*Human and Animal Physiology*

# Human Visual Color Discrimination with Aging

**Khatuna Parkosadze*, Manana Khomeriki**, Archil Kezeli****

* *Laboratory of Vision Physiology, I. Beritashvili Center of Experimental Biomedicine, Institute of Cognitive Neurosciences, Agricultural University of Georgia*
***Laboratory of Vision Physiology, I. Beritashvili Center of Experimental Biomedicine, Tbilisi*

(Presented by Academy Member Nodar Mitagvaria)

**ABSTRACT. Color vision is an important component of human vision and plays a critical role in both perception and communication. The abilities of categorical perception (CP) and color discrimination are some of the necessary attributes of color vision. It is known that healthy aging and age-related optical and neural changes affect many aspects of visual perception. However, color appearance remains remarkably stable in the aging visual system. The aim of our study was to investigate age-related changes of discrimination of colors belonging to the same or different categories. We investigated the impact of developmental aspects and aging on color discrimination ability. 30 observers of three different age-groups participate in the study: Group 1 – elderly (n=10, 60 and over), Group 2 young controls (n=10, 20-32 years old) and Group 3 – children (n=10, 6-15 years old). Our results showed that reaction time for each color pair and each age-group did not differ significantly from each other and post-hoc analysis did not reveal any significant differences in discrimination of different colors. Hence, our results showed that healthy aging has no significant impact on color discrimination. This refers not only to colors discrimination of the same category, but also to those of different categories. We can conclude that age-related changes or ongoing developmental changes have no significant influence on color discrimination process.** *© 2016 Bull. Georg. Natl. Acad. Sci.*

**Key words:** aging, color discrimination, visual perception

Color vision is a critical component of human vision and plays an important role in both perception and communication. Furthermore, color vision makes it possible to perceive the world in all its glory. How color vision can be determined? In a simple manner, it is the ability to distinguish objects according to the light (wavelengths) reflected from them. In fact, we distinguish colors according to their hue, lightness and saturation. Thus we can distinguish about 2 million colors according to these three dimensions [1, 2]. But, when we talk about colors, we never use the above mentioned properties, we simply call them by names, and combine them into categories.

The abilities of categorical perception (CP) and color discrimination are some of the necessary attributes of color vision. Uniting colors of the same hue, which differ in lightness and/or the wavelength, in one category makes it easier to differentiate samples having different hues. Color discrimination, the ability to determine that two spectra differ from each other, is useful for recognizing details in visual images or in visual scene as well. Successful color dis-

**Table 1. RGB coordinates for experimental stimulus and background for each tested colors. There were 6 variations of colors that were randomized as a stimulus and as a background**

| | Black-White | | | Blue | | | Green | | |
|---|---|---|---|---|---|---|---|---|---|
| var. | R | G | B | R | G | B | R | G | B |
| 1 | 255 | 255 | 255 | 0 | 0 | 255 | 70 | 170 | 70 |
| 2 | 0 | 0 | 0 | 70 | 70 | 255 | 0 | 255 | 0 |
| 3 | 160 | 160 | 160 | 0 | 150 | 255 | 0 | 255 | 64 |
| 4 | 220 | 220 | 220 | 86 | 162 | 255 | 40 | 180 | 60 |
| 5 | 190 | 190 | 190 | 150 | 196 | 255 | 0 | 235 | 64 |
| 6 | 150 | 150 | 150 | 168 | 207 | 255 | 0 | 174 | 0 |

| | Blue-Green | | | Red | Yellow | | | | |
|---|---|---|---|---|---|---|---|---|---|
| var. | R | G | B | R | G | B | R | G | B |
| 1 | 70 | 170 | 70 | 255 | 113 | 104 | 255 | 255 | 0 |
| 2 | 0 | 0 | 255 | 255 | 120 | 108 | 249 | 248 | 189 |
| 3 | 0 | 255 | 0 | 255 | 120 | 108 | 255 | 255 | 128 |
| 4 | 150 | 196 | 2552 | 255 | 130 | 119 | 239 | 245 | 120 |
| 5 | 0 | 235 | 64 | 255 | 138 | 128 | 237 | 234 | 0 |
| 6 | 70 | 70 | 255 | 255 | 0 | 0 | 249 | 235 | 140 |

crimination requires different visual responses on the distinct visual objects. When visual scene changes the adaptation process can improve discrimination ability by optimizing the use of the available response range for objects in the scene [3].

During visual search of preferable color objects, the observers use both – categorical perception and color discrimination. There are many factors that could influence on color discrimination process. One of them is the language and the terms of colors. According to our previous data, among Georgian population the most preferable are the basic colors (red, green, blue, yellow, black and white). These colors are most frequently named (the data of the list experiment) and chosen (the data of the visual searching experiments) [4]. There is no universal explanation why some people prefer one color to others: the reasons of color preference are vague and diverse. Some people's preferences may be governed by the object associations, others by basic psychophysical dimensions, others by biological components of color vision [5]. Besides, there are evidences that color discrimination is different during different seasons [6].

