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The Revealing of Color Categorical Boundaries among Georgian Speakers

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ABSTRACT. **For the purpose of studying the peculiarities of color categorization in Georgian population we tried to determine the categorical boundaries between the categories of the red (*tsiteli*)-pink (*vardisperi*) and blue (*lurji*)-light blue (*tsisperi*) colors. In other words, we wanted to specify when the perceptual difference among the colors of the same hue but different lightness and/or wavelength turns to a linguistic category. It appeared that the categorical boundaries between colors are very individual; the etymology of the names of colors does not influence the process of categorization. The character of categorization in the red-pink and blue-light blue pairs is different. It depends on the experimental situation and is conditioned by linguistic peculiarities.** *© 2009 Bull. Georg. Natl. Acad. Sci.*

Key words: *color categories, visual observation, categorical boundaries.*

Introduction. The ability of categorical perception (CP) of colors is one 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 for an individual to differentiate samples having different hues. For instance, in green strawberry leaves, among which newly opened leaves are brighter and lighter than old ones, it is easier to distinguish ripe red fruits with different redness rather than unripe green fruit. According to many researchers, it is a well-known fact that colors are differentiated more quickly between categories than those which belong to one category [1-3]. Categorical perception occurs when stimuli that straddle a category boundary are perceived as more distinct than equivalently-spaced stimuli within a category [4]. As contemporary investigations show, it is possible to reveal the CP in humans ontogenetically even during the first months. It can be said that categorical perception is the physiological basis of linguistic categorization. It should be mentioned that in pre-linguistic babies the lateralization of CP is observed in the right hemisphere which according to a certain view, turns to the left hemisphere after studying the names of colors [5]. This problem raises some questions and requires further investigation.

Perceptual categorization of colors makes their nomination easier as the number of the names of colors is considerably limited in every language in comparison with the number of perceptible colors. CP occurs at boundaries between colors that are linguistically marked in a speaker's language [6, 7]. In some languages the colors singled out as two independent categories and named with different color terms in another language are denoted with one category and named with one color term. For instance, *lurji* (blue) and *tsisperi* (light blue) – in Georgian, *sinii* and *goluboi* – in Russian, in English are denoted with only one category and term – blue. As the researches have shown the linguistic difference leads to differences in color discrimination. Winawer J. et al. [2] tested English and Russian speakers in a speeded color discrimination task using blue stimuli that spanned the *sinii/goluboi* border and found that Russian speakers were faster to discriminate two colors when they fell into different linguistic categories in Russian (one *sinii* and the other *goluboi*) than when they were from the same linguistic category (both *sinii* or both *goluboi*). English speakers tested on the identical stimuli did not show a category advantage in any of the used experimental conditions**.** There exists such a difference in the categorical perception of two blue colors between Russian and English speakers. In the Russian language both these terms are basic unlike the Georgian terms *lurji* and *tsisperi,* of which the former is basic and the latter non-basic [8].

The named category boundaries vary across languages, and categorical perception varies with them [4]. In favor of this consideration we will show the results of one of our experiments. Agreeing with Dr. Franklin A., we used the same method with Georgian speakers which she used in her work together with her colleagues [2]. Roberson D. et al. [9] used the same method with Koreans who have two different categories of the green color. These authors revealed CP of green-blue [2] and green-green [9] colors and, in addition, they indicated a lateralization of CP too by means of measure of reaction times. We were interested whether CP would be revealed while presenting the *lurji* (blue) and *tsisperi* (light blue) colors to Georgian subjects. Like these authors, we used 3 pairs very close-distanced from each other - *lurji-lurji* and *tsisperi-tsisperi* (as within categorical colors) and *lurji-tsisperi* (as between categorical colors) for all participants. But unlike them, we failed to reveal perceptual categorization between *lurji* and *tsisperi* colors and consequently, were not able to get its lateralization. In spite of the fact that in the Georgian language the color blue is expressed by two terms *lurji* and *tsisperi* and both of them are singled out as different linguistic categories, from 30 subjects in each reaction time (RT), during, between and within categories presentation, they differed from each other individually. In total by ANOVA calculation the durations of RTs in the case of across and within categories presentations did not differ significantly (LVF $P<0.08$; RVF $P<0.21$). Consequently, no lateralization was observed or any significant category effect; neither interaction with the hemisphere was revealed.

