A CROSS-CULTURAL STUDY ON COLOR PERCEPTION: COMPARING TURKISH AND NON-TURKISH SPEAKERS' PERCEPTION OF BLUE

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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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ABSTRACT

A CROSS-CULTURAL STUDY ON COLOR PERCEPTION:
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PERCEPTION OF BLUE

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Turkish speakers differentiate the blue region of color spectrum into *mavi* (blue) and *lacivert* (dark blue); whereas non-Turkish speakers in this study had only one color term in the blue region. The present study aimed to explore the predictions of the Linguistic Relativity Hypothesis. Operationally, Categorical Perception (CP) effects were used. In Experiment 1, Turkish speakers performed a naming task to determine an average category boundary between *mavi* and *lacivert*. In Experiment 2, both Turkish and non-Turkish speakers' color-difference detection thresholds were estimated on the average boundary as well as within the *mavi* and *lacivert* categories. The thresholds were also estimated in the green region, in which both groups had only one color term. 2-

TAFC method, which eliminates the effects of memory or labeling and isolates the perceptual processes, was used to estimate the thresholds. Turkish speakers, and not non-Turkish speakers, were predicted to show CP effects only in the blue region: thresholds should be lower on the boundary than within-category. The result revealed that Turkish speakers' color-difference detection thresholds were lower than those of non-Turkish speakers both in the blue and the green regions. The difference in the green region does not rule out the LRH. It is possible that this difference resulted from the limitations of the study. Finally, in Experiment 3, Turkish speakers' thresholds were also estimated on their individual boundaries. The patterns of the thresholds revealed by Experiment 3 were similar to the pattern of the thresholds in Experiment 2.

Keywords: Color Perception, Linguistic Relativity Hypothesis, Categorical Perception, 2-TAFC Method

ÖZ

RENK ALGISI ÜZERİNE KÜLTÜRLER ARASI BİR ÇALIŞMA:
TÜRKLER'İN VE TÜRK OLMAYANLARIN MAVİ ALGILARININ KARŞILAŞTIRILMASI

Kadıhasanoğlu, Didem
Yüksek Lisans, Bilişsel Bilimler
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Türkler, renk spektrumunun mavi bölgesini *mavi* ve *lacivert* olmak üzere iki ayrı kategoriye ayırmaktadır. Bu çalışmaya katılan yabancıların dillerinde ise renk spektrumunun mavi bölgesi için sadece bir renk kelimesi bulunmaktadır. Bu çalışmada Dilsel Görelilik Varsayımı'nın tahminleri araştırılmıştır. İşlevsel olarak, kategorik algı etkileri kullanılmıştır. Birinci deneyde, *mavi* ve *lacivert* arasında ortalama bir kategori sınırının belirlenmesi için, Türkler bir isimlendirme görevi yapmışlardır. İkinci deneyde, Türkler'in ve yabancıların, hem *mavi* ve *lacivert* kategorileri içindeki hem de ortalama sınır etrafındaki renk-farkı algılama eşikleri hesaplanmıştır. Renk-farkı algılama eşikleri, her iki grubun da sadece tek renk kelimesinin olduğu yeşil bölgesi için de hesaplanmıştır. Renk-farkı algılama eşiklerini hesaplamak için belleğin etkilerini ortadan kaldırarak algısal süreçleri yalnız bırakan 2-TAFC metodu kullanılmıştır. Tükler'in sadece mavi bölgesinde kategorik algı etkileri göstereceği; yabancılarda ise böyle bir etkinin görülmeyeceği beklenmiştir. Başka bir deyişle, Türkler'in ortalama sınırdaki renk-farkı algılama eşiklerinin, kategori içi renk-farkı algılama eşiklerine kıyasla daha düşük olacağı düşünülmüştür. Çalışmanın sonuçları, Türklerin renk-farkı algılama eşiklerinin hem mavi bölgesinde hem de yeşil bölgesinde yabancılarınkinden daha düşük olduğunu ortaya çıkarmıştır. Ancak, yeşil bölgesindeki fark Dilsel Görelilik Varsayımını geçersiz kılmamaktadır. Türkler ve yabancılar arasındaki fark, yeşil bölgesinde çalışmanın kısıtlamalarından kaynaklanmış olabilir. Son olarak üçüncü deneyde, Türkler'in renk-farkı algılama eşikleri, *mavi* ve *lacivert* arasındaki kişisel sınırları kullanılarak hesaplanmıştır. Üçüncü deneyde elde edilen renk-farkı algılama eşikleri arasındaki örüntü, ikinci deneyde elde edilenlere benzemiştir.

Anahtar Kelimeler: Renk Algısı, Dilsel Görelilik Varsayımı, Kategorik Algı, 2-TAFC Metodu

To My Dear Husband

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INTRODUCTION

The relationship between language, thought and cognition has long intrigued many researchers. Why do we see the world the way we do? One answer to this question is that our minds impose structure on sensations, and thus appearances are the result of mental constructions. An alternative answer is the theory of direct perception. The Linguistic relativity theory (Whorf, 1956) is related to constructivism: the language we speak influences the way we think and perceive; differences in grammar and vocabulary across languages reveal differences in cognition (Davies & Corbett, 1997). Since languages differ greatly in their color vocabulary, studying how speakers of different languages perceive and think about color could provide insight into the relationship between language and thought. Color cognition has been the natural testing ground for the linguistic relativity theory.

The debate over color language and color cognition consisted of two phases. In the first phase, which lasted until 1970, relativism was the dominant view. With Berlin and Kay's (1969) theory of color universals, the second phase began. In the second phase, universalism became dominant. Berlin and Kay proposed a universal inventory of exactly eleven basic color categories. The color names in languages with fewer basic color terms were always drawn from of this universal set.

Cross-cultural studies comparing the speakers of different languages challenged the Berlin and Kay's (1969) theory and revealed that language may affect color perception. Also, it was found that some languages such as Russian and Turkish have twelve basic color terms. Turkish speakers differentiate the blue region of color space into *mavi* (blue) and *lacivert* (dark blue). The existence of such extra basic terms allows for behavioral tests of cross-cultural perceptual effects by comparing speakers of different languages.

Purpose of the Study

The present study aims to explore the predictions of the Linguistic Relativity Hypothesis; if language influences perception, then Turkish speakers and non-Turkish speakers might show perceptual differences along the *mavi-lacivert* category boundary. Turkish and non-Turkish speakers' color-difference detection thresholds (how much of a difference is necessary for the difference to be perceived) across and within the Turkish blue categories will be compared. Operationally, Categorical Perception (CP) effects (better discrimination across a category boundary than within each category) will be used

Significance of the Study

Color perception has been a natural testing ground for investigating the linguistic relativity theory. Studying how speakers of different languages with different color term repertoires perceive and think about color could provide insight into the relationship between language, thought and cognition.

Many studies comparing speakers of different languages with different color term repertoires have investigated the effect of language on color perception. These studies have revealed cross-language differences in categorical perception indicating that language can influence color cognition. However, all of these studies are vulnerable to the criticism that the observed differences between speakers of different langudes may be due to a direct naming strategy (Roberson & Davidoff, 2000). The question whether speakers of different languages actually see colors differently still needs further investigation. Such investigations should employ a discrimination task which eliminates naming strategies and isolates the perceptual processes. In this study, Turkish and non-Turkish speakers' low-level perception of colors will be investigated using 2 Temporal Alternative Forced Choice (2-TAFC) method, a new method suggested by Özgen *et al.* (2004). Özgen *et al.* states that 2-TAFC method eliminates naming strategies and isolates the perceptual processes.

Hypotheses

Comparison of Turkish and non-Turkish speakers on color-difference detection thresholds across and within the Turkish blue categories is predicted to reveal language effects on perception. Turkish speakers, and not non-Turkish speakers, are predicted to show CP effects: color-difference detection thresholds should be better on the boundary than within-category. In other words, sTurkish speakers should discriminate colors better than non-Turkish speakers around the *mavi-lacivert* boundary.

The organization of this thesis is as follows. In Chapter 2, the literature on color language and color cognition related to the Linguistic Relativity Hypothesis will be reviewed selectively. In Chapter 3, an overview of the study will be given followed by information regarding the methodology and result of the experiments. In Chapter 4, the results will be discussed with possible explanations and limitations. Finally, a brief conclusion on the study will be presented.

CHAPTER 2

LITERATURE REVIEW

2.1 THE LINGUISTIC RELATIVITY HYPOTHESIS

The question whether the language we speak affects the way we think about reality has long been the issue of interest for linguists, philosophers, anthropologists, and psychologists. Do people who speak different languages think about the world differently? Does learning new languages change the way we think? Many studies have been carried out in order to answer these questions.

The linguistic relativity hypothesis (LRH) proposes that languages differ greatly in the way they "break down" the natural world and that the mental processes, or thoughts, of the speakers of a language will be affected by this (Whorf, 1956 [1940]). In other words, the language we speak influences the way we think and perceive, differences in grammar and vocabulary across languages reveal differences in cognition (Davies & Corbett, 1997). The idea that language shapes thought is associated with Benjamin Lee Whorf (Kay & Kempton, 1984; Lucy, 1992). Whorf drew extensively upon the prior work of the anthropologists Franz Boas and Edward Sapir (Lucy, 1992).

Sapir was Boas's student and Whorf, Sapir's. Both Boas and Sapir emphasized that every language classifies experience and this classification can vary considerably from language to language; however, they differ in the importance of this variation for thought and culture (Lucy, 1992). Boas believed that thought and culture have stronger influences on language, and that linguistic classifications reflect thought. Sapir reversed Boas's claim and argued that organized linguistic classifications channel thought. According to Sapir, thought arise from an interpretation of language classification. He dismissed the intuition of being able to think without language.

Whorf furthered the arguments developed by Boas and Sapir (Lucy, 1992). He claimed that an intellectual system embodied in each language shapes the thought of its speakers (Kay & Kempton, 1984). According to Whorf (1956 [1940]),

> The categories and types that we isolate from the world of phenomena we do not find there because they stare every observer in the face. On the contrary the world is presented in a kaleidoscopic flux of impressions which have to be organized in our minds. This means largely by the linguistic systems in our minds (p. 212).

He proposed that the categories and distinctions of each language result in different ways of perceiving, analyzing, and acting in the world. Therefore speakers of different languages should also differ in how they perceive and act in objectively similar situations (Boroditsky, 2001).

Miller and McNeill (1969 cited in Özgen, 2000) suggested that there are three different degrees of the LRH. The strongest form of the LRH is that language determines thinking. A weaker form of the LRH proposes that perception is influenced by language, and the weakest form proposes that higher level cognitive functions like memory is influenced by language. The strongest Whorfian view has long been abandoned in the field (Boroditsky, 2001). Color perception has been a suitable ground for testing the predictions of the weaker forms of LRH since the number of the color-terms varies across languages and it seems that languages partition and encode the continuous color space in different ways (Özgen, 2004). Investigating how speakers of languages with different color term repertoires perceive colors could provide insight into the relationship between language, thought and cognition.

2.2 BASIC CONCEPTS

2.2.1. The Nature of Color

The electromagnetic spectrum is a continuum of all electromagnetic waves that have different wavelengths and frequencies. Light is a narrow range of electromagnetic waves that is visible to the eye. Light of different wavelengths produces different sensation of color (Malacara, 2002). The longest wavelengths produce the perception of red; the shortest ones produce the perception of violet.

The colors produced by a prism are called spectrally pure or monochromatic. They are related to the wavelength. Different spectrally pure colors are said to have a different *hue*. Not all colors in nature are spectrally pure since they can be mixed with each other (Malacara, 2002). *Lightness* is the perceived level of emitted light relative to light from a region that appears white. The vertical axis in Figure 1 shows the change in lightness. *Chroma* is the perceived difference between a color and an achromatic percept of the same lightness; therefore, it is a relative value. The horizontal axis in Figure 1 corresponds to the change in chroma from zero chroma to maximum chroma. *Saturation* is the perceived difference between a color and white, regardless of lightness (Shevell, 2003). It can be seen from Figure 1 that when saturation changes both chroma and lightness changes.

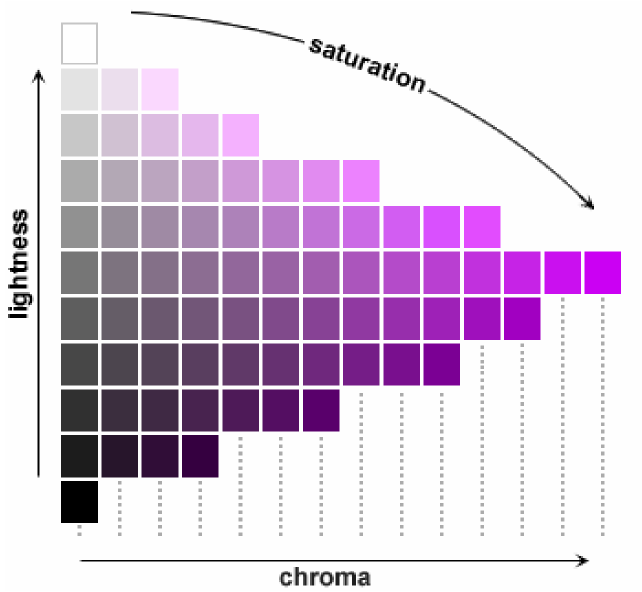

Figure 1 Change in lightness, saturation and chroma.

2.2.2 Color Spaces

The laws of colorimetry state that many color stimuli can be matched in color completely by additive mixtures of three fixed primary stimuli whose radiant powers[1] have been suitable adjusted (Wyszecki & Stiles, 1982). The choice of three primary stimuli can be very wide, but it is not arbitrary. In a primary stimuli set, none of the primary stimuli can be color matched by a mixture of the other two stimuli. Based on this trichoramatic property, any color stimuli can be represented by vectors in three-dimensional space, called *tristimulus space*. In this section, three of these tristimulus spaces will be explained briefly.

CIE Color Space

Within CIE (Commission Internationale de l'Eclairage) color space, colors are represented by red, green and blue components and the proportions of these three must sum to one. The proportions of red (x) and green (y); and a third coordinate lightness (Y) constitute the CIE chromaticity coordinates of color.

[1] Radiant power (or radiant flux) is radiant energy emitted, transferred, or received through a surface, in unit time interval (Wyszecki & Stiles, 1982).

The proportion of the blue light (z) in a color is equal to $1 - (x + y)$. The colors with the same CIE coordinates will look the same (Özgen & Davies, 1998).

The CIE (x, y, Y) space is not perceptually uniform; which means that equal distances in the space do not represent equal perceptual distances[2]. CIE (L^* u^* v^*) space is the transformation of The CIE (x, y, Y) and it is approximately perceptually uniform. Perceptual uniformity is an important property for estimating color differences in terms of perceptual differences. In CIE (L^* u^* v^*) space, u^* is the transformation of x and v^* is the transformation of y. As expected, blue colors have a high proportion of blue and low proportions of red (u^*) and green (v^*) in it; whereas red colors have a high proportion of red in them (Özgen & Davies, 1998). The CIE values of a color are not tided to the device, but to human vision; therefore, they are called device-independent (Wandell & Silverstein, 2003).

Munsell Color Space

The Munsell color space is a collection of standard color chips that serves as s framework for specifying a surface color in terms of three coordinates: hue (H), chroma (C), and value (V; or lightness from black to white through gray) (Indow, 1988). Each chip is identified by a 3-part code. For example, notations such as 7.5R 6.5/10 means that the color is identical to human eyes under standard observation condition (daylight illumination, middle gray to white surroundings), with the color chip to be placed at the position named as 7.5R in hue, 6.5V in lightness, and 10 C in saturation. Munsell Color Space is perceptually uniform[3]. This means equal size steps in Munsell hue have the same perceptual distance across color space (Wyszecki & Stiles, 1982; Indow, 1988).