Healthy aging and age-related optical and neural changes affect many aspects of visual perception. However, color appearance remains remarkably stable in the aging visual system even if the spectral distribution of the retinal stimulus is changed and chromatic sensitivity is lost [7, 8].

Contrast sensitivity is one of the most important attribute of vision. In visual perception the contrast is determined by the difference in the color and brightness between different objects within the same visual field. Because they rely on the same initial representation of spectral information, the two functions - color constancy and color discrimination are considered to be linked to each other. Color constancy cannot be evaluated meaningfully without considering discrimination. It is well known that healthy aging affects the contrast sensitivity, especially at high spatial frequencies [9]. There are not many studies related to aging and contrast sensitivity, and/or aging and color discrimination. However, Pieri et al. [10] showed that contrast sensitivity deficits but not color discrimination deficits correlated with age.

The aim of our study was to investigate age-re-

**Table 2. Group 1 – elderly; Group 2 –young controls and Group 3 – children**

**Reaction times (msec) and Standard Deviations are shown.**

| | Group 1 | Group 2 | Group3 |
|---|---|---|---|
| Black-White | 477 ± 11 | 422 ± 13 | 475 ± 13 |
| Blue | 504 ± 14 | 437 ± 9 | 485 ± 12 |
| Blue-Green | 504 ± 12 | 412 ± 15 | 485 ± 19 |
| Green | 554 ± 66 | 563 ± 84 | 446 ± 38 |
| Red | 497 ± 26 | 560 ± 24 | 498 ± 18 |
| Yellow | 506 ± 10 | 426 ± 14 | 485 ± 10 |

lated changes of color discrimination. For this purpose we used discrimination of different colors of the same or different categories. Observers of three different age-groups participated in our study. We wanted to check weather language and color preferences, developmental aspect and aging had any impact on color discrimination ability.

## Materials and Methods

**Participants.** 30 observers of three different age-groups participated in the study: Group 1 – elderly (n=10; 60 and over), Group 2 young controls (n=10; 20-32 years old) and Group 3 – children (n=10; 6-15 years old).Written informed consent was provided prior to participating in experiments in compliance with international ethical standards for experimentation on human observers. All subjects had normal or corrected-to-normal visual acuity and normal color vision. Visual acuity was determined by the Freiburg visual acuity test [11]. Subjects had to reach a value of 1.0 (corresponding to 20/20) to participate in the experiments. Color Vision was estimated by Ishihara's tests for Color Blindness-24 Plates (ed. 1991).

**Stimuli and procedure.** The experiments were conducted in a dimly illuminated room. Stimuli were displayed on a calibrated SAMSUNG monitor (model Sync Master 997 MB). Participants were seated 60 cm away from the monitor. Stimulus was a color circle (diameter = 3 cm, visual angle of 3.5°) presented on a color background left or right from the centered fixation point. Six different discrimination colored pairs were used in our experiments (RGB coordinates of each color are given in Table 1).

For each pair, one stimulus was used as the target and one as the background, with both stimuli in one pair appearing equally as the target or the background. The discrimination procedure for each color was the same but sequences of different colors were randomized among subjects. Each trial began with the presentation of a gray screen with fixation point on the center. A blank gray screen was presented for 250 milliseconds (ms), followed by the presentation of the target and background for 4 seconds. Participants were instructed that on each trial, the display would consist of a target color on a uniform background of different color and that their task was to decide whether the target was to the left or right of the fixation point and to give response by pressing related keyboard button (left or right arrow keys) as quickly as possible while maintaining high accuracy. For each color pairs there were 96 experimental trials made. Before starting real experiments some practice trials were performed.

**Table 3. The degrees of freedom (df), the F value (F) and the Sig. value (the p value) (*p* < .05, 95% confidence).**

| | | df | F | Sig. |
|---|---|---|---|---|
| Black | Between Groups | 2 | 82.002 | .000 |
| | Within Groups | 33 | | |
| | Total | 35 | | |
| Blue | Between Groups | 2 | 101.623 | .000 |
| | Within Groups | 33 | | |
| | Total | 35 | | |
| Greenblue | Between Groups | 2 | 117.434 | .000 |
| | Within Groups | 33 | | |
| | Total | 35 | | |
| Yellow | Between Groups | 2 | 156.827 | .000 |
| | Within Groups | 33 | | |
| | Total | 35 | | |
| Red | Between Groups | 2 | 29.333 | .000 |
| | Within Groups | 33 | | |
| | Total | 35 | | |
| Green | Between Groups | 2 | 3.510 | .041 |
| | Within Groups | 33 | | |
| | Total | 35 | | |

