the commonness of the stimulus, the RTs is an index of the distinctiveness of the stimulus. A stimulus that results in a rapid response plus a larger mode to the same color term signifies that it is well located in the center zone of a color category (i.e., it is a typical example of that category). The reverse situation, with a long RTs and fewer votes, indicates a stimulus located in the periphery of a category or the boundary between categories.

Figures 5-8 and 5-9 visualize two factors: the 50% and 75% vote threshold and the contour map of RTs, respectively. Both figures contain six luminance levels in the x-y diagram of the same scale. Figure 5-8 uses a unitary criterion to demarcate the boundary of color zones; namely, the vote frequency counts of 75% level (color fills) and 50% level (color lines). Figure 5-9 presents RT in terms of contour lines on the color space. The black area corresponds to RT below 1.5 seconds, while the white area corresponds to time beyond 2.25 seconds.

It is interesting to examine the connection between the spatial constitutions in these two figures. In Figure 5-9, there are several prominent hot spots (black areas) embedded in the inert ground (white areas). The white and lightest grey areas, representing short RTs, are generally consistent with the areas of achromatic center and boundaries between categories in Figure 5-7. The Pearson correlation coefficient of the size of mode and the RT of each stimulus in low to high L conditions is -0.846 ($p < 0.01$), -0.874 ($p < 0.01$), -0.816 ($p < 0.01$), -0.81 ($p < 0.01$), -0.763 ($p < 0.01$) and -0.103($p = 0.67$), respectively. High and stable negative correlation can be observed in most conditions, but this effect disappears in the L=170 condition. Generally, the center tendency index can demarcate the core zone of the category, as shown in Figure 5-7, while the RTs information gives robust weight to the boundary.

The RTs measure also reveals the distribution of perceptual distinctiveness (saliency) on the color space. Figure 5-10 presents the luminance-against-RTs line plot that connects the mean RTs of the color categories in certain L conditions. Note that the figure does not contain every category in every condition. To prevent the interference of the RTs of non-typical judgments, each line of color category only presents the L conditions in which obtained votes surpass 10% of all votes within the category. The white category is not included because its votes ratio reaches 10% only in L=170 condition. The line plot shows that the RTs is both category- and luminance-relevant. For the categories of green, blue and purple, the mean RTs are generally shorter across all L conditions. This suggests that observers can easily and rapidly decide whether a given color belongs to the green, blue or purple categories, even though these three are next-door neighbors on color category maps. However, the lengths of RTs in the other categories are relative to luminance variation. The RTs of Gray drop drastically, indicating that gray is easier to determine in higher L levels, whereas RTs of brown show the reverse trend. The rest of the color categories also have shorter RTs in their corresponding dominant L levels. The mean RTs of the orange category, for instance, drops at L=50, which is the luminance level at which the color is most frequently recognized.

Rapid RTs can be found in the highest L condition of L=170, as shown in Figures 5-9 and 5-10. This appears to be somewhat in conflict with the previous point that RT serves as an index of the ease level of the task. A color displayed in very high luminance should be diluted in hue and saturation, and it should thus become more difficult to determine its appropriate category. However, there are two possible reasons for the actual result. First, the limitation of the display gamut makes the colors of high L conditions vary in restricted numbers of categories. The second reason is that under such high luminance conditions, the observers actually make a color-or-white distinction; that is, they simply sort the stimulus into one of two main categories. The psychological distance between these two categories should be larger than that between many other color categories, such as green and yellow. With the limitation of the gamut display, the number of sub-categories under the broader 'color' category is even fewer, as designated by the yellow, green, blue, and pink zones in Figure 5-8. These factors could reduce the task difficulty in L=170 condition and contribute to the quick response.