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[2] Perceptual distance refers to the perceived difference between two colors. Uniform perceptual distance means that equal distances between colors in a space are perceived by human observers to have the same color difference.

[3] For a detailed explanation about measuring perceptual distances in Munsell space, see Wyszecki & Stiles, 1982.

RGB Color Space

Another common color space is the RGB color Space, which is usually used in television screens and computer monitors. In RGB Color Space three phosphors, red phosphors, green phosphors and blue phosphors, are used to produce colors. The trichoramatic coordinates of these three phosphors form a triangle. Any of the colors inside this triangle can be reproduced; but the colors on the outside of the triangle cannot be produced. This means that, the larger the triangle, the larger the color gamut (Malacara, 2002).

The RGB responses of a device are unique to that device. This means that the colors with the same RGB coordinates will not look the same when displayed, for example, on different computer monitors (Wandell & Silverstein, 2003). The RGB Color Space is not perceptually uniform.

2.2.3 Color Vision

Color is a response of the nervous system to certain stimuli (Abramov, 1997). Color vision is the process by which information regarding the wavelength composition of a visual stimulus is extracted (Nathans, 1999). In other words, it is the ability to distinguish wavelengths of light regardless of their relative intensities. The interactions between light and the nervous system begin at a thin layer of neural tissue, called retina, at the back of the eye. Photoreceptor cells in the retina absorb light and initiate an electrical response. The information in the receptors is transmitted through bipolar cells to the retinal ganglion cells. Then, the information runs through the optic nerve which is formed by axons of the ganglion cells. Eventually, it exits from the eye to continue to the primary visual cortex through thalamus (Abramov, 1997).

Human color vision is *trichromatic*. That is, the number of independent variables in color vision is three. Trichromacy is not a physical property of light but a physiological limitation of the eye. All color perceptions are determined by just three physiological response systems. A linear transform exits between the tristimulus color matching property of the eye and the spectral sensitiveness of the three physiological systems mediating the matches. The three physiological response systems are universally accepted to be the three types of photoreceptor cells, which are called cones, on the retina. The types of the cone cells are L-cones, M-cones, and S-cones. Each type of cones contains a different photopigment having distinct spectral sensitivities or absorption spectra. L-cones are more sensitive to long wavelengths; M-cones are more sensitive for middle wavelengths; and S-cones are more sensitive to short wavelengths. The absorbance spectra of the S-, M-, and L-cone photopigments overlap considerably, but their wavelengths of maximum absorbance are different (Sharpe *et al*., 1999). All of the cone types function well in bright light (photopic vision) (Abramov, 1997).

There is also a fourth type of photoreceptors: the rods. Rods are more sensitive than the cones; however, they do not detect color well. They are adapted for low light levels (scotopic vision). Color vision has been thought to be mediated entirely by the cones. However, there is experimental evidence that rods can contribute to color vision under limited, dim light conditions (Abramov, 1997).

An individual cone cell is color blind. The cone photopigments signal only the rate at which photons are caught. Therefore, lights of different spectral distributions will appear identical if their absorption in the three cone photopigments is the same. Color vision requires comparisons of photon absorption in different photopigments. Consequently, trichromatic color vision requires three independent comparisons. Merely summing the absorptions in the three cone photopigments produces only brightness or contrast discriminations, not color vision (Sharpe *et al*., 1999). There are two requirements for color vision to occur: At least two different photoreceptor types with different absorption spectra must exist in the eye; and postreceptoral mechanisms, which can compare the outputs of the phororeceptor types, must be present (Kremers *et al*., 1999).

As previously stated, the neural code for color begins in the retina. The responses of the cone cells in the retina are independent of wavelength. The wavelength-independent responses are transformed into wavelength-sensitive responses in certain ganglion cells located in the retina (Lee, 1999). In retinal ganglion cells, there are three channels to convey the information from the eye to the brain. (1) L + M or luminance channel carries information about luminance contrast by summing the signals from M- and L-cones; (2) L – M color-opponent channel carries information about the red-green component of a stimulus by subtracting the L- and M-cone signals from each other; and (3) S – (L + M) channel carries information about the blue-yellow component of the stimulus by subtracting the sum of the L- and M- cone signals form the S-cone signal. These three channels are called "cardinal directions" of color space and are functionally independent (Gegenfurtner, 2003).

The axons of the ganglion cells exit the eye and form the optic nerve. The optic nerve enters the brain and terminates in a region of the thalamus which is devoted to vision: the lateral geniculate nucleus (LGN) (Abramov, 1997). LGN cells are different in their functional and chromatic properties. Cells in the mangocellular layers of the LGN are sensitive mostly to luminance information, cells in the parvocellular layers to red-green information, and cells in the koniocellular layers to blue-yellow information (Gegenfurtner, 2003). The LGN cells project the information that they receive from the retina to the primary visual cortex (V1) via three independent anatomical pathways: magnocellular pathway, parvocellular pathway, and koniocellular pathway. The projections from the magno-, parvo-, and koniocellular pathways terminate in different layers of V1 (Gegenfurtner & Kiper, 2003). V1 is the only cortical area that receives projections from LGN (Lennie, 2003).

Although the early stages of color vision have been investigated extensively, the cortical stages are less well understood. Past researchers assumed that there were two types of cells in the visual cortex: cells responding only to luminance and cells responding only to color. However, current studies indicate that there is a continuum of cells, varying from cells that respond only to luminance, to cells responding strictly to color. A cell responding to luminance can also give differential responses to color modulations. Similarly, a cell responding to color can respond to variations in luminance. In the cortex, many cells respond to color and the analysis of luminance and color is not separated (Gegenfurtner, 2003).

Current studies on primate visual cortex suggest that V1 combines the information coming through these three pathways and distributes it to distinct domains in V2 for transmission to higher visual areas (Sincich & Horton, 2005). Neuroimaging experiments showed strong responses to color in V1, V2, and V4 areas. Previously, it was thought that V4 area is uniquely specialized for color vision. However, it is established that V4 is not only responsible for color vision; it is a main center for all aspects of spatial vision and an important link between vision, attention and cognition (Gegenfurtner & Kiper, 2003).

2.3 CATEGORIZATION AND COLOR CATEGORIES

Humans can discriminate a wide range of event and objects in the world. If each event or object encountered were treated as unique, then the complexity of the environment would be overwhelming. Instead, things that are discriminable but in some way related are grouped together and are responded to as equivalent (Bruner, Goodnow, & Austin, 1956). This process is called categorization. One of the advantages of categorization is that it reduces the complexity of the environment. A great deal of information about the environment can be gained while conserving finite resources as much as possible (Rosch, 1978). As Özgen (2000) stated, responding to discriminably different objects in terms of their category membership enables people to learn, and respond to category members much more efficiently and easily. As a result, the degree of learning that is necessary in order to survive in the environment is reduced significantly.

Humans can discriminate millions of colors, yet the number of color terms in every language is comparatively small (Hardy *et al.*, 2005). Responding to each instance of colors as unique would be inefficient. Instead, some colors are grouped together and distinct categories such as *red*, *green*, or *turquoise* are formed. These color categories are examples of natural categories (Rosch, 1975), the categories that people use when they label natural or cultural objects (Bybee & Moder, 1983).

The prototype theory of natural categories states that some members of a category are better representatives of that category than others (Rosch & Mervis, 1975; Rosch, 1978). According to this theory, an object is perceived as a member of a category or not, on the basis of how much it resembles a best exemplar, or *prototype*. Focal colors are the best exemplar of color categories. Rosch (Heider, 1971; Heider, 1972) stated that focal colors are prototypical members of color categories and they differ from non-focal-colors on linguistic and behavioral measures. As Özgen (2000) stated, the prototypical nature of color categories has led to the development of important theories (e.g. Kay & McDaniel, 1978) and empirical studies (e.g. Heider, 1971) that contributed to the linguistic relativity debate.

2.4 CATEGORICAL PERCEPTION

Categorical perception is a psychophysical[4] effect in which a physical continuum is partitioned into discontinuous regions by a perceptual mechanism (Livingston *et al.*, 1998). Harnad (1987) described the CP effect as follows: Equal-sized physical differences between stimuli are perceived as larger or smaller depending on whether the stimuli are in the same category or in different ones. Figure 2 demonstrates the CP effect.

[4] Psychophysics deals with the relationship between physical stimulation and their perception.

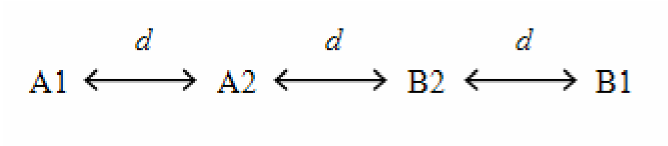

Figure 2 The categorical perception effect (taken from Özgen, 2000).

In Figure 2, A1 and A2 belong to category A, and B1 and B2 belong to category B. Discriminating A2 and B2 will be easier or more accurate than discriminating either A1 and A2 or B1 and B2, although the distance *d* is equal for all three distances. Distance *d* may refer to distances in perceptually uniform spaces or physical distances (e.g. wavelength, stimulus size in cm, etc.).

The CP effect is not only a quantitative effect; it is also a qualitative one (Harnad, 1987). A blue looks more similar than a green to another blue even though the distances between the three colors are equal in wave length. However this qualitative difference cannot be measured objectively since the only available information is the participant's own experience. On the contrary, the quantitative differences can be tested experimentally by comparing identification and discrimination performances for a set of stimuli, which usually vary along a physical continuum. Identification requires categorizing stimuli using labels (for example, to say whether a stimulus is blue or green). A CP effect occurs when a set of stimuli ranging along a physical continuum is given one label on one side of a category boundary and another label on the other side. Discrimination requires telling apart stimuli presented in pairs (for example, by indicating whether they are the same or different). In this case, a CP effect occurs when a participant can discriminate smaller physical differences between pairs of stimuli that cross the boundary than between pairs that are entirely within one category or the other. In other words, category boundaries become sensitized. Goldstone (1994) also showed that sensitization within categories may also occur as a result of categorization. However, this type of sensitization is relatively small compared to the sensitizations around category boundaries.

Categorical perception effects have been best revealed by speech phoneme categories. For example, Liberman *et al.* (1957) generated a continuum of consonant-vowel syllables between /be/ and /de/. Participants listened to three sounds: A followed by B followed by X. The task was to indicate whether X was identical to A or B. Performance of the participants was better when syllables A and B belonged to different phonemic categories (/be/ vs. /de/) than when they were from the same category (both /be/ or both /de/). Since Liberman *et al.* (1957), CP has been found in a variety of domains such as perception of familiar faces (Beale & Keil, 1995), newly learned faces (Viviani *et al.*, 2007), facial expressions (Campanella *et al.*, 2002), familiar objects (Newell & Bülthoff, 2002), and faces of different species (Campbell *et al.*, 1997). Color perception has also provided a fruitful ground for demonstrations of CP effects.

2.5 CATEGORICAL PERCEPTION OF COLORS

Although the color spectrum is a continuum of wavelength of visible light, the perception of it is discontinuous, i.e., it is perceived as distinct groups of hues which have names such as “red”, “green”, “blue” and “yellow” (Özgen, 2000). Figure 3 demonstrates the categorical perception of color.

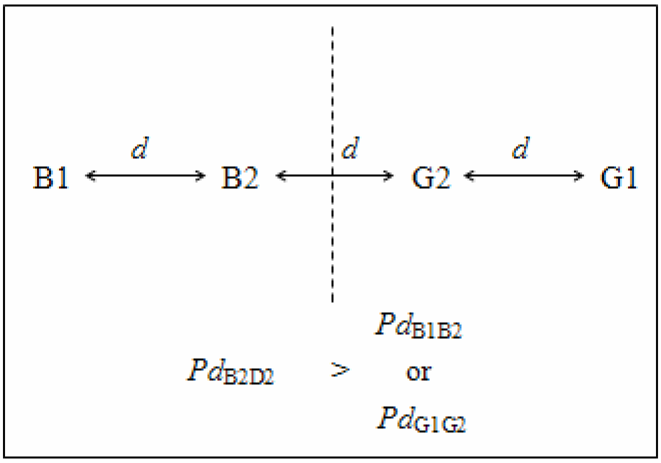

Figure 3 Diagram demonstrating categorical perception of color (taken from Özgen, 2004).

In Figure 3, there are four colors which are separated from each other by equal distances. The colors B1 and B2 are examples of blue and the colors G1 and G2 are examples of green. The dashed line represents the category boundary between blue and green. It is easier (faster, or more accurate) to decide that B2 and G2 are different, than to decide B1 and B2 or G1 and G2 are different. In other words, people find is easier to distinguish between two colors when they are from separate categories than when they are both from the same category. The perceptual distance, *Pd*, is greater for the pair that crosses the boundary than for the pairs that do not. The CP effects on color perception could be innate; or, since color categories are created by language, they could be induced by language. Thus, the CP effects on color perception made it possible to test the LRH particularly through investigations of color categorization across different cultures (Özgen, 2004).

2.6 MAJOR FINDINGS AND THEORETICAL DEVELOPMENTS

The history of the debate over color language and color cognition consisted of two phases. In the first phase, which lasted until 1970, relativism was the dominant view. With Berlin and Kay's (1969) theory of color universals, the second phase began. In this section, major findings and theoretical developments following the seminal study of Brent Berlin and Paul Kay (1969) will be reviewed.

2.6.1 The Berlin and Kay Theory

Work within the color framework divides into two phases (Davies & Corbett, 1997). Before 1969, prevalent assumption was that languages encoded color "without constraint". The continuum of the color spectrum was segmented arbitrarily into categories corresponding to the lexical terms in language. This relativist view was consistent with the apparent diversity of color categories across languages. However, Berlin and Kay (1969) studied the color terms of many languages and found evidence for much less variation in the color terms across languages than supported previously. They brought about two important theoretical and methodological developments (Özgen, 2000; Özgen & Davies, 1998). First, they restricted color terms to a subset, to the Basic Color Terms (BCTs) and suggested that what was relevant to the debate was only the BCTs of languages. Berlin and Kay stated that much less variation was observed on the focal points (the best exemplars, or foci) of color terms than on their boundaries. So, as a second development, they defined color categories in terms of their foci rather than their boundaries and suggested that the investigation of foci of the BCTs would provide more insights into patterns across languages.

According to Berlin and Kay (1969), if a color term is basic, then it should exhibit the following four characteristics:

(i) Its meaning should not be predictable from the meaning of its part. This criterion eliminates color terms like “light blue”, “bluish” or “lemon-colored”.

(ii) Its signification is not included in that of any other color term. This criterion eliminates color terms like “violet” which is a kind of purple, or “scarlet” which is a kind of red.

(iii) Its application must not be restricted to a narrow class of objects. This criterion eliminates color terms like “blond” which is used only for hair, complexion and furniture; or terms like “color of petrol”.

(iv) It must be psychologically salient. In other words, it must come to mind easily, and it must be used frequently.

Berlin and Kay showed that the foci of the BCTs across languages showed great similarity and suggested that the BCTs in all languages were drawn from a set of just eleven universal color terms. They also proposed that languages encoded these BCTs in an orderly way, probably based on perceptual physiology. The hierarchy shown in Figure 4 represents the evolutionary order in which languages acquire BCTs.