This fact can be explained only by the peculiarities of the perceptual categorization in this language group. Moreover, there is a view according to which "…certain cultures may vary a uniform pattern of categorization of basic hues because certain peoples may actually perceive colors differently and therefore categorize them differently" [10] and the differences between languages induce differences in perception [11]. It is possible that here the color basicness also plays its role as the perceptual boundary is more distinct among the focal colors. In the Georgian language focal colors are the primary categories and are denoted with the basic terms. The systems of these terms completely correspond to Berlin's and Kay's universal model of the color categorization. Focal colors seemed to constitute a universal cognitive basis for both color language and color memory. Rosch E. [12] found that the focal colors were remembered more accurately than other colors across speakers of languages with different color naming systems. Additionally we can say that according to our list-experiments, while oral listing these focal colors (red, yellow, green, blue, white and black) are named earlier than other colors [13]. As the linguist E. Soselia [8] indicates, in the Georgian language the basic colors mixing with each other produce new categories:

tsisperi (light blue) = ([blue] + [white]);
vardisperi (pink) = ([red] + [white]);
narinjisperi (orange) = ([red] + [yellow]);
kavisperi (brown) = ([black] + [yellow]);
iisperi (violet) = ([red] + [blue]);
natsrisperi (gray) = ([black] + [white]).

These categories are secondary and are denoted with non-basic terms. The terms of all the above denote a certain object - for instance, *tsisperi* (light-blue) – *tsa* (sky) and the second word in each of them is the word *peri* (color). In the Georgian language a lot of colors are named according to this principle – two-, three- or more words form compound words (the last word of a compound is always the word - *peri* (color).

Of the basic colors, only three of them – red, blue and black-turn into a linguistically new category after being mixed with white. *Tsisperi, vardisperi* and *natsrisperi* are the same as light blue, light red and light black after blue, red and black reach a certain degree of lightness. In the case of black and gray this degree can be determined with more or less exactness, in other words, it is possible to merge these two categories perceptually and linguistically. It is enough to add a bit of white (approximately 10 %) in order to perceive black as dark gray (the Georgian word for gray "*natsrisperi*" in word for word translation means color of ashes). The terms *tsisperi, vardisperi* and *natsrisperi* etymologically come from the words sky (*tsa*), rose (*vardi*) and ash (*natsari*). But perceptually they are less saturated blue, red and black diluted with white. When does the perceptual difference among the colors of the same hue but different lightness or wavelength turn into linguistic categorization? Does the etymology of categorical terms influence this process in linguistic categorization among Georgian population? For what reason we have not got revealing and lateralization of CP in the above mentioned experiment? This was the goal of our investigation.

Methods. 32 native Georgian speakers (35 ±10) years old were recruited from I. Beritashvili Institute. The experiments were divided into two parts. The first and the second experiments tested the red-pink and blue-light blue boundaries.

In the first experiment (simultaneous single observation) we used the single observation of the color palettes red (*tsiteli*)-pink (*vardisperi*) and blue (*lurji*)-light blue (*tsisperi*) for participants. On the screen of the monitor (Sync Master 997 MB) the subjects at first observed the red-pink palette, then the blue-light blue one. We asked the subjects to look at the monitor with red-pink palette, track the squares from the first one above left, toward left to right and top to bottom and tell us which colored square was already pink. The subject moved the cursor until this colour after which the RGB coordinates of it occurred on the monitor. Then a similar procedure was carried out in the case of the blue-light blue palette presentation. The time for the observation was limited to 5 sec. This time was quite enough to survey the whole palette calmly.

In the second experiment (separated successive observation) use was made of the software presentation of the same *tsiteli* (red) and *vardisperi* (pink) and *lurji* (blue) and *tsisperi* (light blue) color stimuli. The first part of this experiment included the red and pink colors, the next one the blue and light blue colors. Now the color squares occurred on the monitor singly and once, one after another, in the same sequence as they were set on red-pink and blue-light blue palettes. In this case each color presented separately on the black background seemed brighter than the same color set on the palette among other colors. This would naturally cause the shift of *vardisperi* and *tsisperi* towards red and blue respectively. That is why we chose such gray background (R-100 ± 5, G-100 ± 5, B-100 ± 5) against which luminance of the separately presented stimuli was almost the same subjectively as on the palettes for each participant. The participant had to press the key “Y” if he/she considered that the square appearing on the monitor was still red (or blue in the second part of the experiment) and had to press the key “N” if the appearing square was already pink (or light blue) for him/her. When the subject pressed the key “N”, the presentation of the colored squares was stopped. So we fixed the color-boundary between *tsiteli* (red) and *vardisperi* (pink) and *lurji* (blue) and *tsisperi* (light blue). Each of the subjects repeated this procedure three times.

Subjects were instructed to make all judgments as accurately and quickly as possible. The testing took place in a quiet, darkened room.

In the first experiment each of the used palettes was formed by 64 (8x8) colored squares. The distances between the squares were 8 mm. The color squares were 2 cm per side, and subjects viewed the screen from ~60 cm. For an intensification of color perception during the simultaneous observation all of the presented colors the backgrounds for both palettes were black R-0, G-0, B-0.