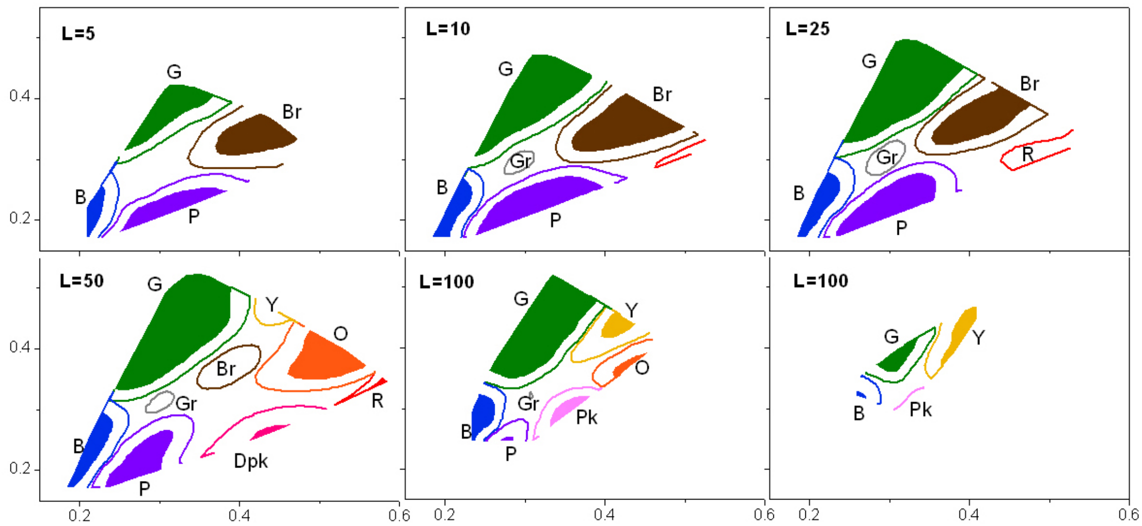


Figure 5.8. Zones of color categories in six luminance conditions. The boundaries are demarcated by 75% and 50% votes ratio, which are marked with color fills and color lines, respectively. These two threshold levels partition the x-y surface into distinct zones without overlapping.

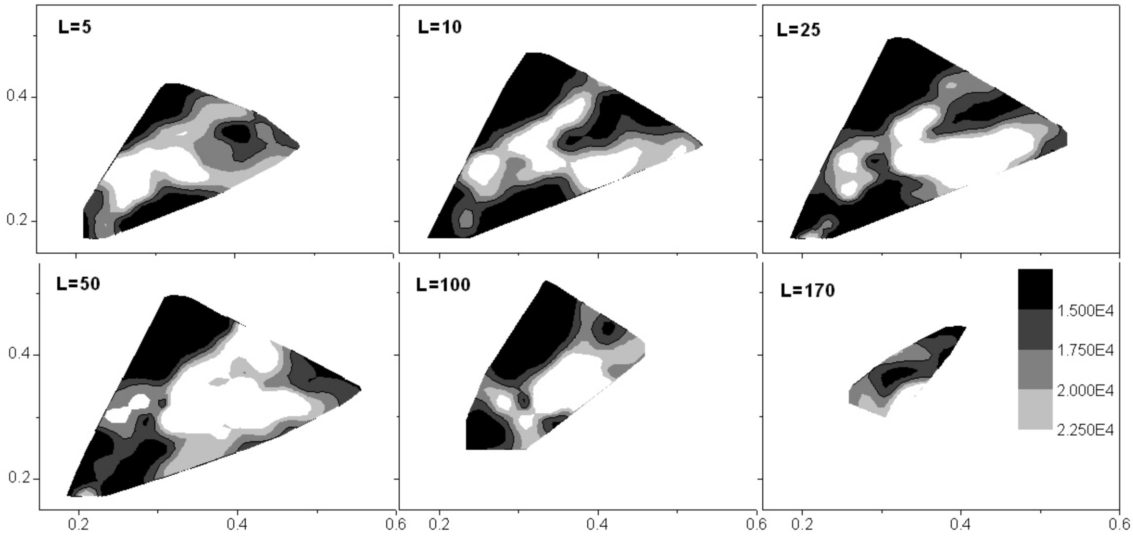


Figure 5.9. Contour maps presenting RTs in six luminance conditions. The light areas indicate longer RTs, or the more difficult sorting decisions, while black areas indicate the faster RTs and easier response zones. The darker areas roughly correspond to the color zones in Figure 8, except in L=170 condition.

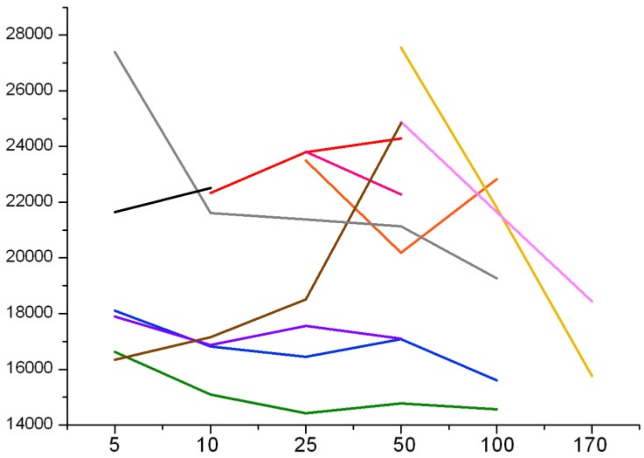


Figure 5.10. Line plot of the mean RTs of 11 color categories (white is excluded) in their frequently identified luminance conditions. The y-axis shows milliseconds and the x-axis shows luminance.