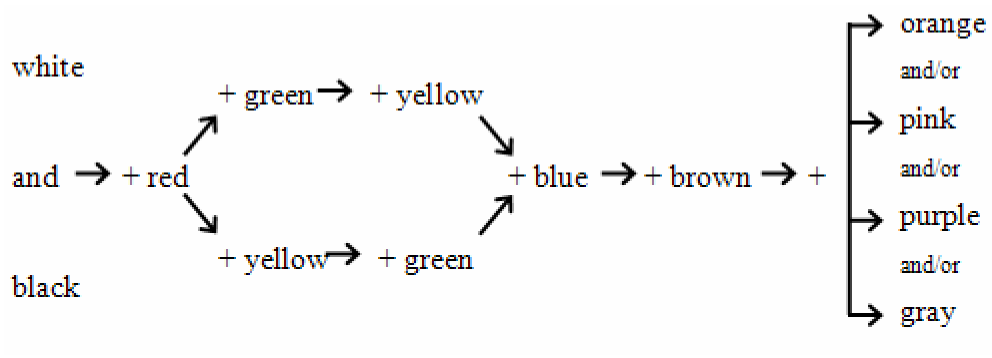

Figure 4 The evolutionary order for BCTs proposed by Berlin and Kay (1969).

According to this hierarchy, all languages start with two terms: WHITE and BLACK (capitals denote the hypothetical universal categories); the third term to be acquired is RED. As a fourth term, either GREEN or YELLOW is encoded. The fifth term is whichever of GREEN and YELLOW is missing; and so on up to the eleven universals. Further, if a language has a term in a given position in the series, then according to this theory, it should have all the terms with earlier position in the series.

In later years, Berlin and Kay, together with colleagues, revised their theory in order to adapt it to cross-linguistic data that cannot be explained with the theory and provide stronger links with perceptual physiology (for details, see Kay & McDaniel, 1978; Kay, Berlin & Merrifield, 1991; Kay, Berlin, Maffi & Merrifield, 1997). For example, they relaxed the hierarchy of BCTs in order to accommodate the early appearances of terms such as BROWN and GREY. They allowed these terms to appear anywhere in the order of BCTs (Kay, Berlin & Merrifield, 1991). The major development to the theory was made by Kay and McDaniel (1978). Kay and McDaniel extended the Berlin and Kay theory based on the universal physiology and fuzzy set theory. The Kay and McDaniel theory will be discussed in detail later.

The Berlin and Kay theory led to important findings. It suggested that the common assumption that languages encoded color "without constraint" might not be true. Indeed, there seem to be universal constraints and consistent patterns on color cognition across languages. The Berlin and Kay theory gave rise to new methods for cross-cultural research on color cognition.

2.6.2 Dani Language and English

One of the important studies that had an impact on the research of color cognition came from Elenaor Rosch Heider. She studied the color cognition of Dani and English speakers whose languages divide the color spectrum in radically different ways (Heider, 1972; Heider & Olivier, 1972). The language spoken by the Dani of Indonesian New Guinea -a stone-age, agricultural people- had only two color terms: *mili* and *mola*. *Mili* included both dark and cold colors; *mola* included light and warm color. Rosch (Heider, 1972) investigated four questions: 1) Where is the location of focal colors on the saturation dimension? 2) Are focal colors more codable[5] than non-focal colors across languages? 3) Will focal colors be more accurately remembered than non-focal colors when a short-term recognition task is employed as a memory measure? and 4) Will focal colors be more easily retained in long-term memory and become more easily associated with color names? These questions were addressed by four experiments.

In the first experiment, there were participants representing eleven languages, including English. Color stimuli were selected from a set of emulated Munsell colors for eight of the universal color categories proposed by the Berlin and Kay theory (RED, YELLOW, GREEN, BLUE, PINK, ORANGE, BROWN, and PURPLE). For each color, there were several samples: one of them was at maximum saturation; and the others were at lesser saturation for the same hue and value. Participants were asked to choose the best examples of the colors. Regardless of the language spoken, the most saturated colors were chosen as the best examples of the basic color names by all participants. The second experiment showed that focal colors that were determined in the first experiment were given shorter names and named more rapidly than the non-

[5] Codability is a composite measure of agreement in naming, length of name, and response latency in naming (Heider, 1972).

focal colors, indicating that the focal colors are more codable than non-focal colors.

Consistent with the Berlin and Kay theory, Rosch hypothesized that the focal colors were universally perceptually salient. So, the hypothesis of the third experiment was that in a short-term recognition task, focal colors should be remembered more accurately than non-focal colors even by speakers of Dani whose language lacked basic color terms. However, according to the LRH, Dani speakers' memory performance would be the same for focal and non-focal examples of the basic color terms which were absent in their language. The results of the third experiment showed that focal colors were remembered more accurately than non-focal colors both by Americans and Dani. However, the overall memory performance of Dani speakers was much poorer than that of Americans.

A learning task was employed in the fourth experiment. All participants were Dani and they were required to learn new names for the color categories that their language lacked. The hypothesis of the fourth experiment was that focal colors would also be more easily become associated with color names since they retained in the long-term memory more easily. As expected, the result of the experiment showed that focal colors became associated with color names more rapidly than non-focal colors.

The result of the study was consistent with the universal salience of focal colors, since the color cognition of Dani revealed the existence focal colors even without the existence of a word for those colors. Rosch's findings were often taken as counter-evidence for the LRH. However, the overall poor memory performance of Dani speakers compared to Americans can be explained by the lack of categorical distinction in their language and this suggestion is consistent with a weaker of the LRH.

Although Rosch's work with the Dani has been one of the most influential studies, her methodology has also received considerable criticism. One of those criticisms came from Lucy and Schweder (1979). They showed that the focal colors in the stimulus array used by Rosch were easier to discriminate from among the other colors in the array. Lucy and Schweder constructed another stimulus array by eliminating colors in Rosch's array that were frequently confused with other colors. When the new stimulus array was used, the advantage of focal colors over non-focal colors disappeared. Similar results also reported by Roberson *et al.* (2000). They conducted several experiments with a group of people from Papua New Guinea who speak Berinmo, which has five basic color terms. The results of the experiments showed that when Rosch's stimulus array was used, focal colors were remembered more accurately. However, when Lucy and Schweder's (1979) stimulus array was used, the advantage of focal colors disappeared.

Despite the criticisms it has received, Rosch's work provided insight for further cross-cultural studies on color cognition. The idea that color categories have a prototypical nature, which predicts the focality effect, gave rise to important empirical and theoretical studies such as the Kay and McDaniel Theory (Özgen, 2000).

2.6.3 The Kay and McDaniel Theory

Kay and McDaniel (1978) extended the Berlin and Kay theory based on the universal physiology. They proposed that similar and consistent patterns across different languages were based on the pan-human neurophysiological processes in the perception of color. They also proposed a model for the evolution of color categories based on the perceptual physiology and fuzzy set theory. The physiological evidence of that time suggested that there were six fundamental neurological color primitives organized in three opponent process pairs: black-white; red-green; and blue-yellow (Özgen & Davies, 1998). Kay and McDaniel defined these neurological color primitives as *primary* color categories. They proposed two other kinds of basic color categories: *composite* categories and *derived* categories. Composite and derived categories are non-primary color categories. Composite color categories are the fuzzy set union of two or more primary categories. Derived color categories are the fuzzy set intersection of two primary color categories. In fuzzy set theory, category members vary in their strength of membership. So it is consistent with the notion of defining a category by its focus.

According to the Kay and McDaniel theory, the first stage of the hierarchy shown in Figure 4 corresponds to two composite categories: BLACK-BLUE-GREEN and WHITE-RED-YELLOW. Stages two to five correspond to successive decomposition of the two composite categories into six primary color categories. Stages six and seven correspond to development of the five derived color categories: BROWN = BLACK − YELLOW; ORANGE = RED − YELLOW; PINK = RED − WHITE; PURPLE = RED − BLUE; GRAY = BLACK − WHITE (Özgen & Davies, 1998). There are some possible derived terms which are not present in the universal set of eleven basic color categories. The Kay and McDaniel theory doesn't explain, though, why some derived terms have occurred whereas others have not. But it implies that these missing derived terms, such as turquoise (fuzzy set intersection of BLUE and GREEN), may result in languages with more than eleven BCTs.

Although the Kay and McDaniel theory provides a useful framework for color term evolution, it suffers from incompatibility with current empirical evidence on color vision and color processing in the brain (Özgen, 2000).

2.6.4 Cross-Cultural Studies on Categorical Perception of Color

Color categorization has been a natural ground to explore the predictions of the LRH. Early studies generally focused on the effects of language on color memory. For example, Brown and Lenneberg (1956) found a correlation between codability of a color and participants' ability to recognize colors. The more codable colors were remembered better since they could easily be coded linguistically and stored in memory.

Recently, researchers have begun to investigate the predictions of the LRH with cross-cultural studies based on the categorical perception of color. Some African languages provide good opportunity for the cross-cultural study of color CP, since they use a single color term to indicate a region of color space that other Western languages including English encode using two or more terms (Özgen, 2004). For example Setswana, a language spoken in southern Africa, has a single composite term for BLUE and GREEN: *botala*. This means that there is no linguistic category boundary between BLUE and GREEN in Setswana. The question is, do speakers of languages that lack some linguistic boundaries lack these boundaries perceptually as well? Davies *et al.* (1996) compared Setswana and English speakers' performances around the blue-green boundary with a same-different task[6]. They found that English speakers were more accurate around the blue-green boundary. However, Setswana speakers showed no such effect.

In another study comparing speakers of English and Tarahumara, a language spoken in northern Mexico, on a triad task (which of these colors is the odd one out?), Kay and Kempton (1984) found that English speakers showed CP effects across the blue-green boundary whereas Tarahumara speakers, whose language does not distinguish blue and green, did not. English speakers tended to choose the color which was from a different category, whereas Tarahumara speakers did not show such an effect since, according to them, all the colors were from the same category.

Roberson *et al.* (2000) compared speakers of English and Berinmo, a language spoken in Papua New Guinea with five BCTs, using a similar triad task. English has a category boundary between *blue* and *green* whereas Berinmo language does not have. On the contrary, Berinmo language has *nol-wor* boundary that does not exist in English. The *wor* category includes some of

[6] In a same–different task, participants are asked to respond ''same'' when two or more stimuli are identical and ''different'' if one or more of the stimuli are different from the others.

green region of the color spectrum; the *nol* includes much of the green, blue and purple/blue regions. The results of the study were consistent with the RLH: English speakers showed CP effects only at the *blue-green* boundary; Berinmo speakers showed CP effects only at the *nol-wor* boundary.

All of these studies suggest that the CP effects on color perception could be learned by linguistic categories, rather than being innate. However, Bornstein *et al.* (1976) found that after habituating to a given color, four-month-old infants looked more at a new color if it came from a different color category than if it came from the same category as the habituation color, although both colors were physically (in wave length terms) equidistant from the habituation color. Infants responded to colors from the same category as they are the same, suggesting that prelinguistic infants perceive colors categorically. Color order systems such as Munsell are intended to be perceptually uniform. This means equal size steps in Munsell hue have the same perceptual distance across color space. Gerhardstein *et al.* (1999) found that when the distances between colors equated in Munsell units, four-month-old infants showed no CP effects while adults did. According to Özgen and Davies (2002), these findings suggest that along the physical continuum of the color space, infants' color perception shows similar effects to that of adults, but there may still be scope for language to influence color perception, including acquired CP across the borders of a language's main color terms.

2.6.5 The Effect of Verbal Interference on CP Effects

Recently, in a series of experiments, Roberson and Davidoff (2000) examined the effects of verbal interference on CP effects found in the perception of color and facial expressions. They used a two-alternative forced choice (2-AFC) recognition memory paradigm. In the 2-AFC paradigm, a target stimulus is followed after an interstimulus interval (ISI) by two simultaneous test stimuli one of which was physically identical to target. The participants had to choose the one that matches the target. The verbal interference that was employed by Roberson and Davidoff was a list of nonbasic color words selected according to the criteria set out in Berlin and Kay (1969). These nonbasic color words were presented visually. Roberson and Davidoff found that verbal interference selectively affected cross-category comparisons. When verbal interference was employed, the difference between within category and cross-category judgments was not significant anymore; in other words, categorical perception disappeared. They explained the disappearance of CP as follows. Visual coding could be useful for both cross-category and within-category judgments. However, verbal coding would not be useful for within-category judgments in which two test stimuli shared the same category label. On the contrary, for cross-category judgments, verbal coding could be used to differentiate test stimuli. Based on these findings, Roberson and Davidoff proposed that CP effects arose through the use of verbal labeling and rehearsal strategies.

Based on the findings of Roberson and Davidoff (2000), all of the cross-cultural studies reviewed above are vulnerable to the criticism that the observed differences may merely be due to a direct naming strategy[7] (Özgen & Davies, 2002). For instance, the CP effect found in the triad tasks stated above may have occurred because subjects chose the color with a different label. Generally, in discrimination tasks that have memory demands, people may strategically label color with one category name and keep these labels in memory. In order to discriminate colors, they may compare labels. However, Özgen (2004) states that this strategy is restricted to the way people remember colors, not the way people perceive them.

The question whether speakers of different languages with different color term repertoires actually see color differently still needs further investigations. In order to perceive colors differently, changes in color perception at low levels of visual processing are necessary. This means that color perception should be modifiable. Perceptual learning, which refers to performance changes induced by practice or experience in a perceptual skill, indicates that perception can be

[7] Naming strategy involves labeling stimuli and keeping these labels in memory. Then, people compare these labels in order to discriminate between stimuli.

modified; and this learning occurs at the beginning of the visual processing, in the primary visual cortex (Özgen, 2004).

Özgen and Davies (2002) showed that CP effects in color discrimination could be acquired through perceptual learning, more specifically category learning. They defined new category boundaries on the focal areas of the blue and green regions and trained participants to categorize colors across these new boundaries. After training, participants showed CP across the new boundaries. These findings indicate that the weaker form of LRH may be true: Learning a language may affect color perception. Özgen (2004) states that this issue should be further investigated with studies focusing on low-level perception of color by speakers of different languages and with a discrimination task which requires no memory involvement. He suggests that color-difference detection thresholds of speakers of different languages can be compared. Any observed difference in thresholds for an area that is around a linguistic boundary in one language but not the other will most likely reflect differences in low-level perceptual sensitivities. Demonstrating such low-level differences will be compelling evidence for the LRH.

2.6.6 Two Basic Terms for Blue

Cross-cultural studies have also challenged Berlin and Kay's theory of the evolution of BCTs. These studies revealed that some languages appeared to have twelve BCTs. Russian and Turkish are the strongest candidates (Özgen & Davies, 1998). In both languages, the blue region is divided into two BCTs, mainly on the basis of lightness. Thus, Russian and Turkish provide an opportunity to test the predictions of the LRH. Russian distinguishes between light blue, *goluboj*, and dark blue, *sinij*. *Laws et al.* (1995) compared speakers of English and Russian in a series of experiments. However, they could not find any CP effects in any of the triad task, similarity judgment task and color sorting task they employed. Laws *et al.* stated that the focal areas for *goluboj* and *sinij* were small and there was a large area between these colors where naming behavior is unstable. They also stated that their Russian participants had some knowledge of English. According to Laws *et al.*, these two facts may be the reasons for not obtaining any CP effects.

