The colour lexicon of the Serbian language –
a study of dark blue and dark red colour categories
Part 2: Categorical facilitation with Serbian colour terms

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Part 1 of this study (Jakovljev & Zdravković, 2018) isolated two frequent and salient non-BCTs in the Serbian language: teget ‘dark blue’ and bordo ‘dark red’, that segregate the blue and the red part of the colour space respectively. Now we conducted two experiments to additionally test the cognitive salience of these terms, investigating whether they can produce the category effects in a colour discrimination task. We demonstrated within- and between-participants agreement about the placement of the boundary in the blue and the red part of the colour space, additionally showing that Serbian speakers have distinctive representations of these categories. Analysis of RT in the discrimination task showed category effects – participants were faster when discriminating colour pairs that belong to different linguistic categories than the pairs from the same category. These results for the first time demonstrated category effect in the Serbian language as well as the category effect in speeded discrimination of the red part of the colour space for any language. They also support views that category effect is linked to higher cognitive processes; hence it can be language specific.

Key words: categorical perception of colour, categorical facilitation, Serbian colour terms

Highlights:

- NonBCTs teget ‘dark blue’ and bordo ‘dark red’ produced category effects in colour discrimination task.

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• High consistency and consensus about the placement of plavo-teget and crveno-bordo boundary.
• Category effects are linked to categories specific to language.

Linguistic categorization of the colour space reflects the cognitive economy principles of simplicity and informativeness (Rosch, 1999) – millions of colours that we can perceive are grouped into a limited number of colour categories labeled with colour terms in order to support efficient communication (Regier, Kemp, & Kay, 2015). Moreover, studies have shown that this categorization of the colour space affects colour discrimination. A variety of experimental tasks demonstrated that shades from different linguistic categories are discriminated faster and/or with greater accuracy than the shades that share the same name, even when distances between cross-category pairs and distances between within-category pairs are controlled in a perceptually meaningful way (Bornstein & Korda, 1984; Gilbert, Regier, Kay, & Ivry, 2006; Roberson & Davidoff, 2000; Roberson, Pak, & Hanley, 2008). This effect is known as categorical perception of colour (CPC effect). Studies investigating CPC effect provided further insights into the relationship between perception and language and impacted universalistic/relativistic debate, described in the Part 1 of this study.

Several developmental studies showed CPC effect in toddlers before they have learned colour terms, supporting the universalistic view that in its nature this effect is inherent and perceptual (Franklin, Clifford, Williamson, & Davies, 2004; Franklin, Pilling, & Davies, 2005; Franklin et al., 2008). However, a large number of studies strongly opposed this view showing a crucial role of language for the CPC effect. These studies showed that this effect is lateralized to the language-specialized left hemisphere (Drivonikou et al., 2007; Gilbert et al., 2006; Mo, Xu, Kay, & Tan, 2011) and that it can be cancelled if verbal interference is applied simultaneously with a colour discrimination task (Pilling, Wigget, Özgen, & Davies, 2003; Roberson & Davidoff, 2000; Wigget & Davies, 2008). Also, studies have demonstrated cross-cultural differences in CPC effect, suggesting its link to the language-specific colour categories (Kay & Kampton, 1984; Roberson, Davies, & Davidoff, 2000; Roberson, et al., 2008; Winawer et al., 2007).

In their study in 2007, Winawer and colleagues demonstrated category effect between two Russian terms for blue shades (Winawer et al., 2007). Namely, Russian speakers were faster when discriminating shades if one of them fell in goluboy ‘light blue’ category while another fell in siniy ‘dark blue’, in comparison to the situation where both shades belonged to the same linguistic category. In the same study, they demonstrated that this type of category advantage did not occur for English speakers who use only one basic term for the blue colour region (Winawer et al., 2007). Language-specific category effects were also observed for two blue categories in the Greek
language (Thierry, Athanasopoulos, Wiggett, Dering, & Kuipers, 2009) and two blue categories in the Japanese language (Athanasopoulos, Damjanovic, Krajciova, & Sasaki, 2011). Roberson and colleagues demonstrated that, unlike English speakers, Korean speakers showed CPC at the boundary between Korean categories yeondu ‘yellow-green’ and chrok ‘green’ but only with supratreshold stimuli, while the smallest differences in shade that can be discriminated (just noticeable differences – JND) were the same for both group of speakers (Roberson et al., 2008; Roberson, Hanley, & Pak, 2009). Based on their results, Roberson and colleagues (2009) concluded that CPC effect does not reflect differences in perceptual sensitivities around category boundaries.