5.3.3. Summary

The experiment presents the formation of color categories through a 12-color-terms sorting experiment that employs native Mandarin speakers as participants. The adopted categorical color terms were determined to be universal among human cultures (e.g. Berlin &

Kay, 1969; Guest & Van Laar, 2000; Lin, et al., 2001a, 2001b, 2001c; Lindsey & Brown, 2006; Lu, 1997; Shinoda, et al., 1993), and were confirmed to be frequently used by a free-recall pretest. The range of each term-related color category among observers was carefully plotted on the CIE 1931 chromaticity diagram on six luminance surfaces. Unlike many studies adopting reflective materials, limited saturation or luminance setting, or irregular sampling in designing stimuli, this study's illuminant stimuli vary regularly in terms of hue, lightness and saturation and can systematically capture the spatial structure of color categories in different perceptual dimensions. In general, this experimental design leads to an intriguing finding in the results; namely, the changing shape of the color zone depending on purity and luminance. These two colorimetrical parameters correspond roughly to saturation and lightness. In the seminal *Color Categories in Thought and Languag* (Jameson & D'Andrade, 1997), Jameson and D'Andrade argue that within the internal perceptual color space, hue interacts with saturation and lightness to produce 'bumps.' Bumps are defined as the salient representation of color categories, or the foci colors. The formation of focal color zones located at different luminance levels and eccentricities apparently support, and 'visualized' this theory.

The formation of color categories shows the various degrees of the luminance effect. The most luminance-irrelevant cluster includes green, blue, purple, and gray. These four colors, particularly green and blue, are identified across all luminance levels. Additionally, the shape of the corresponding contour map remains stable, and the location of the foci of these categories is consistent across all conditions. Moreover, the RTs of the green, blue, and purple categories are the shortest among all colors, and are unrelated to variances in luminance. All measures indicate that these three color concepts, particularly green, are more psychologically distinctive, salient and robust than others. Green gained the most votes in the experiment with the lowest mean RTs, and its zones are encircled by sharp contour edges. Interestingly, the locations of these three categories on the color space are close. Blue is adjacent to green and purple is adjacent to blue. These color categories are similar in terms of chromaticity, but distinct in category distinguishing. Nevertheless, many categories can be frequently identified and appear typical only in certain restricted luminance ranges. Red is typical in L = 10-25, deep pink in L = 50, orange in L = 50-100, pink in L = 100, and yellow in L = 100-170. Conceptually, these color categories are different shades of the 'warm' color cluster, and are bound tightly by luminance conditions. In low luminance levels, the same chromaticity location of warm colors could easily be identified as brown. Additionally, the red, deep pink and pink categories, which belong to the 'Hong' (red) cluster in Mandarin, appear to be typical in three distinct ascending luminance levels. Their foci locations do not overlap. These factors indicate that Hong, Fen-Hong and Tao-Hong could be independent categories. Also, the claims of earlier studies of Mandarin, which accounted for only six color categories(Berlin & Kay, 1969), could be inappropriate to apply to the contemporary Mandarin environment. In Berlin and Kay's survey on the development of color terms in worldwide languages, Mandarin has only four chromatic color terms: red, green, yellow and blue. Some researchers argue that these limitations are refutable and have tried to propose new evidence (Lu, 1997).

Furthermore, it is important to note that the foci of brown and gray are located symmetrical to the reference white. Traditionally, gray should serve as a representation of achromatic stimuli, but the results show that it actually stands in for 'cold' colors in low saturation conditions, while brown stands in for warm colors in similar conditions. The exact neutral gray may only exist in perfectly controlled viewing conditions, which are seldom found in the real world. Supposedly, these two wild-card color concepts (Greenfeld, 1986) are capable of conveying near achromatic shades of cold– and warm–tinted colors.