The foci of the Turkish blue terms are different from those of Russian. *Mavi*, Turkish color term for blue, seemed to have its focus at the universal blue and the *lacivert*, second Turkish color term for blue, corresponded to dark blue (Özgen & Davies, 1998). Özgen and Davies (1998) showed that a small region of the color space evoked the label *lacivert*. This was consistent with there being a dark blue category defined by its focus. However, in the same study, participants also indicated that *lacivert* was a kind of *mavi*, which violates the characteristics of BCTs proposed by Berlin and Kay (1969): the meaning of a BCT should not be included in the meaning of other color term. Based on these findings, Özgen and Davies suggested that we might be witnessing the formation of a twelfth basic color term by the intersection of BLUE − BLACK.

In a study comparing Turkish and English speakers, Özgen (2000) found that Turks tended to group *mavi* and *lacivert* colors separately, whereas English speakers mostly grouped these colors together. In the same study, Turkish speakers showed CP effects across the boundary between the *mavi* and *lacivert*; whereas English speakers did not. These findings suggest that the effect of the Turkish extra BCT on color perception provides a further opportunity to test the predictions of the LRH.

2.7 THE PRESENT THESIS

Many studies comparing speakers of different languages with different color term repertoires have investigated the effect of language on color perception. These studies employed different discrimination tasks such as visual search task, triad task, and same-different judgments. In a visual search task, participants are shown a target color. Then, a set of stimuli were presented and participants are asked to choose the colors which are the same as the target. In a triad task, participants are shown three colors and asked to pick the odd one out. In a same-different judgment, participants were shown a target color. As Roberson and Davidoff (2000) pointed out all of these tasks are vulnerable to the criticism that the observed CP effects may merely be due to a direct naming strategy. Also, visual search tasks and same-different judgments have a memory component as the target has to be retained across the ISI in some form, so the origin of CP effects could be memory or labeling.

Özgen *et al.* (2004) suggested a new method called "2 Temporal Alternative Forced Choice" (2-TAFC). In the 2-TAFC method, an adjacent pair of colors is followed after an ISI by another adjacent pair of colors. Participants have to choose the pair which has different colors. In this way, the participants do not have to retain any information, except whether or not the pair is different, across the ISI; and judgments about the second stimulus will not be affected by the judgments of the first stimulus. The 2-TAFC method requires no memory involvement since two colors are displayed simultaneously. Thus, Özgen *et al.* suggests that 2-TAFC eliminates the effects of memory or labeling and isolates the perceptual processes.

As mentioned in the previous section, the evidence consistent with the suggestion that there may be linguistic influences on the perception and the cognition of color and the finding of the extra BCT, *lacivert*, of Turkish provides a fruitful ground for a cross-cultural investigation between Turkish and non-Turkish speakers. In the light of these ideas, the present study aims to investigate Turkish and non-Turkish speakers' low-level perception of colors by comparing their color-difference detection thresholds on the *mavi-lacivert* boundary. The 2-TAFC method will be used in the study.

It is expected that Turkish speakers show CP effects across the category boundary between *mavi* and *lacivert*, whereas non-Turkish speakers do not show such CP effects since their language does not segment the blue region of the color spectrum into two different categories. If such CP effects are obtained, then, based on the 2-TAFC method that will be used in the experiments, they are due to low-level cognitive functions rather than high level functions such as memory or labeling. Thus this result will support the idea that language may affect perception.

CHAPTER 3

EXPERIMENTS

3.1 OVERVIEW

Evidence reviewed in the previous chapter suggests that there may be linguistic influences on the perception of color and Turkish has an extra BCT, *lacivert*, in the blue region of the color spectrum. The Turkish extra color term provides a further opportunity to test the predictions of the LRH. If language influences perception, then only Turkish speakers should demonstrate CP effects around the boundary between the two blue categories, *mavi* and *lacivert*, of Turkish. Two experiments will be reported in this chapter. In Experiment 1, a forced-choice naming task was used to determine an average category boundary between *mavi* and *lacivert*. In Experiment 2, the 2-TAFC method was used to determine the color-difference detection thresholds of both Turkish and non-Turkish speakers whose language has only one color term for the blue region of the spectrum. In Experiment 3, first, Turkish speakers' individual *mavi-lacivert* boundaries were determined. Then, Turkish speakers' color-difference detection thresholds were estimated on their individual boundaries.

3.2 EXPERIMENT 1: COLOR NAMING

The first experiment was a forced choice color naming task. Stimuli were drawn from the *mavi-lacivert* region of the color spectrum. Each color in the stimuli was displayed on the monitor of a computer and participants were asked whether the displayed color is *mavi* or *lacivert*. The aim of this experiment was to find out an average category boundary between *mavi* and *lacivert*.

3.2.1 Method

3.2.1.1 Participants

There were 42 participants (23 women and 19 men); they were all undergraduate students at Bilkent University, Ankara, Turkey, and received course credits for their participation. All of the participants were native Turkish speakers having some knowledge of English. Mean age was 20.02 years, with a range of 18 to 24 years. All participants had normal color vision as assessed by the Ishihara's Tests for Color-Blindness (Ishihara, 2003).

3.2.1.2 Apparatus

A personal computer running experimental software written in Microsoft Visual Basic (v. 6.0) programming language and a Philips 202P70/00 CRT monitor were used. Monitor calibration and color measurements were made using a GretagMacbeth spectrophotometer. Participants used a keyboard for responses.

3.2.1.3 Stimuli

As the first step, a good example of *lacivert* and a good example of *mavi* were selected. A pilot study preceding Experiment 1 was carried out in order to determine the good example of *lacivert*. In this pilot study, stimuli taken from *mavi* and *lacivert* region of the color spectrum were displayed one by one as 9.5 cm × 9.5 cm squares in the center of the screen against a gray background and participants were asked whether the presented color was *lacivert* or not. If the answer to this question is yes, then they were asked whether it was a good example of *lacivert* or not. Twenty five people participated in this pilot study and the majority of them agreed on one of the stimulus as a good example of *lacivert*. Therefore, it was selected as the good example of *lacivert*. A blue, which had the same chroma as that of the good example of *lacivert* and also was not discernibly different from the universal blue suggested by Rosch

Heider (1972), was selected as the good example of *mavi*. Table 1 shows the Munsell, CIE $L^*u^*v^*$, and RGB coordinates of the good examples of *lacivert* and *mavi*.

Table 1 Munsell, CIE L^* u^* v^*, and RGB coordinates of the good examples of *lacivert* and *mavi*.

Color	Munsell Coordinates			CIE $L^*u^*v^*$ Coordinates			RGB Coordinates		
	Hue	Value	Chroma	L^*	u^*	v^*	R	G	B
Good example of *mavi*	77.19	0.77	11.82	8.22	-0.24	-24.40	0	1	62
Good example of *lacivert*	74.03	4.69	11.81	48.35	-28.49	-73.06	2	117	193

The second step was to draw a line connecting the good examples of *lacivert* and *mavi* in order to obtain a continuum between these colors. It was not possible to draw this line in Munsell Space, because *lacivert* is a color with a high chroma. As a result, the chroma values of the majority of the colors on the line exceeded the maximum possible chroma that could be realized on the computer. Therefore, the line was drawn in RGB Space. The equation of the line passing through the good examples of *mavi* and *lacivert* is

$$k = \left(\frac{r}{2}\right) = \left(\frac{g-1}{116}\right) = \left(\frac{b-62}{131}\right) \qquad (1)$$

where r, g, and b denote the R, G, B coordinates of the points on the line. The stimuli of Experiment 1 consisted of 30 colors on this line which were equidistant from each other in RGB Space. Table 2 shows Munsell, CIE L^* u^* v^*, and RGB coordinates for all stimuli.

Table 2 Munsell, CIE $L^* u^* v^*$, and RGB coordinates of all stimuli.

Color	Munsell Coordinates			CIE $L^* u^* v^*$ Coordinates			RGB Coordinates		
	Hue	Value	Chroma	L^*	u^*	v^*	R	G	B
1	77.19	0.77	11.82	8.22	-0.24	-24.40	0	1	62
2	77.22	0.86	11.10	9.10	-0.61	-27.30	2	5	67
3	77.27	0.93	10.38	9.84	-0.95	-29.40	0	9	71
4	77.31	1.01	9.74	10.69	-1.35	-31.78	0	13	76
5	77.22	1.11	9.91	11.76	-1.89	-34.47	0	17	80
6	77.13	1.25	10.21	13.08	-2.57	-37.91	2	21	85
7	77.07	1.33	10.21	13.94	-3.06	-39.60	2	25	88
8	77.00	1.48	10.45	15.35	-3.85	-42.89	0	29	94
9	76.93	1.60	10.39	16.55	-4.61	-44.82	0	33	98
10	76.86	1.75	10.56	18.04	-5.52	-47.83	2	36	103
11	76.79	1.89	10.48	19.45	-6.47	-49.76	0	41	107
12	76.72	2.036	10.59	20.91	-7.43	-52.19	2	44	112
13	76.60	2.19	10.63	22.45	-8.49	-54.30	2	49	116
14	76.50	2.34	10.79	23.97	-9.51	-56.65	0	52	121
15	76.36	2.47	10.61	25.33	-10.59	-57.36	0	56	125
16	76.27	2.63	10.79	27.00	-11.74	-59.78	0	60	130
17	76.06	2.80	10.54	28.72	-13.184	-60.06	2	65	134
18	75.97	2.96	10.66	30.36	-14.37	-61.93	2	69	139
19	75.77	3.13	10.65	32.15	-15.81	-62.79	2	73	143
20	75.56	3.27	10.58	33.62	-17.07	-62.96	2	77	147
21	75.56	3.39	10.95	34.82	-17.81	-65.34	2	80	152
22	75.44	3.55	11.16	36.53	-19.08	-67.01	0	85	157
23	75.29	3.70	11.22	38.05	-20.31	-67.68	0	90	161
24	75.21	3.84	11.45	39.58	-21.42	-69.23	0	93	166
25	75.03	3.98	11.40	40.99	-22.66	-69.10	2	97	170
26	74.87	4.13	11.57	42.60	-23.87	-70.49	0	101	175
27	74.72	4.27	11.70	43.98	-24.92	-71.56	2	105	179
28	74.43	4.41	11.67	45.43	-26.16	-71.69	2	109	184
29	74.19	4.56	11.72	46.97	-27.41	-72.27	2	113	188
30	74.03	4.69	11.81	48.35	-28.49	-73.06	2	117	193

3.2.1.4 Procedure

All participants were tested individually in a darkened room. They first completed the Ishihara's Tests for Color-Blindness, which took about two minutes. Each of the 30 colors in the stimulus set was shown 4 times. The colors were displayed randomly and one by one as 9.5 cm × 9.5 cm squares in the center of the screen against a gray background with a color temperature of 6500°K and a brightness of 48.88 candelas per square meter. Participants were asked to decide whether the color on the screen was *mavi* or *lacivert* as quickly as possible without elaborating. They pressed the left arrow key on the keyboard for *lacivert*; and the right arrow key for *mavi*. Each color was displayed until a response was made. Control of the experiment and randomization were achieved through the experimental software. The naming task took about five minutes.

3.2.2 Results and Discussion

Each participant's number of *mavi* responses was counted for each of the colors in the stimuli. Then, the average number of *mavi* responses was calculated for each color (see, Figure 5).

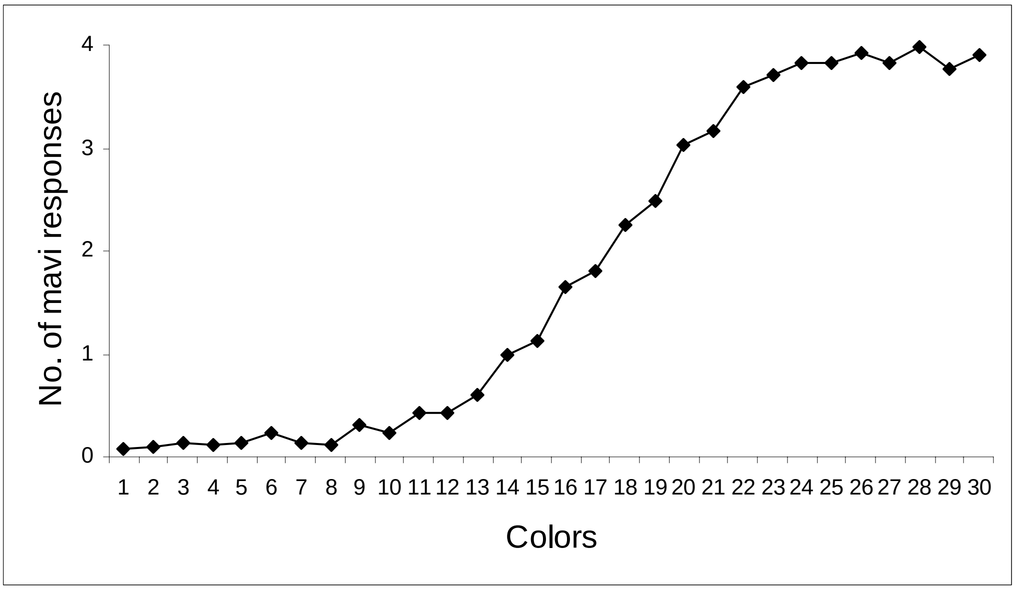

Figure 5 The average number of *mavi* responses for each color in the stimuli.

Based on the S-shape of the response curve, the data was fitted to a sigmoid curve using Matlab 6.5 in order to find the boundary point between *mavi* and *lacivert*. To fit the data, first of all, the probability of being *mavi* was calculated for each color in the stimuli. For example, if the average number of *mavi* responses for a color is 0, this means that the color's probability of being *mavi* is 0. Similarly, if the average number of *mavi* responses for a color is 4, then the probability of being *mavi* is 1. In this case, the boundary point corresponds to the point whose probability of being *mavi* is 0.5. Secondly, the colors were mapped between 0 and 1 in order to determine the boundary point more easily.

0 corresponded to first color, which is the good example of *lacivert*; and 1 corresponded to thirtieth color, which is the good example of *mavi*. The distance between colors was 0.03448276. In other words, 0.03448276 corresponded to the second color; 0.06896552 to the third color and so on.

The sigmoid function was defined by the formula

$$P(x) = \frac{1}{1+e^{-a(x-b)}} \tag{2}$$

where *P(x)* denotes the probability of a color being *mavi*, *a* is the slope coefficient which defines the steepness of the curve, and *b* is the shift coefficient of the curve on Colors axis. *b* also corresponds to the color whose probability of being *mavi* is 0.5. In other words, it indicates the boundary point. Figure 6 shows the sigmoid curve fitted to the data and Table 3 summarizes the results of the curve fitting.

R-square is equal to 0.996, indicating that 99.6% of the variability in the naming data can be explained by the sigmoid curve fitted to the data. *b* is found to be 0.56. This means that the color with 0.5 probability of being *mavi* is the color which corresponds to 0.56 between 0 and 1. The boundary point was between the 17^{th} and the 18^{th} colors. The RGB coordinates of the boundary point was calculated using the equation given in Formula 1. Table 4 shows the Munsell, CIE $L^* u^* v^*$, and RGB coordinates of the boundary point.