**Table 4. Paired samples t-test compared reaction time differences between different colors. The Table shows the degrees of freedom (df), the T-statistics and the Sig. value (the p value, $p < .05$)**

| Paired Samples Test | | T | df | Sig. (2-tailed) |
|---|---|---|---|---|
| Pair 1 | black - blue | -5.654 | 35 | .000 |
| Pair 2 | black green/blue | -2.230 | 35 | .032 |
| Pair 3 | black - yellow | -4.447 | 35 | .000 |
| Pair 4 | black – red | -5.982 | 35 | .000 |
| Pair 5 | black - green | -3.692 | 35 | .001 |
| Pair 6 | blue – green/blue | 2.446 | 35 | .020 |
| Pair 7 | blue - yellow | 1.004 | 35 | .322 |
| Pair 8 | blue – red | -4.210 | 35 | .000 |
| Pair 9 | blue - green | -2.688 | 35 | .011 |
| Pair 10 | green/blue yellow | -1.479 | 35 | .148 |
| Pair 11 | green/blue - red | -4.241 | 35 | .000 |
| Pair 12 | green/blue green | -3.063 | 35 | .004 |
| Pair 13 | yellow - red | -4.060 | 35 | .000 |
| Pair 14 | yellow - green | -2.854 | 35 | .007 |
| Pair 15 | red – green | -.114 | 35 | .910 |

**Data analysis.** Average reaction time and standard deviation for each discriminated color were calculated separately for each age-group.

One-way ANOVA with the Bonferroni correction for post-hoc multiple comparisons was applied to compare performance between different age-groups and a paired sample *t*-test was used to compare reaction time for different colors.

## Results.

Reaction times in milliseconds and standard deviations for each discriminated colors are presented in Table 2. Reaction time for each color pair and for each age-group did not differ significantly from each other. These results are in accordance to well-known evidences how reaction time changes with aging [12-14] (Table 2).

One-way ANOVA proved that reaction time is significantly different for different age- groups (Table 3).

Results of one-way ANOVA are shown in Table 3 and the results of paired sample *t*-test are shown in Table 4.

Bonferroni correction for post-hoc multiple comparisons showed that for Blue, Blue-Green, Green and Yellow colors pair there are no significant differences in performance among different groups. For Black-White color discrimination we found that performance did not differ between the Groups 1 and 3 ($p = 0.83$), but Group 2 showed significant difference compared to the other two groups ($p = 0.00$). The same comparison revealed also the same results for Red color. Red-pink discrimination did not differ between the Groups 1 and 3 ($p = 0.97$), and Group 2 showed significant difference compared to the other two groups ($p = 0.00$). We can explain such difference for Red and Black-White colors as different emotional load for those colors for different age people; for some people red is very active color, related to many emotions and could be described as warm and positive, or as violated color for others; black and white colors are more neutral colors and individual mental processing time can be affected by such differences. Black-White colors, as neutral ones, having no emotional load and are processed faster in young controls. Hita and colleagues [15] measured reaction times for chromatic stimuli with dominant wavelengths (472, 500, 547, 571, 602 and 634 nm) and found that there is no correlation between reaction time and chromaticity. On the other hand, it is also shown that reaction time for red color is longer compared to reaction time on green [16].

**Conclusions.** The results of our experiments showed that healthy aging has no significant impact on color discrimination. This refers not only to discrimination of colors in the same category, but also to discrimination of colors in different categories. Age-related changes or ongoing developmental changes have no significant influence on the color discrimination process.

*ადამიანისა და ცხოველთა ფიზიოლოგია*

# ადამიანის მხედველობითი ფერების დისკრიმინაციის ასაკობრივი ცვლილებები

**ზ. ფარქოსაძე*, მ. ხომერიკი**, ა. კეზელი****

** ი. ბერიტაშვილის ექსპერიმენტული ბიომედიცინის ცენტრი, მხედველობის ფიზიოლოგიის ლაბორატორია; საქართველოს აგრარული უნივერსიტეტი, კოგნიტიურ ნეირომეცნიერებათა ინსტიტუტი*

***ი. ბერიტაშვილის ექსპერიმენტული ბიომედიცინის ცენტრი, მხედველობის ფიზიოლოგიის ლაბორატორია*

(წარმოდგენილია აკადემიის წევრის ნ. მითაგვარიას მიერ)