A previous study uses similar viewing conditions and color space to examine Japanese speakers as observers (Shinoda, et al., 1993). In the Japanese study, the location of boundaries between blue and green are different than the location observed in this study. The green areas in this study's color zone maps extended further than the blue areas, while the reverse was found in the comparative study. The red area in this study is narrower than that in the Japanese study. Other than the differences in area size of red and the boundary location of blue and green, the remaining color categories were similarly spaced in both studies. Interestingly, blue and green can be loosely represented by a term in a literary language used by ancient Chinese, and this ancient Chinese written language influenced both modern Mandarin and Japanese. Perhaps the conventional definitions of blue and green in modern Mandarin and Japanese developed differently. In the fields of color categorization and naming, a conventional view is still developing. A greater quantity of substantial empirical data would undoubtedly improve the overall understanding of the fields.

CHAPTER 6. GENERAL DISSCUSION

This chapter gives general discussions regarding cross and within study results comparisons. A comparison of popularity raking of color terms between three free-recall studies is presented in Section 6.1. The color category map derived from free-naming task and sorting task would be compared in Section 6.2. Section 6.3 gives the cross-culture color sorting comparison, and Section 6.4 sketches some extendable future works.

6.1 Comparing popularity ranking of color terms between studies

The Mandarin color lexicon survey in Chapter 3 gives an overview of present Mandarin color terms in frequent use and the diversity among these color expressions. There are two previous surveys of color terms conducted with the free recall method, which are comparable with the current results. Table 6-1 listed the popularity rank order and the corresponding color terms of current results and the two comparative studies. One of these is a Japanese color terms survey carried out by James Stanlaw in 1990s (Stanlaw, 1997). There were 91 native Japanese speakers participated in a free recall task. The participants were asked to recall those color terms that they consider the most common or important in everyday life in Japan. There is a few detailed requests differing with the present study: those Japanese participants were encouraged not to contemplate too long over the task, i.e., there was time limit of three to five minutes; and they were told only the first fifteen terms would be counted; moreover, the participants were allowed to use compound terms modified with common modifiers, or the form of combining two common basic color terms. Other than these, the rest of the procedures are similar to the current work. Both native Japanese vocabulary and English loanwords are acceptable. The other comparative study was conducted by Lu in which deliberated samplings of informants were employed.

Table 6.1. A comparison of the popularity of color terms elicited with free recall task between current study and two previous studies(Lu, 1997; Stanlaw, 1997).

	Current study		Japanese study		Previous Mandarin study	
	Mandarin	English	Japanese	English	Mandarin	English
1	藍 Lan	Blue	Shiro	White	桃 Tao	(deep) pink
2	紅 Hong	red	Aka	Red	灰 Hui	Grey
3	綠 Lu	Green	Kuro	Black	黑 Hei	Black
4	紫 Zi	Purple	Ao	Blue	褐 He	Brown/tan
5	橘 Ju	tangerine / Orange	Ki-iro	Yellow	白 Bai	White
6	黃 Huang	Yellow	Midori	Green	橙 Cheng	Orange
7	粉紅 Fenhong	(light) pink	Cha-iro	Brown	黃 Huang	Yellow
8	灰 hui	Gray/ash	Murasaki	Purple	紫 Zi	Purple
9	咖啡 ka-fei	Brown/coffee	Pinku	Pink	紅 Hong	Red
10	桃紅 Taohong	(dark)pink	Orenji	Orange	綠 Lu	Green
11	橙 Cheng	Orange	Kon	Dark blue	藍 Lan	Blue
12	褐 He	Brown/Tan	Ki-midori	Yellow-green		
13	膚 Fu	Skin	Mizu-iro	Light blue		
14	棕 Zong	Brown/palm	Hai-iro	Grey		
15	米 Mi	Rice	Gin-iro	Silver		
16	茶 Cha	Tea	Guree	Grey		
17	靛 Dian	Indigo	Kin-iro	Gold		
18	銀 Yin	Silver	Buraun	Brown		
19	青 Ching	Blue/Green	Kaaki	Khaki		
20	金 Jin	Golden	Beeju	Beige		
21	黑 Hei	Black	Kuriimu-iro	Cream		
22	白 Bai	White	Remon	Lemon		
23	卡其 Kaqi	Khaki	Emerarudo guriin	Emerald green		
24	磚 Zhuan	Brick	Hada-iro	Flesh		
25	藕 Ou	Lotus root	Nezumi-iro	Grey		
26	駝 Tuo	Camel	Sora-iro	Sky blue		
27	杏 Xing	Apricot	Koge-cha	Dark brown		
28	香檳 Xiangbin	Chanpagne	Momo-iro	Pink		
29	橄欖 Ganlan	Olive	Daidai-iro	Orange		