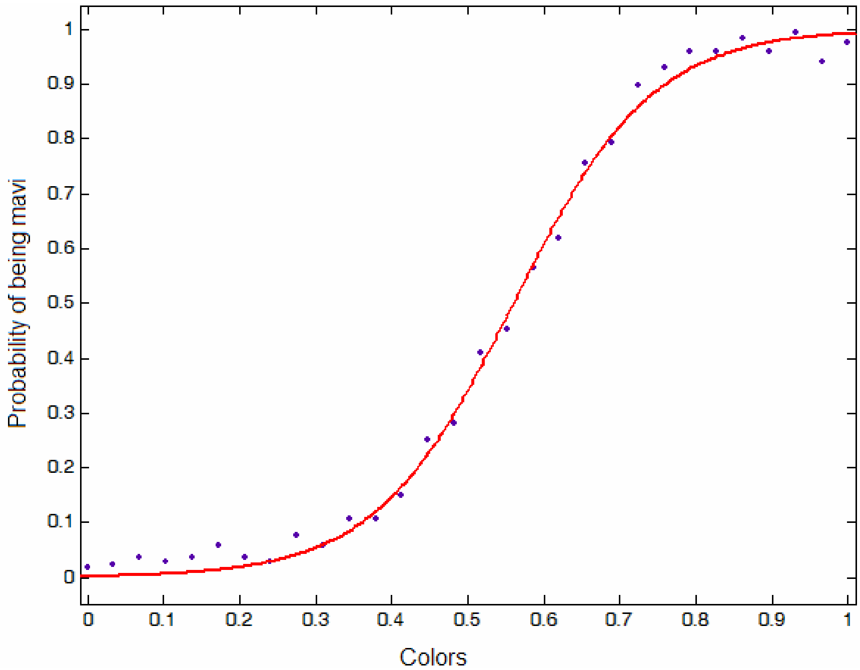

Figure 6 Sigmoid curve fitted to the naming data.

Table 3 The summary of the curve fitting.

Coefficients (with 95% confidence bounds)	
a	10.99 (10.22, 11.77)
b	0.56 (0.5527, 0.5672)
Goodness of fit:	
SSE	0.01864
R-square	0.996
Adjusted R-square	0.9958

Table 4 Munsell, CIE $L^*\ u^*\ v^*$, and RGB coordinates of the boundary point between *mavi* and *lacivert*.

Color	Munsell Coordinates			CIE $L^*u^*v^*$ Coordinates			RGB Coordinates		
	Hue	Value	Chroma	L^*	u^*	v^*	R	G	B
boundary	76.08	2.81	10.64	28.85	-13.23	-60.63	2	66	135

3.3 EXPERIMENT 2: THRESHOLD ESTIMATIONS

The aim of the second experiment was to estimate and compare the color-difference detection thresholds of Turkish and non-Turkish speakers on the average boundary that was determined in the first experiment. Stimuli were drawn from the blue and the green regions of the color spectrum. *Lacivert* is a dark color while *mavi* is a light one. Stimuli from the green region were included in order to control for the possible effects of lightness. For the blue region, three thresholds were estimated: one on the average boundary determined in Experiment 1, and two within the *mavi* and *lacivert* categories. For the green region, first a dark green and a light green were selected. Then, a line passing through these colors was drawn. After that, a boundary point between light green and dark green was determined. Finally, three thresholds were estimated: again one on the boundary point, and two within light green and dark green.

In the green region of the spectrum, both Turkish and non-Turkish speakers have only one color category. Therefore, all participants, regardless of their nationality, are predicted to behave similarly in the green region. However, it is expected to find that Turkish speakers, and not non-Turkish speakers, will show CP effects in the blue region: thresholds should be lower on the boundary than within-category. In other words, it is expected that Turkish speakers should discriminate colors better than non-Turkish speakers around the *mavi-lacivert* boundary.

In Experiment 2, the 2 Temporal Alternative Forced Choice (2-TAFC) method was used instead of the standard 2 Alternative Forced Choice (2-AFC) method.

3.3.1 Method

3.3.1.1 Participants

Participants consisted of two groups: Turkish speakers and non-Turkish speakers. There were 28 Turkish speakers (16 women and 12 men) who also participated in Experiment 1. Their mean age was 19.96 with a range of 18 to 23 years; all were undergraduate students at Bilkent University, Ankara, Turkey and received course credits for their participation. All of the Turkish speakers had some knowledge of English. There were 11 non-Turkish speakers[8] (7 women and 4 men): 6 British, 1 American, 1 Australian, 1 Irish, 1 Dutch, and 1 Belgian. Their mean age was 42.36 with a range of 27 to 53 years. The native languages of all non-Turkish speakers do not differentiate the blue region of the color spectrum into different categories. All of the non-Turkish speakers were international faculty members at Bilkent University, Ankara, Turkey and their participation was voluntary. All had some knowledge of Turkish. Both Turkish and non-Turkish speakers had normal color vision, as assessed by the Ishihara's Tests for Color-Blindness (Ishihara, 2003).

3.3.1.2 Apparatus

The apparatus was the same as that of Experiment 1 except that the participants used a mouse to give their responses instead of a keyboard.

3.3.1.3 Stimuli

Two stimulus sets were constructed in the RGB Space: one in the blue region and the other in the green region. In each of the stimulus set, there were two types of color pairs: cross-category and within category pairs. If the two colors in a pair were from two separate categories (*mavi* vs *lacivert*, or dark green vs. light green), then that pair was called a cross-category pair. If the two colors in a pair were from the same category, (for example, both from *mavi* or both from dark green) then that pair was a within category pair.

Each stimulus set was divided into three areas: two areas for within-category threshold estimations and one area for cross-category threshold estimation. There were two things to be determined to divide each stimulus set: points of

[8] The following data about non-Turkish speakers was not collected:

- The level of their Turkish knowledge.
- How long they have been living in Turkey.
- Whether they were familiar with the term *lacivert* before their participation.

estimation (PoEs) and the maximum contrast. PoEs were the points on which the thresholds were estimated. The experimental software chose two equidistant colors from both sides of a PoE to form a pair of colors. The maximum contrast corresponded to the maximum distance between two colors in a pair that was used in the 2-TAFC method. The maximum contrast is important for ensuring that there are no overlaps between within category and cross-category threshold estimation areas. For each of the stimulus set, the process of determining PoEs and the maximum contrast is explained in detail below.

RGB color space is not perceptually uniform. This means that equal distances between points do not represent equal perceptual differences. However, CIE *L*u*v** Space is a perceptually uniform space. Therefore, when forming pairs, the distance between a color and a PoE were estimated using the CIE *L*u*v** coordinates of the colors. This means that each color in a pair had equal perceptual distances to the PoE.

<u>Stimuli from the blue region</u>:

The thresholds for the blue region were estimated on the same line between the good examples of *mavi* and *lacivert* that was determined in Experiment 1. Figure 7 shows the PoEs and the maximum contrast which were determined for the blue region.

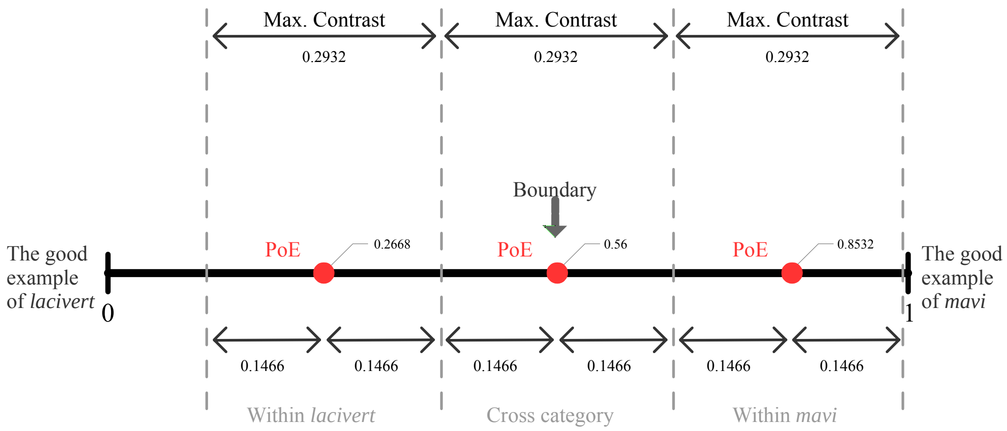

Figure 7 The PoEs and the maximum contrast for the blue region.

The boundary point, which was determined in Experiment 1, was taken as the PoE for the cross-category threshold. The PoEs for within-category thresholds and the maximum contrast were determined as follows. The distance between the boundary point and the good example of *mavi* was 0.44. This distance was smaller than the distance between the boundary point and the good example of *lacivert*. Therefore, the maximum contrast was estimated using this distance. 0.44 was divided by three. The result of the division was 0.1467 rounded to four decimal places. In order not to cause overlaps between the threshold estimation areas, 0.1466 was taken and multiplied by two. The result was 0.2932. 0.2932 was added to 0.56 to find the intra-*mavi* PoE; and it was subtracted from 0.56 to find the intra-*lacivert* PoE. The intra-*mavi* and intra-*lacivert* PoEs were 0.8532 and 0.2668 respectively. Consequently, the maximum contrast was equal to 0.2932. Table 5 shows the Munsell, CIE $L^*u^*v^*$, and RGB coordinates of the three PoEs.

Table 5 Munsell, CIE L^* u^* v^*, and RGB coordinates of the PoEs for the blue region.

Color	Munsell Coordinates			CIE $L^*u^*v^*$ Coordinates			RGB Coordinates		
	Hue	Value	Chroma	L^*	u^*	v^*	R	G	B
Intra-*mavi* PoE	74.92	4.08	11.52	42.07	-23.48	-69.98	0	100	174
Boundary PoE	76.08	2.81	10.64	28.85	-13.23	-60.63	2	66	135
Intra-*lacivert* PoE	76.93	1.59	10.32	16.50	-4.60	-44.55	0	33	97

By determining the PoEs and the maximum contrast in this way, it was ensured that there were no overlaps between the within-category areas and the cross-category area. In other words, each color on the line appeared in the estimation of only one threshold.

Stimuli from the green region:

A dark green and a light green whose lightness values were the same as those of the good examples of *lacivert* and *mavi* respectively were selected. The distance between the hue values of the good examples of *lacivert* and *mavi* was also preserved for the hue values of the dark green and light green. Table 6 shows the Munsell, CIE L^* u^* v^*, and RGB coordinates of the dark green and light green.

Table 6 Munsell, CIE L^* u^* v^*, and RGB coordinates of the dark green and light green.

Color	Munsell Coordinates			CIE $L^*u^*v^*$ Coordinates			RGB Coordinates		
	Hue	Value	Chroma	L^*	u^*	v^*	R	G	B
Dark green	74.74	0.98	1.88	10.46	-2.34	-7.62	0	30	0
Light green	47.23	4.71	7.34	48.61	-40.80	16.50	0	131	94

A line passing through the dark green and the light green was drawn in the RGB space. The thresholds for the green region were estimated on this line. The equation of the line is

$$r = 0, \quad k = \frac{(g-30)}{(101)} = \frac{(b)}{(94)} \tag{3}$$

where r, g, and b denote the R, G, B coordinates of the points on the line respectively. A point on this line, which had the same lightness value as that of the boundary point between *mavi* and *lacivert*, was selected as the boundary point between dark green and light green. The PoEs and the maximum contrast were determined as in the blue region described above. Figure 8 shows the PoEs and the maximum contrast which were determined for the region. Table 7 shows the Munsell, CIE $L^*u^*v^*$, and RGB coordinates of the three PoEs determined for the green region.

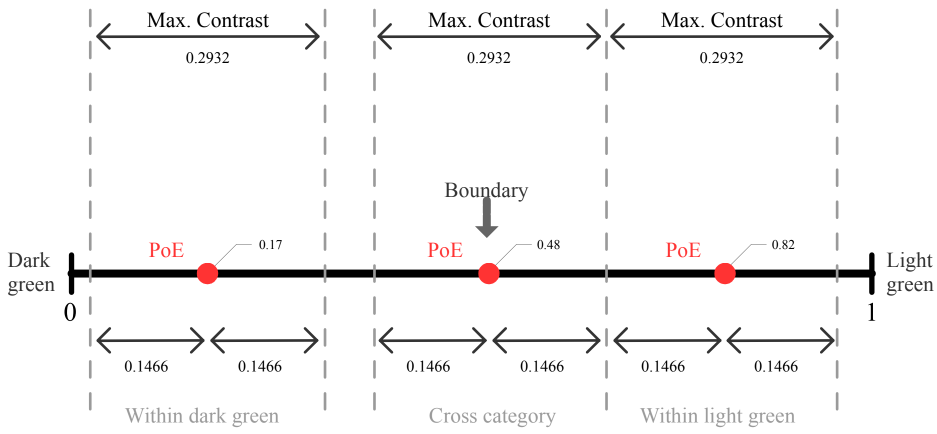

Figure 8 The PoEs and the maximum contrast for the green region.

Table 7 Munsell, CIE *L* u* v**, and RGB coordinates of the PoEs for the green region.

Color	Munsell Coordinates			CIE *L*u*v** Coordinates			RGB Coordinates		
	Hue	Value	Chroma	*L**	*u**	*v**	R	G	B
Intra light green PoE	46.75	4.07	6.45	41.95	-34.60	14.75	0	113	77
Boundary PoE	45.57	2.83	5.03	28.98	-22.06	10.70	2	78	43
Intra dark green PoE	54.88	1.58	2.35	16.35	-8.34	-1.53	0	47	15

3.3.1.4 Design

The experiment was a 2 × 3 × 2 mixed design. The independent variables were region (blue vs. green), color (intra-dark, boundary, intra-light) and nationality (Turkish vs. non-Turkish). The dependent variable was the threshold estimations. The region and the color were within-subjects variables and the nationality was between-subjects variable. All analyses were mixed-design ANOVA with one or both of the two within-subjects variables.

3.3.1.5 Procedure

All participants were tested individually in a darkened room. All of the Turkish participants already completed the Ishihara's Tests for Color-Blindness, before they took part in Experiment 1. All of the non-Turkish participants first completed the Ishihara's Tests for Color-Blindness (Ishihara, 2003).

Each participant was seated at a computer. All the instructions were presented in writing to the participant. The participant read the instructions, followed by a clarification by the experimenter. After that, each participant completed a demo version of the experiment, which took about one minute, in order to make sure that they understood the instructions.

In the experiment, the 2-TAFC method, which was described above, was used. Each color in a pair had the size of 9.5 cm × 9.5 cm. The pairs were displayed 106.6 *ms* in the center of the screen against the same background as in Experiment 1. The inter stimulus interval (ISI) between the two pairs was 150 *ms*. Participants first saw a fixation point in the center of the screen; pairs were not displayed unless participants pressed the space bar. When they pressed the space bar, an adjacent pair of colors was followed after the ISI by another adjacent pair of colors. Participants were asked to choose the pair which had different colors as quickly as possible without elaborating. They pressed the left mouse button if they thought that the first pair had different colors; they pressed the right mouse button if they thought that the second pair had different colors. Participants received a feedback only when their answers were incorrect. The experimental software automatically displayed the fixation point when participants pressed one of the left or the right mouse buttons.

The experiment consisted of 6 blocks: 4 blocks for within category thresholds (*lacivert*, *mavi*, dark green and light green) and 2 blocks for cross category thresholds (*lacivert-mavi* and dark green-light green). The order of the blocks was changed randomly between participants by the experimental software. Color-difference detection thresholds were estimated using the ZEST method (King-Smith, Grigsby, Vingrys, Benes & Supowit, 1994). The ZEST Method used in the experiment can be explained as follows: A pair of colors with a certain contrast is displayed. If the color difference in this pair is detected by the participant, then the experimental software decreases the contrast and forms another pair. This process continues until an incorrect response is given by the participant. When an incorrect response is given, the experimental software increases the contrast a little. Thresholds are estimated by decreasing and increasing the contrast. In Experiment 2, each threshold was estimated in 32 steps.