The initial square of the red-pink palette was pure red (R-255, G-0, B-0) and the last one was pure white (R-255, G-255, B-255). The initial square of the other palette blue-light blue was pure blue (B-255, G-0, R-0) and the last one was pure white (R-255, G-255, B-255). On both palettes, to start from the second square the RGB of each other squares was changed by 4 pitch (for example – in the case of red-pink palette, if the first square had RGB – R-255, G-0, B-0, RGB of the next square was R-255, G-4, B-4, RGB of the other next square was R-255, G-8, B-8 etc). The hue of red was changed into the hue of pink in such a way until we got pure white. The changes of G and B (red-pink variant) and R and G (blue- light blue variant) were equal. The wavelengths of all stimuli were measured by the colorimeter “Gretag Macbeth Eye-One display 2 colorimeter” and their *Yxy* coordinates are presented in correspondence with the Commission Internationale de l’Eclairage (CIE).

In the first experiment each of the speakers had to determine the boundaries between *tsiteli* (red) and *vardisperi* (pink), *lurji* (blue) and *tsisperi* (light blue) color categories. They observed each of the palettes carefully and then indicated from which square were the stimuli already *vardisperi* (the first palette), or *tsisperi* (the second palette).

In the second experiment the request was the same, but the speakers had to determine the boundaries between the categories by memory, because in this case the colored squares were presented singly and once successively one after another on the monitor.

Results. The results of the first as well as the second experiment are rather individual. Each subject has his/her individual boundaries among categories.

On the palettes at simultaneous observation, the coordinates of the average value of boundaries between the red-pink colors is the following: x-0.428, y-0.332, Y-41.35, but between the blue-light blue colors - x-0.188, y-0.156, Y-38.78.

At separated successive observation the coordinates of the average value of boundaries between the red-pink colors correspond to – x-0.462, y-0.334, Y-36.20, but between the blue-light blue colors – to x-0.171, y-0.120, Y-27.28.

If we compare the data of these two experiments, we will notice that in the first case the average values of boundaries of the red-pink and blue-light blue categories in comparison with the second case are significantly shifted towards red and blue (by ANOVA calculation – red- pink P<0.000246, blue – light blue P<2.61E-07). But unlike the simultaneous single observation, at separated successive observation the average values (RGB) of boundaries of the red-pink and blue-light blue categories are very little removed from each other. Thus, in order to merge the two categories at successive separated observation, the subjects added more white to blue (P<0.024) to make it light blue (tsisperi) than to red to make it pink. They fixed lighter colors as pink and light blue than in the case of the simultaneous observation. The boundaries fixed in both cases sometimes coincide with each other. While surveying palettes, the most frequent cases of the coincidence of the boundaries between the red – pink colors is noticed in 25 % of observers (x-0.400, y-0.331, Y-49.2), but there was coincidence of the boundaries between the blue – *tsisperi* colors in 32 % (x-0.180, y-0.143, Y-34.2). Only one subject chose one and the same color as pink on the palette as well as at the successive separated observation (x-0.400, y-0.331, Y-49.2). The coordinates of this color coincide with the most frequently chosen pink on the palette. Only one subject (but in this case another one) chose one and the same color as *tsisperi* (light blue) on the palette as well as at successive separated observation (x-0.180, y-0.143, Y-34.2). The coordinates of this color also coincide with the most frequently chosen *tsisperi* (light blue) on the palette. At successive separated observation, the frequency of the coincidence of the boundaries is lower in the case of the red-pink colors – 16 % and corresponds to the color with the coordinates x-0.462, y-0.336, Y-37.6, but in the case of the blue-light blue colors the frequency of the coincidence of the boundaries is 19 % and it corresponds to the color with the coordinates x-0.166, y-0.111, Y-24.41.

Discussion. In the described experiments the subjects had two kinds of conditions in order to fix the categorical boundaries between the red-pink and blue-light blue colors. The first condition, i.e. the survey of the red-pink and blue-light blue palettes intended to merge the colors shown on the monitor as the red and pink categories and the blue and light blue categories on the basis of the comparison of these colors. The instruction strictly required to indicate only that color (to fix it by pressing a key) after which *vardisperi* (*tsisperi* in the second case) started on the palette. The subjects were comparing every following color to the previous one and in the case of enough light were fixing *vardisperi* (or *tsisperi*) color. It appeared that each participant has individual boundaries among these color categories. The boundaries of red-pink [(x-0.354, y-0.329, Y-36.2) – (x-0.508, y-0.347, Y-31.89)] and blue-light blue[(x-0.216, y-0.214, Y-63.89) – (x-0.173, y-0.124, Y-28.07)] fixed by all of them waver within certain scopes which are wide enough.