A noticeable discrepancy between the current results and the other results is the rank order of black and white. The low rank order of these two neutral color terms could be attributed to the instruction given by the researcher to recall any "color" (perhaps with emphatic tone) terms you frequently use, hear or read. Except for that, the salient color terms to the participants of these three studies seem to be very similar. Save for fact that black and white ranked 21th and 22th respectively in this study, and grey was the 14th for Japanese, the color terms representing B&K's eight basic color categories, red, orange, yellow, green, blue, purple, pink and brown are consistently ranked in the top eleven.

Moreover, the phenomenon of using multiple terms to represent the same category was found in both the current study and the Japanese data. Japanese use Buraun, Cha-iro and Koge-cha to represent brown, and also use Orenji and Daidai-iro to represent orange.

6.2 Comparing with other studies' free-naming results

The most comparable free naming study was carried out by Guest (Guest & Van Laar, 2000). They employed native English speakers as participants. While there are other studies adopting the free naming method, such as Lin's study (Lin, et al., 2001), their stimuli and coding methods are very different from that in the current study. It is therefore less straightforward to compare their results with the current results.

Table 6-2 summarizes the comparison between Guest's free naming results with ours. The occurrence rate of each class of color terms in both studies are listed along with the mean response time and the mean confidence rating. The methods for measuring response time and confidence level in both studies are identical. The S (secondary) class and the A (antique) class in the current study are equivalent to the class of other monolexemic terms in Guest's study. There are several noticeable differences between these two studies:

(1) On average the RTs of Mandarin speakers is longer across all types of terms.

(2) English speakers produced larger ratio of basic color terms, including LB and OB classes,

than Mandarin speakers, the occurrence rates are 52.2% versus 31.7%.

(3) The Mandarin speakers tended to use more compound color terms, i.e., classes of BB, SB, MB and C.

(4) The average confidence rating given by Mandarin speakers is generally lower than that by English speakers. However, some classes, such as the BB and MB, were rated with great confidence by Mandarin speakers.

(5) Complex color terms were more frequently used by Mandarin speakers than English speakers; the occurrence rates are 3.96% and 1.4% respectively.

Table 6.2. A comparison of free naming results between the current Mandarin study and the previous English study (Guest & Van Laar, 2000).

	Current Mandarin study			Comparative English study		
Class	Occurrence%	MRTs	MCR	Occurrence%	MRTs	MCR
LB	G 6.48%	1854	3.84	20.7%	1939	3.56
	R 2.21%	1541	3.98			
	B 3.53%	3672	3.45			
	Y 2.28%	2683	3.67			
OB	17.2%	4126	3.27	31.5%	2018	3.26
S	6.8%	4419	2.48	13.5%	2535	3.02
A	2.4%	5263	2.54			
BB	19.6%	4673	3.29	11.5%	3234	2.6
SB	17.1%	4889	3.02	5.9%	2992	3.04
MB	24.9%	3960	3.60	13.5%	2796	3.14
MS	1.8%	5142	2.73	2.1%	3143	2.54
C	3.96%	5406	2.42	1.4%	3623	2.44

6.3 Comparing free naming and sorting maps within this study

This study adopted two techniques to map the space of main color categories. In the first free-naming task (in Chapter 4), the participants were encouraged to use any color expressions that they considered capable of conveying the quality of a given stimulus. In the sorting task (in Chapter 5) the number of optional categories was constrained, and participants were forced to make a decision to classify every stimulus into one of the twelve given categories.

If B&K's basic color categories are universally salient for most cultures and languages, as was affirmed repeatedly in many studies involving other languages, the pattern of these categories should emerge from the statistical results of free naming. The color naming map presented in Figure 4-4 had shown the distribution of terms corresponding to main perceptual categories, but only in the peripheral districts did one find obvious pattern that matches the main categories. The finely plotted contour map of main color categories might provide a reference to examine the categorical organization of the central zones of the color naming map. Figure 6-1 is an overlay map combining the color term map and category sorting map at the level of 50 cd/m^2. That contour map shows three consensual threshold levels of 75%, 50%, and 25%, marked with filled categorical color, thick line and thin line, respectively. The focal zone (75%) of each category satisfactorily matches high frequency names, although the simplex monolexemic terms, such as 綠, 藍, 紫, 黃, 橘, 紅 and 桃紅 (the term tao-hong equal to 桃 tao, which is treated as a monolexemic color term in the study), were only seen in peripheral districts. The terms within the central 75% zone tend to be compound terms due to the reduction of purity. A few stimulus spots within the 75% focal zones were associated with unexpected naming results. A stimulus located at the edge of 75% green gained the consensual term 藍灰 (blue-grey). Another stimulus located around the central of 75% orange was consensually named as 橘紅 (orange-red).