In each of the six blocks, three thresholds were estimated simultaneously in three different runs. Each run started with different contrasts. The experimental software switched randomly between the runs. In this way, it became possible to display a pair whose contrast is higher than that of the previous pair even though the color-difference in the previous pair was correctly detected by a participant. Thus, participants were not biased in a way that the task would get harder by giving correct responses. For each block, the average of the three thresholds estimated was taken. Statistical analyses were conducted on the average thresholds.

If a participant kept giving incorrect responses at the beginning of a block, the participant was notified with a feedback and the experimental software restarted the block in order not to exceed the maximum contrast. At the end of each block, participants were informed that they were at the end of the block. The next block did not start unless participants pressed the space bar. Participants were also told that if they felt tired, they could use the time between blocks to rest and they were free to discontinue participation at any time. The experiment took about forty minutes. All of the participants were debriefed about the purpose of the study after they had completed the experiment and thanked for their participation.

3.3.2 Results

Thresholds within the blue region vs. thresholds within the green region:

First, a $2 \times 3 \times 2$ mixed design ANOVA was conducted on the thresholds with region (blue vs. green) and color (intra-dark, boundary, intra-light) as within-subjects factors and nationality (Turkish vs. non-Turkish) as between-subjects factor. The comparisons important for the purpose of this study are the comparisons between Turkish speakers and non-Turkish speakers. It can be seen from Figure 9 that the thresholds in the green region were higher than those in the blue region regardless of the participants' nationality. This was supported by a significant main effect of region, $F(1, 37) = 70.56$, $p < .001$. Figure 9 also shows that the thresholds of Turkish speakers were lower than those of non-Turkish speakers both in the blue and green regions. This was supported by a significant main effect of nationality, $F(1, 37) = 9.26$, $p < .0043$, and a non-significant region by nationality interaction, $F(1, 37) = 1.09$, $p = .30$. The main effect of color was also significant, $F(2, 74) = 65.53$, $p < .001$. Pairwise comparisons revealed that all of the three values of color (intra-dark, boundary, intra-light) were significantly different from each other at $p < .001$ level. The three-way interaction of nationality, region and color was not significant, $F(2, 74) = 3.05$, $p < .0535$.

Separate two-way mixed design ANOVAs were conducted on the blue region and the green region with color (intra-dark, boundary, intra-light) as within-subjects factor and nationality (Turkish vs. non-Turkish) as between-subjects factor. As the three-way ANOVA revealed, the main effect of nationality was significant in both of the blue ($F(1, 37) = 9.10$, $p < .0046$) and the green ($F(1, 37) = 7.74$, $p < .0084$) regions, indicating that the thresholds of Turkish speakers were significantly lower than those of non-Turkish speakers in both regions.

Turkish speakers have an extra BCT in the blue region; however in the green region, both Turkish and non-Turkish speakers have only one BCT. The LRH predicts that the pattern of the thresholds should be different for Turkish and non-Turkish speakers only in the blue region. This means that the nationality by color interaction should be significant for the blue region but not for the green region. However, the results were the reverse: the nationality by color interaction was significant for the green region, $F(2, 74) = 5.75$, $p < .0048$; but not for the blue region, $F(2, 74) = 3.05$, $p < .0532$. Since the nationality by color interaction was significant in the green region but not significant in the blue region, the three-way interaction of nationality, region and color approached but failed to reach significance ($p < .0535$).

In order to further investigate the nationality by region interaction in both regions, Tukey's Honestly Significant Difference (HSD) tests were employed as post-hoc comparisons. Tukey's HSD tests in the blue region revealed that the thresholds of Turkish speakers were significantly lower than those of non-Turkish speakers both within *lacivert* ($p < .0001$) and within *mavi* ($p < .0072$). However, there was no significant difference between the thresholds on the *mavi-lacivert* boundary ($p < .1742$). This finding is inconsistent with the expected predictions of the LRH (significantly lower threshold on the boundary than within categories).

Tukey's HSD tests in the green region showed that the thresholds of Turkish speakers were significantly lower than those of non-Turkish speakers both within dark green ($p < .0001$) and across the dark green-light green boundary ($p < .0029$). The difference between the thresholds was not significant within light green ($p < .8437$). However it was expected to find no significant difference between the thresholds of Turkish and non-Turkish speaker in the green region since both groups had only one color category in this region.

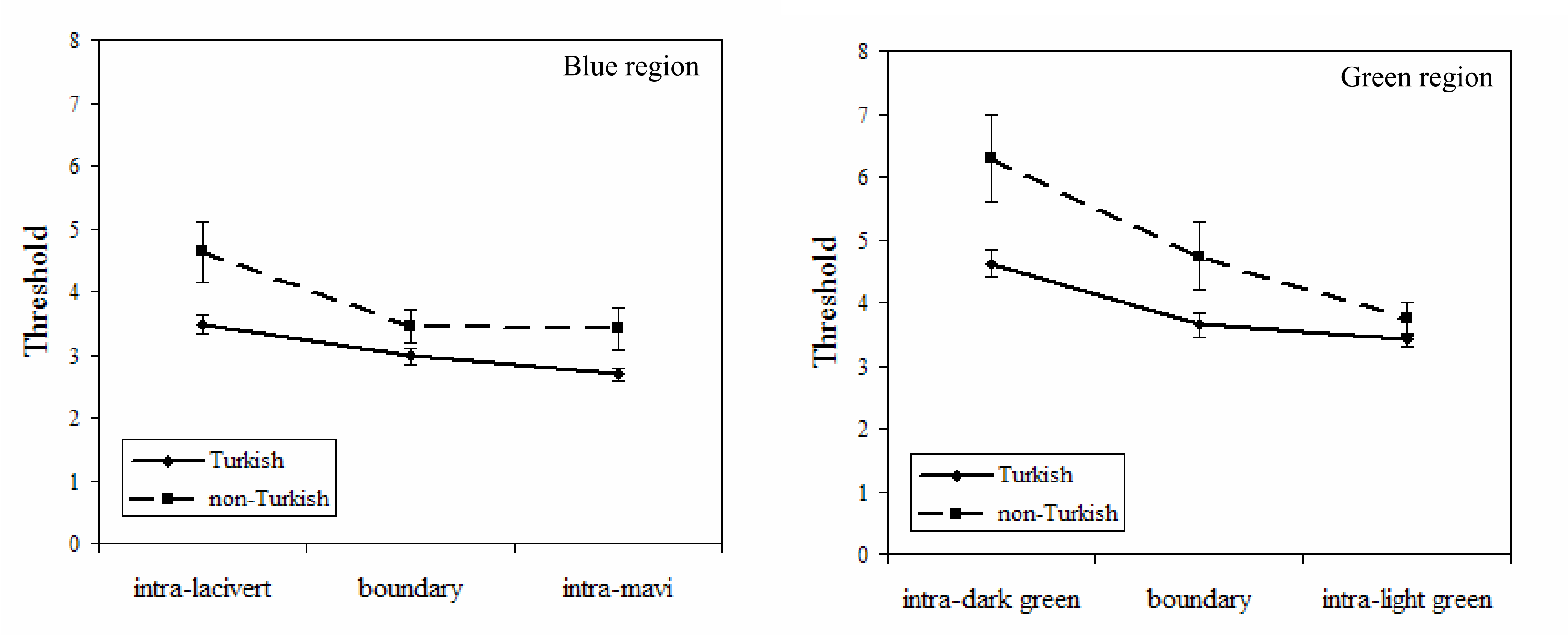

Figure 9 Mean thresholds for Turkish and non-Turkish speakers in the blue and the green regions. Error bars represents ± 1 standard error. The numbers on the *y*-axis represents the threshold estimations. Threshold is equal to 5 means that if the distance (in RGB Space) between two colors in a pair is smaller than 5% of the distance (in RGB Space) between the good examples of *mavi* and *lacivert*, then the color difference in that pair cannot be detected by participants.

3.3.3 Discussion

There was a difference between the thresholds estimated in the blue and the green regions. The thresholds estimated in the green region were greater for both Turkish and non-Turkish speakers. However, the thresholds were estimated in the computer's RGB space. This means that perceptual uniformity was not controlled. As a result, higher thresholds in the green region do not mean that discriminating two greens was more difficult than discriminating two blues. Higher thresholds in the green region may be the result of non-uniformities in the computer's RGB space: perceptual distances in the blue and green regions may not match because of computer graphics characteristics. Similarly, higher thresholds for dark colors do not suggest that discriminating between dark colors was more difficult than discriminating between light colors because of non-uniformities in the computer's RGB space. Since perceptual uniformity was not controlled, the absolute numbers in Figure 9 are not reliable. The only reliable results of this study are the comparisons between Turkish and non-Turkish speakers.

In the blue region, Turkish speakers, and not English speakers, were predicted to show CP effects. Figure 10 illustrates various theoretical predictions of the LRH in the blue region. If both Turkish and non-Turkish speakers had only one color term in the blue region, the pattern of the thresholds in the blue region would be as in Figure 10 (a). Goldstone (1994) suggests several CP effects. One case is *acquired equivalence*: when people learn categories, their perceptual sensitivity for items that are categorized together decreases. This means that differences within categories become less important. The pattern of the thresholds which correspond to acquired equivalence is illustrated in Figure 10 (b). The second case is *acquired distinctiveness*: when people learn categories, their perceptual sensitivity for items that are categorized differently increases. In other words, differences across a category boundary become more important. Figure 10 (c) illustrates this kind of a pattern for thresholds. When learning categories, both acquired equivalence and acquired distinctiveness may occur at the same time. In this case, the pattern of the thresholds would be

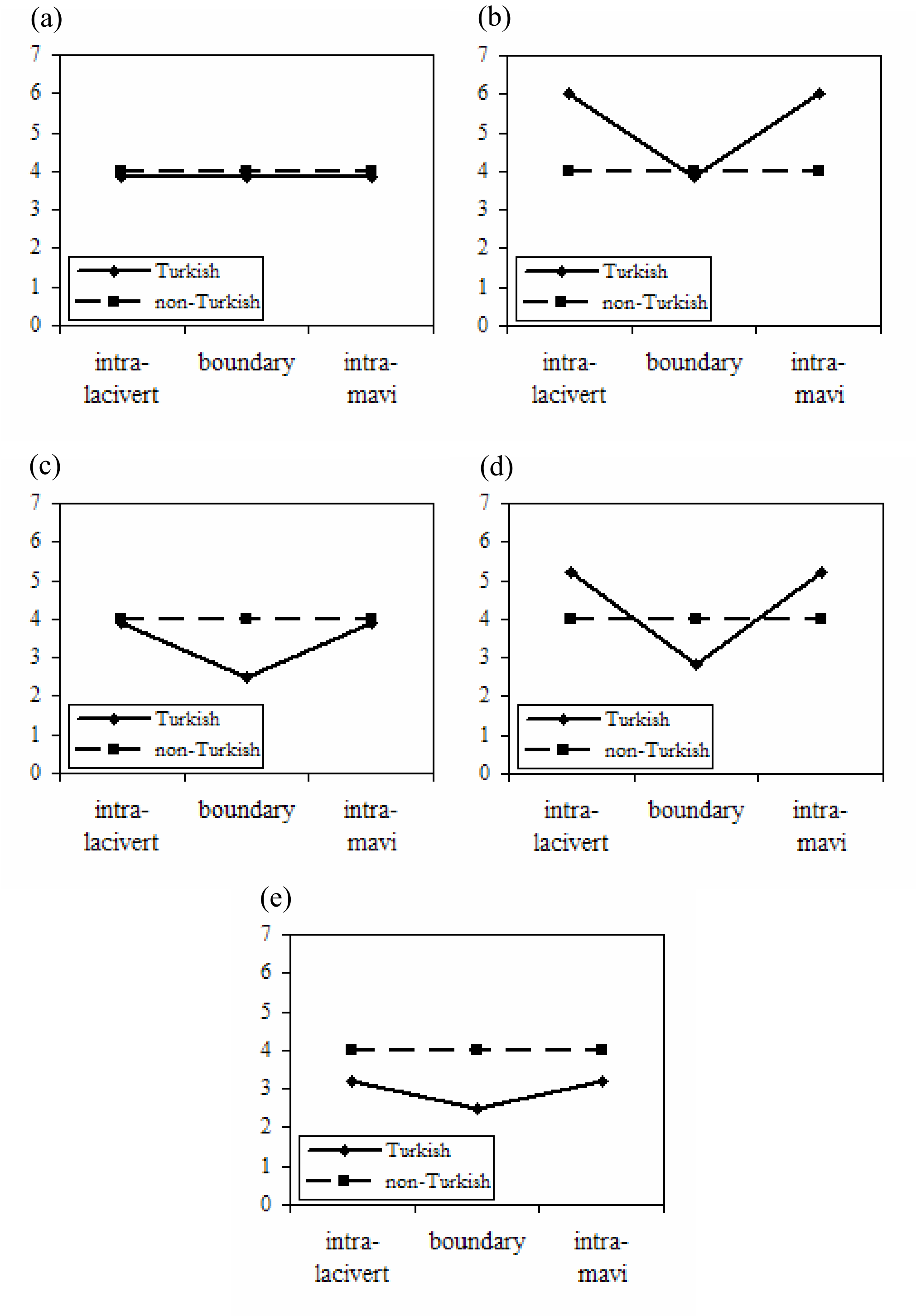

Figure 10 Various theoretical predictions of the LRH in the blue region. (a) corresponds to the case where both Turkish and non-Turkish speakers show no CP effects. (b) illustrates acquired equivalence. (c) illustrates acquired distinctiveness (d) shows the case where acquired equivalence and acquired distinctiveness occur at the same time. (e) illustrates an overall improvement as a result of categorization.

as in Figure 10 (d). Goldstone (1994) also found that in addition to sensitization across a category boundary, sensitization within categories may also occur as a result of categorization. Özgen (2000) compared Turkish and English speakers in the blue region of the spectrum using similarity judgments. He found an overall improvement in Turkish speakers' performance. Turkish speakers were better than non-Turkish speakers both within-category and cross-category judgments. These findings suggest another pattern for the thresholds in the blue region which is illustrated in Figure 10 (e).

The results of the study revealed that the overall performance of Turkish speakers in the blue region was better than that of non-Turkish speakers. More specifically, the thresholds of Turkish speakers were better than those of non-Turkish speakers within *lacivert* and within *mavi*; but not on the boundary. The pattern of the thresholds in the blue region resembled the pattern given in Figure 10 (e). The difference was that the results of this study did not revealed a significant difference between Turkish speakers' and non-Turkish speakers' thresholds around the *mavi-lacivert* boundary. Experiment 1 revealed that the boundary between *mavi* and *lacivert* is not stable. The non-significant difference between Turkish speakers' and non-Turkish speakers' thresholds around the *mavi-lacivert* boundary may be the result of the unstable boundary between *mavi* and *lacivert*.

The pattern of the thresholds in the blue region can also be explained as follows. *Lacivert* corresponds to a narrow region of the color spectrum. Also, the boundary between *mavi* and *lacivert* is not stable. Therefore, for Turkish speakers, identifying the good examples of *lacivert* and *mavi* may become more important than identifying colors which are not *lacivert* or *mavi*, while they are learning to use two BCTs for the blue region. As a result, they may become sensitized only to within category differences. The pattern of the thresholds in the blue region revealed by this study could be another pattern in which LRH manifests itself. However, further investigations should be carried out before drawing such a conclusion.