The second condition intended the fulfillment of the same task, but in this case it should be done on the basis of comparing each following color presented on the monitor separately to the previous one. At this time the subjects were comparing redness (bluishness) of colors by memory and were fixing (by pressing the key "N") how they turned into pink (light blue). As it appeared, the images of pink and light blue existing in the memory are lighter than the colors perceived in the comparative context while simultaneously making visual observation. In this case, also, the boundaries of red – pink [(x-0.399, y-0.335, Y-47.54) – (x-0.518, y-0.345, Y-30.71)] and blue – light blue [(x-0.200, y-0.183, Y-48.68) – (x-0.155, y-0.088, Y-16.21)] fixed by all subject waver within a certain range and this range is wide enough. It should also be mentioned that at the successive separated observation the range of the red-pink boundaries is smaller in comparison with the case of simultaneous observation, but the scopes of the boundaries of the blue-light blue categories are a bit wider. In the explanatory dictionary of the Georgian language *vardisperi* is defined as light *tsiteli* and *tsisperi* – as light *lurji*. It seems that the words *vardi* (rose) and *tsa* (sky) which are the components of the compounds expressing these colors (*vardisperi* and *tsisperi*) do not have the semantic influence on merging the *tsiteli* and *vardisperi* and *lurji* and *tsisperi* colors as categories. After the experiments were over, we asked the subjects what considerations they were guided by while making their choice. We were quite astonished at their answers that for all of them *vardisperi* and *tsisperi* were only lighter *tsiteli* and *lurji* to some extent. The fact that in order to determine the boundaries of blue – *tsisperi* it is necessary to add more white, i.e. it is necessary to make blue lighter in comparison with red – pink, probably can be explained by one linguistic statement – in the

Georgian language the degree of membership of the red and pink colors in the red category is higher than the degree of membership of blue and light blue in the blue category.

When we deal with such scattering of the individual boundaries between colour categories, probably, it is difficult to choose such two very close-distanced colors of different categories which would have one and the same perceptual boundary for a statistically significant number of subjects. The negative result of the experiment given in the introduction which was carried out to reveal the CP between blue-*tsisperi* colors can be explained by this consideration.

Conclusions. Determining the boundaries between the categories of colors of the same hue having different lightness and/or the wavelength among Georgian population has an individual character and depends on those conditions of observation in which the categories are merged. As is seen from the experiment, while making the observation on separately presented colors:

1. The average values (RGB) of the boundaries determined by memory between the *tsiteli* (red) and *vardisperi* (pink) categories and *lurji* (blue) and *tsisperi* (light blue) categories are considerably closer to each other than the average values of the boundaries determined by comparing them while making simultaneous observation of colors.

2. In comparison with simultaneous observation, subjects add more white while turning *lurji* (blue) into *tsisperi* (light blue) than while turning *tsiteli* (red) into *vardisperi* (pink) by memory. It strengthens linguist, view that the degree of membership of the *tsiteli* and *vardisperi* colors in the *tsiteli* category is higher than the degree of membership of *lurji* and *tsisperi* in the *lurji* category.

3. Among Georgian speakers the etymology of the pink and light blue terms does not influence determination of the boundaries. For observers *vardisperi* (pink) and *tsisperi* (light blue) are merely light red and light blue. They are not associated with the components of these compounds *vardi* (rose) and *tsa* (sky).

4. Generally, the spread in values (RGB) of the individual boundaries between the red and pink categories and the blue and light blue categories is so wide that it should be difficult to choose one and the same very little-distanced pair of red - pink (or blue - light blue) colours for the revealing of CP for a statistically significant number of subjects. We suppose the reason why we failed to get CP between *lurji*-*tsisperi* in our experiment (see Introduction) consists in this fact.

ადამიანის და ცხოველთა ფიზიოლოგია

ზოგიერთ ფერთა კატეგორიებს შორის საზღვრების გამოვლენა ქართულად მეტყველ ადამიანებში

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(წარმოდგენილია აკადემიის წევრის ზ. ქევანიშვილის მიერ)

კვლევის მიზანს წარმოადგენდა ლურჯ-ცისფერ და წითელ-ვარდისფერ კატეგორიებს შორის იმ საზღვრების დადგენა, სადაც პერცეპტუალური კატეგორიზაცია გადადის ლინგვისტურ კატეგორიზაციაში. ექსპერიმენტის საფუძველზე დგინდება, რომ აღნიშნულ ფერთა კატეგორიებს შორის ასეთი საზღვრები ძალზე ინდივიდუალურია. ფერთა ეტიმოლოგია გავლენას არ ახდენს ამ ფერთა კატეგორიზაციის ხასიათზე. ფერთა ერთი და იგივე წყვილი კატეგორიული აღქმის საზღვრების დასადგენად ყველა ცდისპირის მიმართ არ შეიძლება იქნეს გამოყენებული.

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