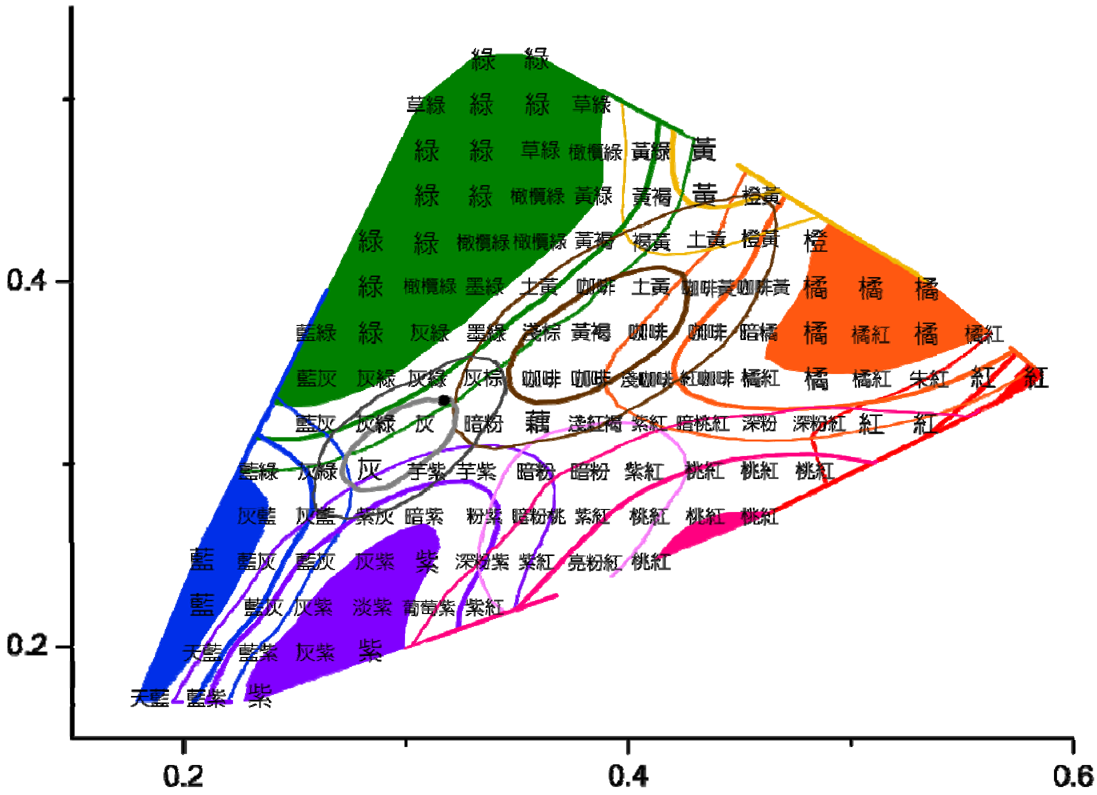


Figure 6-1. The lexical color category map overlaying the free-naming and sorting results.