The overall better performance of Turkish speakers was not restricted to the blue region only. Turkish speakers' thresholds were lower than those of non-Turkish speakers also in the green region. More specifically, the thresholds of Turkish speakers were better than those of non-Turkish speaker within dark green and on the dark green-light green boundary. Figure 10 (a) also illustrates the expected pattern of the thresholds in the green region. Goldstone (1994) states that same-different judgments involve attentional mechanisms. Attention performances decline as age increases, especially for tasks in which demands on visual attention are great (McDowd & Shaw, 2000). Therefore, the overall better performance of Turkish speakers both in the blue and the green regions may be the result of the age difference between Turkish and non-Turkish speakers. However, it is important to note that Turkish speakers' better performance in the green region does not rule out the possibility of a Whorfian effect. For example it is possible that Turks are better in the blue region because of language, but they are better in the green region because of age. It is not possible to draw definite conclusions with the current data. Another important point is that the age of participants in aging studies is generally above 60. However, the mean age of the non-Turkish speakers participated in this study was 42.36 with a range of 27 to 53 years. Non-Turkish speakers may not be old enough to show the effects of the age differences. Therefore, further studies controlling the age factor are needed to draw more accurate conclusions.

All of the Non-Turkish speakers were living in Turkey and they had also some knowledge of Turkish. They might be familiar with the color term *lacivert*. As a result, their threshold estimations in the blue region may be affected by their knowledge of Turkish. However, such an effect of bilingualism also requires further investigation.

Another possible explanation of the findings can be that *lacivert* is not basic enough to produce CP effects. Davies and Corbett (1995) suggested a method for identifying basic color terms in a language. The method consisted of two tasks: an elicited list task (tell me as many as color terms you know) and a color naming task. Using this method, Özgen and Davies (1998) found that both in list and naming tasks, *lacivert* turned out to be a good candidate for the 12th BCT for Turkish. However, when participants were asked to indicate whether *lacivert* is a kind of *mavi*, majority of them indicated *lacivert* as a kind of *mavi*. This result violates the characteristics of BCTs proposed by Berlin and Kay (1969): the meaning of a BCT should not be included in the meaning of other color term.

The unstable the boundary between *mavi* and *lacivert* might affect the patterns of the thresholds. Therefore, in order to investigate this issue, a third experiment was carried out in order to estimate color-difference detection thresholds on individual boundaries.

3.4 EXPERIMENT 3: THRESHOLD ESTIMATIONS ON INDIVIDUAL BOUNDARIES

Pilot studies (personal communication with Özgen) and the results of Experiment 1 suggest that the boundary between *mavi* and *lacivert* is not stable; it varies between Turkish speakers. This lack of stability may affect the threshold estimations on the average boundary and may lead to weak CP effects. The aim of the third experiment was to estimate color-difference detection thresholds of Turkish speakers on their individual boundaries. Stimuli were drawn from the *mavi-lacivert* region of the color spectrum. All participants first completed a naming task to determine their boundaries between *mavi* and *lacivert*. After that their color-difference detection threshold were estimated on their individual boundaries using 2-TAFC method.

Experiment 3 was a psychophysics experiment. In psychophysics experiments, the individual performances of participants are investigated rather than the overall pattern in the data. This means that psychophysics experiments do not require large samples and they are statistics-free. Therefore, the results of Experiment 3 were not analyzed statistically.

3.4.1 Method

3.4.1.1 Participants

There were 5 participants: 2 women and 3 men. Their mean age was 25.2 with a range of 23 to 31 years. All of the participants were native Turkish speakers having some knowledge of English. All had normal color vision assessed by the Ishihara's Tests for Color-Blindness (Ishihara, 2003). Their participation was voluntary.

3.4.1.2 Apparatus

The apparatus for the naming task was the same as that of Experiment 1; and the apparatus for the threshold estimations was the same as that of Experiment 2.

3.4.1.3 Stimuli

<u>Naming:</u>

The same stimuli that were used in Experiment 1 were used for the naming task.

<u>2-TAFC:</u>

Thresholds were estimated only in the *mavi-lacivert* region of the spectrum. As in Experiment 2, estimations were made on the same line between the good examples of *mavi* and *lacivert* that was determined in Experiment 1. Each participant's points of estimation (PoEs) and maximum contrast were determined as in Experiment 2. Table 8 shows each participant's PoEs and maximum contrast.

Table 8 Each participant's PoEs and maximum contrast in the blue region.

Participant	PoE (Within *lacivert*)	PoE (Cross category)	PoE (Within *mavi*)	Maximum Contrast
NBA	0.3034	0.5814	0.8594	0.278
AK	0.1278	0.3828	0.6378	0.255
DÖ	0.1714	0.5028	0.8342	0.3314
DD	0.1226	0.3676	0.6126	0.245
ÇT	0.0924	0.2772	0.462	0.1848

3.4.1.4 Procedure

Naming:

The procedure of the naming task was the same as that of Experiment 1.

2-TAFC:

The procedure of the threshold estimations was the same as that of Experiment 2. The only difference was that this time the experiment consisted of 6 blocks: 2 blocks for within category thresholds (*lacivert* and *mavi*) and 1 block for cross category threshold. The experiment took about twenty minutes. All of the participants were debriefed about the purpose of the study after they completed the experiment and thanked for their participation.

3.4.2 Results and Discussion

Naming:

Figure 11 shows the sigmoid curves fitted to each participant's data and Table 9 summarizes the results of the curve fitting. As described earlier, *b* values in Table 8 correspond to the boundary points between 0 and 1. The RGB coordinates of each participant's boundary point were calculated using the equation given in Formula 1. Table 10 shows the Munsell, CIE $L^* u^* v^*$, and RGB coordinates of each participants' within *mavi* PoE, within *lacivert* PoE and boundary point.

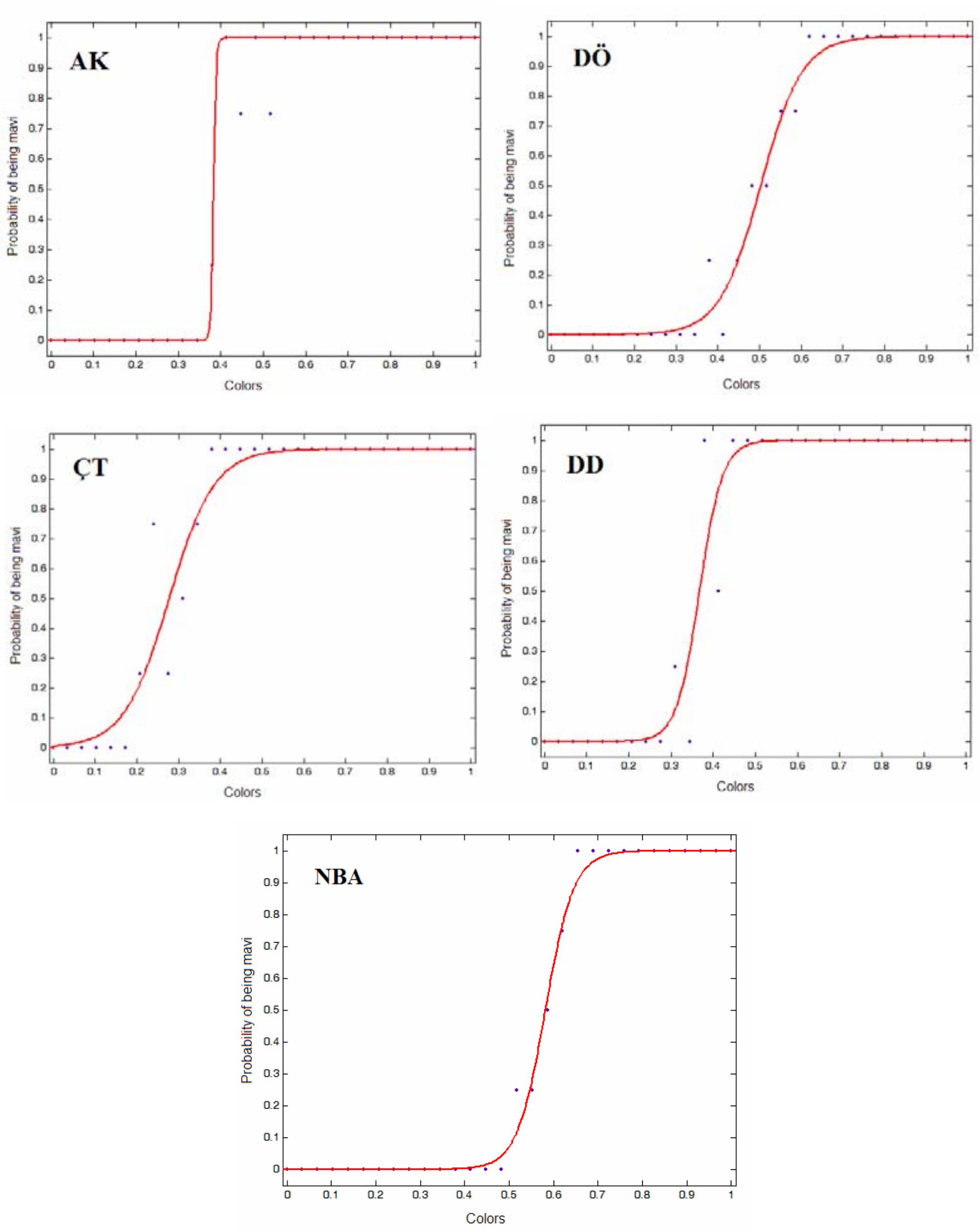

Figure 11 Sigmoid curves fitted to each participant's naming data.

Table 9 The summary of each curve fitting.

Participants	Coefficients		Goodness of fit		
	a	*b*	SSE	R-square	Adjusted R-square
AK	310.4	0.3828	0.125	0.9813	0.9806
DÖ	20.2	0.5028	0.08667	0.9861	0.9856
DD	36.78	0.3676	0.3896	0.9409	0.9388
ÇT	18.51	0.2772	0.2995	0.9412	0.9391
NBA	31.34	0.5814	0.03195	0.9951	0.9949

Table 10 Munsell, CIE *L* u* v**, and RGB coordinates of each participants' within *mavi* PoE, within *lacivert* PoE and boundary point.

Part.	Color	Munsell Coordinates			CIE *L*u*v** Coordinates			RGB Coordinates		
		Hue	Value	Chroma	*L**	*u**	*v**	R	G	B
NBA	Boundary	75.98	2.92	10.60	29.96	-14.11	-61.29	2	68	138
	Intra-*lacivert* PoE	76.86	1.74	10.50	17.99	-5.50	-47.57	0	37	102
	Intra-*mavi* PoE	74.87	4.13	11.57	42.60	-23.87	-70.49	0	101	175
AK	Boundary	76.72	2.04	10.59	20.91	-7.43	-52.19	2	44	112
	Intra-*lacivert* PoE	77.24	1.09	9.85	11.48	-1.75	-33.74	2	16	79
	Intra-*mavi* PoE	75.69	3.20	10.69	32.87	-16.38	-63.28	0	75	145
DÖ	Boundary	76.27	2.58	10.63	26.51	-11.45	-58.59	0	59	128
	Intra-*lacivert* PoE	77.14	1.23	10.07	12.95	-2.52	-37.31	2	21	84
	Intra-*mavi* PoE	75.09	3.99	11.56	41.07	-22.63	-69.99	2	97	171
DD	Boundary	76.71	2.02	10.32	20.72	-7.39	-50.97	2	44	110
	Intra-*lacivert* PoE	77.26	1.06	9.86	11.27	-1.64	-33.32	2	15	78
	Intra-*mavi* PoE	75.79	3.10	10.60	31.80	-15.57	-62.38	2	72	142
ÇT	Boundary	76.93	1.60	10.39	16.55	-4.61	-44.82	0	33	98
	Intra-*lacivert* PoE	77.30	0.97	9.81	10.31	-1.18	-30.37	2	12	73
	Intra-*mavi* PoE	76.37	2.42	10.46	24.89	-10.34	-56.26	2	55	123

2-TAFC:

Figure 12 shows the thresholds of the participants. For each participant, it was expected that the thresholds should be lower on the boundary compared to the thresholds within *mavi* and within *lacivert*. In other words, the pattern of each participant's thresholds should have demonstrated a V-shape. It can be seen from Figure 12 that only one participant (NBA) out of five participants had a V-shaped threshold pattern. The examination of the threshold patterns obtained in Experiment 2 revealed that, in the blue region, only 6 participants out 28 had a V-shaped threshold pattern in the blue region. So, the ratios of the v-shaped threshold patterns were similar in Experiment 2 and Experiment 3. Experiment 3 failed to reveal stronger CP effects.

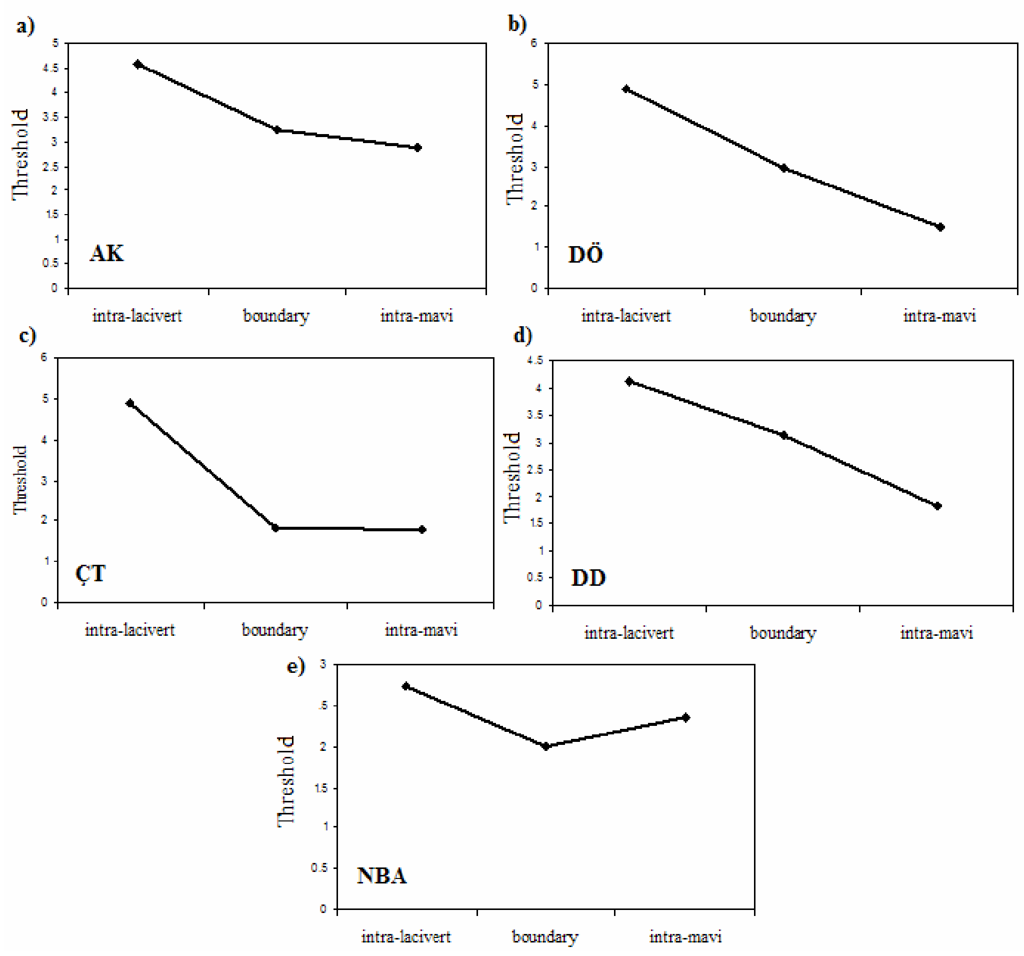

Figure 12 The thresholds of the five participants.