**ფერადი მხედველობა ადამიანის მხედველობის მნიშვნელოვანი კომპონენტია და გადამწყვეტ როლს თამაშობს აღქმასა და კომუნიკაციაში. ფერადი მხედველობის აუცილებელი ატრიბუტებია კატეგორიული აღქმისა და ფერთა დისკრიმინაციის უნარები. ცნობილია, რომ ჯანმრთელი სიბერე და ასაკთან დაკავშირებული ოპტიკური და ნეირონული ცვლილებები გავლენას ახდენს მხედველობითი აღქმის მრავალ ასპექტზე, თუმცა, ფერების აღქმა შედარებით მდგრადი რჩება ასაკოვან მხედველობით სისტემაში. ჩვენი კვლევის მიზანი იყო შეგვესწავლა, იცვლება თუ არა ერთი და იმავე და სხვადასხვა კატეგორიებში შემავალი ფერების დისკრიმინაციის უნარი ასაკის მომატებასთან ერთად. ჩვენ შევისწავლეთ განვითარების ასპექტებისა და ასაკის მატების გავლენა ფერთა დისკრიმინაციის უნარზე. კვლევაში მონაწილეობდა სამ ასაკობრივ ჯგუფად განაწილებული 30 ცდისპირი: ჯგუფი 1 – ხანდაზმულები (10 ადამიანი 60 წელს ზემოთ), ჯგუფი 2 – ახალგაზრდა კონტროლები (10 ადამიანი 20–32 წლის) და ჯგუფი 3 – ბავშვები (10 ადამიანი 7–15 წლის). მიღებულმა შედეგებმა გვიჩვენა, რომ რეაქციის დრო ფერთა თითოეული წყვილისთვის და თითოეულ ასაკობრივ ჯგუფში სარწმუნოდ არ განსხვავდება ერთმანეთისგან, ხოლო პოსტ-ჰოკ ანალიზმა არ გამოავლინა რაიმე სარწმუნო განსხვავება სხვადასხვა ფერების დისკრიმინაციის უნარში. ამრიგად, ჩვენი შედეგები აჩვენებს, რომ ჯანმრთელი სიბერე არ ახდენს ზეგავლენას ფერთა დისკრიმინაციის უნარზე, ეს ეხება არა მხოლოდ ერთ კატეგორიაში შემავალ ფერებს, არამედ სხვადასხვა კატეგორიებში შემავალ ფერებსაც. შედეგებიდან გამომდინარე შეგვიძლია დავასკვნათ, რომ ასაკთან ან ორგანიზმის განვითარებასთან დაკავშირებული ცვლილებები ფერთა დისკრიმინაციის პროცესებზე სარწმუნო გავლენას არ უნდა ახდენდნენ.**

## REFERENCES

1. *Linhares J.M., Pinto P.D., Nascimento S.M.* (2008) J. Opt. Soc. Am. A Opt. Image Sci. Vis. **25,** 12:2918-2924.
2. *Witzel C., Gegenfurtner K.R.* (2013) J. Vis. **13**, 7: 1, 1-33.
3. *Walvaren J., Enroth-Cugell C., Hood D.C. et al.* (1990) Visual perception: the neurophysiological foundations. San Diego. 53-101.
4. *Khomeriki M., Lomashvili N., Kezeli A.* (2006) Bull. Georg. Natl. Acad. Sci. **174**, 2: 326-329.
5. *Taylor C., Clifford A., Franklin A.* (2013) J. Exp. Psychol. Gen. **142**, 4: 1015-27.
6. *Welbourne L.E., Morland A.B., Wade A.R.* (2015) Cur. Biol. **25**, 15: R 646-7.
7. *Delahunt P.B., Webster M. L., Werner J.S.* (2005) Visual Neuroscience. **21**: 301–307.
8. *Werner J.S.* (1996) Progress in retinal and eye research. In: Osborne NN, Chader J. (editors). Oxford: Pergamon Press; 15**,** 2: 621–645.
9. *Owsley C.* (2011) Vision Research. 51 (13): 1610–1622.
10. *Pieri V., Diederich N.J., Raman R. et al.* (2000) J. Neurolog. Sci. **172**: 7–11.
11. *Bach M.* (1996) Optom Vis. Sci. **73** (1): 49-53.
12. *Welford A.T.* (1977) In: J. E. Birren, K. W. Schaie (Eds.), Handbook of the Psychology of Aging. Van Nostrand Reinhold, New York, 450-496.
13. *Jevas S. and Yan J. H.* (2001) Research Quarterly for Exercise and Sport. **72:** A-49.
14. *Rose S.A., Feldman J. F., Jankowski J. J. et al.* (2002) Child Develop. **73**, 1: 47.
15. *Hita E., Gomez J. L., Jimenez Del Barco L., et al.* (1986) J. Optics, **17**, 4: 197–202.
16. *Venkatesh D., Ramachandra D.L., Rajan B. K.* (2002) Indian J.Phys. & Pharmacol. **46** (3): 333–337.

*Received December, 2015*