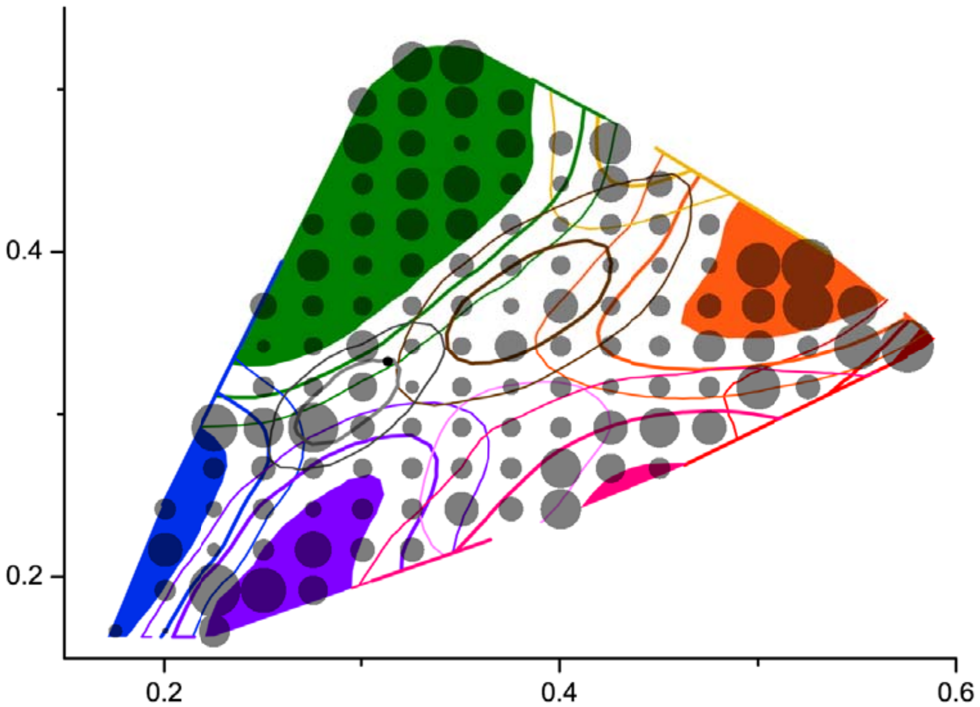


Figure 6-2. The lexical color category map overlaying the free-naming and sorting results.

The location of the extraordinary color term 藕(Oh, lotus root) is also intriguing. This color term is translated as “pinkish grey” in the Oxford Han-English dictionary, and is often considered as the shade of dull light pink in low tone in daily color experiences. However, its matching category is not between grey and pink, but between brown and pink instead, and its location is not even covered by the zone of 25% pink.

Save for the existence of those unexpected cases, the pattern of color naming is generally in accordance with the density line of the sorting results. Many compound terms of the BB class are rightly given to the stimuli located between the focal zones of two categories, for example 藍紫(blue-purple), 黃綠(yellow-green), and 灰綠(grey-green).

The other noticeable point is that the consensus level in the sorting task seems to be incompatible with that in the naming task. Figure 6-2 is another overlaying map of contour lines of category sorting and the mode size of results in the naming task. The smaller sizes of modes are not always located in the boundaries between categories, or in the central zone with low saturation and ambiguous hue appearance. The correlation between mode size and the degree of agreement is relatively weak, with a Pearson correlation coefficient of 0.42. This indicates that the naming consensus is not necessarily equivalent to the sorting consensus, which serves as the reliable index of the location of foci color.

6.4 Future works

The empirical observations of the present study provide substantial evidence to improve our overall understanding of the interaction between language and perception of color. This is a critical issue related to the scientific field of cognitive linguistics, and it is also a fundamental topic in psychology. The current results are also comparable with the data in the WCS project.

Beyond the academic interests, from the practical point of view, knowledge about lexical color category is the groundwork in applied researches of color. It is meaningful and applicable to all kinds of visual display and communication involving colors. When color serves as a visual medium in carrying and conveying information, choosing them carefully from the well-known color categories would be a wiser strategy. People in the modern world rely on colors for acquiring immediate messages. We are so accustomed to dealing with innumerous types of color coded materials. Efficient color design in such message indexing applications requires the use of the most distinguishable colors, i.e., colors from distinct mental categories. The psychological distance between colors selected from independent color categories would be maximized, and thus minimizing the tax on the cognitive resource for recognizing these colors. The advance in the knowledge about color categories would certainly benefit design works involving colors as indexing symbols.

Further extension works of current study will focus on two lines: (1) deepen the understanding of color concept and color expressions in Mandarin. There is quite a few unsolved problems left by current research, and there is also a vacancy of color- related empirical data contributed from Mandarin, such as the development of secondary color terms, or the characteristics of modifiers. (2) Applying the knowledge of lexical color categories on practical issues. For example, the PCCS color system specifies corresponding range for color tones with modifiers like dull, bright, light, deep, and dark. Color specifications with language would greatly improve the efficiency and precision in the color planning works. Moreover, the features of categorical color perception and color lexical expressions could potentially link with many psychological aspects of color, including color associations and emotion, and even the preference of the color. These interesting issues await further investigations.

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