CHAPTER 4

GENERAL DISCUSSION

4.1 EXPLANATIONS OF FINDINGS

Since Whorf (1956 [1940]), the idea that the language we speak might influence the way we think has inspired research and much of this research has been carried out in the color domain. Languages with different color term repertoires made it possible to test the predictions of the LRH comparing the speakers of those languages. Many cross-cultural studies comparing speakers of different languages revealed CP effects, using discrimination tasks such as the visual search task, the triad task or same-different judgments. However, differences between speakers of different languages revealed by these studies do not provide satisfactory evidence about the nature of the observed differences. As Roberson and Davidoff (2000) pointed out, most of these studies were vulnerable to the criticism that the observed CP effects may merely be due to a direct naming strategy, rather than pure perception. In order to answer the question whether speakers of different languages actually see color differently, it was necessary to carry out studies focusing on the low-level perception of color by speakers of different languages using a discrimination task which has no memory components.

Turkish has two BCTs for blue, *mavi* and *lacivert*, distinguishing light and dark blues. This extra color term in Turkish provided an opportunity to test the predictions of the LRH. In the light of these ideas, the present study investigated the possible effects of the Turkish extra color term on the color-difference detection thresholds of Turkish speakers in three experiments. The 2-TAFC method, which eliminates the effects of memory or labeling and isolates the perceptual processes, was used to determine the thresholds. Turkish speakers' color-difference detection thresholds were compared to those of non-Turkish speakers whose language had only one color term for blue, both in the blue and the green regions of the color spectrum. Comparisons between Turkish and non-Turkish speakers were made on within and cross category judgments. It was expected to find that Turkish speakers, and not non-Turkish speakers, should display CP effect in the blue region. Turkish speakers' thresholds should be lower on the boundary. According to the LRH an effect should be restricted to the blue region, since this is the only region in the color spectrum that the languages differ.

In the first experiment, an average boundary between *mavi* and *lacivert*, which was used in the second experiment, was determined with a forced-choice naming task. Experiment 1 also revealed that the *mavi-lacivert* boundary was unstable and there was a relatively large area between *mavi* and *lacivert*. In the second experiment color-difference detection thresholds of Turkish and non-Turkish speakers were estimated. The thresholds were estimated in the computer's RGB space. This means that perceptual uniformity was not controlled. Therefore, any comparison including absolute values of the thresholds was not reliable. The only reliable results of the study were comparisons between Turkish and non-Turkish speakers.

Experiment 2 revealed differences between the thresholds of Turkish and non-Turkish speakers in the blue and the green regions of the color spectrum. In the blue region, Turkish speakers' color discrimination was better than that of non-Turkish speakers within *mavi* and *lacivert*, but not on the boundary. The similar color discrimination performances of Turkish and non-Turkish speakers around the *mavi-lacivert* boundary could be the result of the unstableness of the boundary. Another explanation could be that *mavi* and *lacivert* may not be clearly separated perceptual categories. *Lacivert* corresponds to a narrow region of the color spectrum (Özgen & Davies, 1998) and there was a relatively large area between *mavi* and *lacivert*. This might give rise to the obtained threshold pattern. The pattern of the thresholds in the blue region revealed by this study could be another pattern in which the LRH manifests itself. However, further investigations are necessary in order to draw such a conclusion.

There is also the possibility that non-Turkish speakers' thresholds in the blue region were influenced by their knowledge of Turkish. Ervin (1961) stated that when people learn a second language with two categories where their first language has only one, the boundary point between these categories reveal the effects of learning that second language. Therefore, it might be useful to replicate the second experiment with monolingual non-Turkish speakers.

Turkish speakers' color discrimination was better than that of non-Turkish speakers also in the green region. According to the LRH, differences between Turkish and non-Turkish speakers should be restricted to the blue region, since this is the only region in the color spectrum that the languages differ. The overall better performance of Turkish speakers in both blue and green regions might be due to the age difference between Turkish and non-Turkish speakers. However, the better performance of the Turkish speakers in the green region does not rule out the LRH. Turks may be better in the blue region because of language, and they are better in the green region because of age. The effect of the age difference can be investigated further by controlling the age factor.

Another possible explanation could be that *lacivert* may not be basic enough to produce expected CP effects. As Özgen and Davies (1998) pointed out, *lacivert* was reported by Turkish speakers as a kind of blue, which violates characteristics of BCTs proposed by Berlin and Kay (1969).

Non-Turkish speakers in this study were from several nationalities, whose languages have only one color term for the blue region. This increased the cultural diversity. It is not clear what the results of this cultural diversity would be. In order to further investigate this issue, studies can be carried out controlling the nationality factor.

In order to investigate the effects of the unstable boundary on the thresholds, a third experiment was carried out to estimate color-difference detection thresholds on individual boundaries. Experiment 3 did not reveal different threshold patterns for Turkish speakers. The patterns of the thresholds revealed by Experiment 3 were similar to the pattern of the thresholds in Experiment2.

To sum up, the results of this study reveled differences between Turkish and non-Turkish speakers both in the blue and the green regions of the color spectrum. However, the differences in the green do not rule out the LRH. For example, it is possible that Turks are better in the blue region because of language, but they are better in the green region because of age. The current data alone is not adequate to draw a definite conclusion.

4.2 LIMITATIONS OF THE STUDY

There was an age difference between Turkish speakers and non-Turkish speakers: Mean age was 20.02 years ± 1.41 (standard deviation) in the Turkish group and 42.36 years ± 8.78 (standard deviation) in non-Turkish group. All non-Turkish speakers were speakers of languages with one term in the blue region. However, they were from several nationalities, which increased the cultural diversity. A third limitation was the fact that non-Turkish speakers had some knowledge of Turkish, which might affect their threshold estimations.

CHAPTER 5

CONCLUSION

The present study investigated the possible effects of the Turkish extra color term on the color-difference detection thresholds of Turkish speakers. 2-TAFC method, which eliminates the effects of memory or labeling and isolates the perceptual processes, was used to determine the thresholds. Turkish speakers' color-difference detection thresholds were compared to those of non-Turkish speakers whose language had only one color term for blue, both in the blue and the green regions of the color spectrum. Consistent with the LRH, it was expected to find that Turkish speakers, and not non-Turkish speakers, would display CP effects only in the blue region of the color spectrum. The results of this study reveled differences between Turkish and non-Turkish speakers both in the blue and the green regions of the color spectrum. However, the differences in the green region do not rule out the LRH. It is possible that Turks are better in the blue region because of language, but they are better in the green region because of age. Although the pattern of the thresholds in the blue region was not one of the expected threshold patterns predicted by the LRH, it is possible that it could be another pattern in which the LRH manifests itself. Therefore, the results of this study call for further research, in which the limitations mentioned above are controlled, to investigate the nature of the differences between Turkish and non-Turkish speakers.

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APPENDICES

APPENDIX A INSTRUCTIONS FOR EXPERIMENTS

Experiment 1

Bu deneyde, bilgisayar ekranında bazı renkler göreceksiniz. Sizden bu renkleri isimlendirmeniz istenecektir. Ekrandaki rengin lacivert oldugunu düşünüyorsanız klavyenin sol ok tuşuna; mavi olduğunu düşünüyorsanız sağ ok tuşuna basınız. Lütfen her renk için cevabınızı çok düşünmeden, hızlı bir şekilde vermeye çalışın. Deney ortalama 5 dakika sürecektir. Katılım sırasında herhangi bir nedenden ötürü kendinizi rahatsız hissederseniz deneyi yarıda bırakıp çıkmakta serbestsiniz. Böyle bir durumda deneyi uygulayan kişiye, deneyi tamamlamadığınızı söylemeniz yeterli olacaktır. Bu çalışmaya katıldığınız için şimdiden teşekkür ederiz.

Experiment 2 (in Turkish)

Bu deneyde bilgisayar ekranında ard arda iki renk çifti göreceksiniz. Sizden, bu renk çiftlerinden hangisinde farklı renkler olduğunu söylemeniz istenecektir. Cevabınızı bilgisayarın faresini kullanarak verebilirsiniz. Birinci renk çiftinin farklı olduğunu düşünüyorsanız farenin sol tuşuna; ikinci renk çiftinin farklı olduğunu düşünüyorsanız farenin sağ tuşuna tıklayın. Lütfen cevabınızı çok düşünmeden, hızlı bir şekilde vermeye çalışın. Deney ortalama 40 dakika sürecektir ve altı bloğa ayrılmıştır. Eğer dinlenmek isterseniz blokların arasındaki süreyi dinlenmek için kullanabilirsiniz. Katılım sırasında herhangi bir nedenden ötürü kendinizi rahatsız hissederseniz deneyi yarıda bırakıp çıkmakta serbestsiniz. Böyle bir durumda deneyi uygulayan kişiye, deneyi tamamlamadığınızı söylemeniz yeterli olacaktır. Deney sonunda, bu çalışmayla ilgili sorularınız cevaplanacaktır. Bu çalışmaya katıldığınız için şimdiden teşekkür ederiz.

Experiment 2 (in English)

In this experiment, an adjacent pair of colors will be displayed on a computer screen and it will be followed by another adjacent pair of colors after an inter-stimulus interval. You have to choose the pair which has different colors. You can give your answer by using the mouse. If you think that the first pair has different colors, then click on the left button of the mouse. If you think that the second pair has different colors, then click on the right button of the mouse. Please try to give your answers as quickly as possible without elaborating. The experiment is divided into six blocks and will take approximately 40 minutes to complete. If you feel tried you can use the time between blocks to rest. You are free to discontinue participation at any time. Your questions will be answered after the experiment. Thank you for participating to this experiment.

Experiment 3

Bu deney iki bölümden oluşmaktadır. Birinci bölümde bilgisayar ekranında bazı renkler göreceksiniz. Sizden bu renkleri isimlendirmeniz istenecektir. Ekrandaki rengin lacivert oldugunu düşünüyorsanız klavyenin sol ok tuşuna; mavi olduğunu düşünüyorsanız sağ ok tuşuna basınız. Lütfen her renk için cevabınızı çok düşünmeden, hızlı bir şekilde vermeye çalışın. Deney ortalama 5 dakika sürecektir.

Bu deneyin ikinci bölümünde bilgisayar ekranında ard arda iki renk çifti göreceksiniz. Sizden, bu renk çiftlerinden hangisinde farklı renkler olduğunu söylemeniz istenecektir. Cevabınızı bilgisayarın faresini kullanarak verebilirsiniz. Birinci renk çiftinin farklı olduğunu düşünüyorsanız farenin sol tuşuna; ikinci renk çiftinin farklı olduğunu düşünüyorsanız farenin sağ tuşuna tıklayın. Lütfen cevabınızı çok düşünmeden, hızlı bir şekilde vermeye çalışın. Deney ortalama 20 dakika sürecektir ve üç bloğa ayrılmıştır. Eğer dinlenmek isterseniz blokların arasındaki süreyi dinlenmek için kullanabilirsiniz.

Katılım sırasında herhangi bir nedenden ötürü kendinizi rahatsız hissederseniz deneyi yarıda bırakıp çıkmakta serbestsiniz. Böyle bir durumda deneyi uygulayan kişiye, deneyi tamamlamadığınızı söylemeniz yeterli olacaktır. Deney sonunda, bu çalışmayla ilgili sorularınız cevaplanacaktır. Bu çalışmaya katıldığınız için şimdiden teşekkür ederiz.

APPENDIX B DEBRIEFING FOR EXPERIMENT 2 AND EXPERIMENT 3

KATILIM SONRASI BİLGİ FORMU

Bu çalışma, Bilkent Üniversitesi Psikoloji Bölümü öğretim üyelerinden Doç. Dr. Emre Özgen'in danışmanlığında, Orta Doğu Teknik Üniversitesi Enformatik Enstitüsüne bağlı Bilişsel Bilimler Anabilim Dalı yüksek lisans öğrencisi Didem Kadıhasanoğlu tarafından yürtülen, renk algısı ile ilgili, kültürler arası bir çalışmadır. Türkleri ve Türk olmayanları kapsayan bu çalışmanın temel amacı, Dilsel Görelilik Varsayımı'nı test etmektir.

Bazı dillerde 11 farklı temel renk kelimesi bulunmaktadır. Türkçe'de ise bu sayının 12 olduğu düşünülmektedir. Türkler, renk spektrumunun mavi bölgesini *mavi* ve *lacivert* olarak iki ayrı kategoriye ayırmaktadır. Bu çalışmada Dilsel Görelilik Varsayımı'nın tahminleri araştırılmaktadır. Başka bir deyişle, konuşulan dil algıyı etkiliyorsa, *mavi-lacivert* kategori sınırında Türkler ve dillerinde 11 renk kelimesi olan yabancılar algısal farklılıklar göstereceklerdir. Katıldığınız ilk deneyde *mavi* ve *lacivert* arasındaki kategori sınırının belirlenmesi amaçlanmıştır. İkinci deneyin amacı ise, Türklerin ve yabancıların daha onceden belirlenen *mavi-lacivert* kategori sınırı etrafındaki, *mavi* kategorisi içindeki ve *lacivert* kategorisi içindeki renk-farkı algılama eşiklerini hesaplamak ve karşılaştırmaktır. Türklerin *mavi-lacivert* kategori sınırında, kategorik algı etkileri göstermeleri beklenmektedir. Başka bir deyişle, Türklerin *mavi-lacivert* kategori sınırı etrafındaki renk-farkı algılama eşiklerinin, kategori içi renk-farkı algılama eşiklerine kıyasla daha düşük olacağı düşünülmektedir. Yani, farklı renklerden oluşan bir renk çiftinde, renklerden biri *mavi* kategorisine, diğeri de *lacivert* kategorisine aitse Türklerin bu çiftteki renk farkını algılamalarının, aynı kategoriye ait iki farklı renkten oluşan bir çiftteki renk farkını algılamalarından daha kolay ve çabuk olacağı düşünülmektedir. Yabancılarda ise böyle bir etkinin görülmesi beklenmemektedir.

Bu çalışmadan elde edilen bilgiler sadece bilimsel araştırma ve yazılarda kullanılacaktır. Katıldığınız için çok teşekkür ederiz!

DEBERIEFING

This research is being conducted by Didem Kadıhasanoğlu, who is a MS. student in Middle East Technical University, Informatics Institute, Cognitive Science Program, under the supervision of Assist. Prof. Emre Ozgen, who is a faculty member in Bilkent University, Department of Psychology. It is a cross-cultural research on color perception in which Turkish and English speakers will participate. It aims to test the Linguistic Relativity Hypothesis.

Turkish and some other languages differ in their number of basic color terms. Turkish appears to have twelve basic color terms whereas some languages have eleven. Turkish speakers differentiate the blue region of color space into *mavi* (blue) and *lacivert* (dark blue) categories. The present study aims to explore the predictions of the Linguistic Relativity Hypothesis; if language influences perception, then Turkish and non-Turkish speakers, whose language has only one color term for the blue region, might show perceptual differences along the *mavi-lacivert* category boundary. The aim of this experiment is to estimate and compare the color-difference detection thresholds of Turkish and non-Turkish speakers within *mavi* and *lacivert* categories as well as on the *mavi-lacivert* category boundary which was determined before. Turkish speakers, and not non-Turkish speakers, are predicted to show categorical perception effects: thresholds should be better on the boundary than within-category. In other words, if a pair of color having different colors consists of one *mavi* and one *lacivert*, then Turkish speakers will detect the color difference more easily compared to a pair of color consisting of two different *mavi*s or two different *lacivert*s.

The data obtained from this research will not be given to third party and will be used only for research purposes. Thank you for your participation!