Similar notion regarding the fact that categorical perception is not a perceptual phenomenon has been made recently by Witzel and Gegenfurtner (Witzel & Gegenfurtner, 2015; Witzel & Gegenfurtner, 2016). These authors criticized previous studies of CPC effect that focused on the blue-green colour boundary since that boundary coincides with low-level sensory mechanisms, and therefore might not be due to language but to sensory mechanisms. To investigate the effect of language on colour discrimination, Witzel and Gegenfurtner (2016) studied the red-brown boundary, which is not directly linked to the low-level vision mechanisms. Results of this study have shown that perceptual sensitivity is not categorical, but that category effect observed in the colour discrimination might emerge as a consequence of the attention shifting to the linguistic distinction between colour categories. This kind of category effect has been named categorial facilitation (Witzel & Gegenfurtner, 2015, 2016).

In the present study, we aimed to investigate category effects in the context of specific linguistic categories used in the Serbian language. Given that our results provided in the Part 1 of this study (Jakovljev & Zdravkovic, 2018) showed that teget ‘dark blue’ and bordo ‘dark red’ are salient non-basic colour terms (non-BCTs) that are frequently used among Serbian speakers, we decided to investigate category effects between categories plavo ‘blue’ and teget ‘dark blue’ (Experiment 1), and crveno ‘red’ and bordo ‘dark red’ (Experiment 2). In each experiment, we conducted a simultaneous colour discrimination tasks (as in Winawer et al., 2007) in order to investigate categorical facilitation in speeded discrimination for suprathreshold stimuli. The shorter reaction times in the discrimination of shades from different categories (specific for the Serbian language) would have two relevant implications. First, they would further support the idea that category effects are determined by the specific linguistic partition of the colour space and would support studies showing that these effect can be observed beyond the inventory of 11 basic colour terms (BCTs proposed by Berlin and Kay, 1969; Athanasopoulos et al., 2011; Roberson et al., 2008; Winawer et al., 2007). Our results would be especially significant because they would be the first demonstration of category effect in speeded discrimination task within the red part of the colour space. The second implication would be that category effects in the blue and the red part of the colour space further
support our findings from the Part 1 of this study regarding the high cognitive salience of terms *teget* and *bordo*.

**Method**

**Participants**

28 first-year Psychology students from the University of Novi Sad participated in the experiments (23 female, 5 male, 14 per experiment). All participants were native Serbian speakers with normal or corrected-to-normal visual acuity and reported to not to have any colour vision deficiencies. Participants signed the informed consent and were given course credit for their participation.

**Apparatus**

Experiments were run on a 1.4 GHz Macmini computer. The only source of illumination in the experimental room was a computer screen (ViewSonic CRT PerfectFlatTM; resolution 1152 x 864 pixels; frequency 75 HZ) used for stimuli presentation. The chin rest was used to make sure that participants were at the distance of 55cm from the screen. Colour specifications were measured by using X-Rite i1 Pro spectrophotometer and BabelColor Software.

**Colour stimuli**

In both experiments, coloured squares of 5.19x5.19 deg visual angle (5x5cm) were presented on the computer screen. For *plavo* ‘blue’ and *teget* ‘dark blue’ stimuli, we used 11 computer-made shades ranging from dark blue (stimulus 1; CIELAB coordinates: 3.89, 14.74, -27.07) to medium blue (stimulus 11; CIELAB coordinates: 23.54, 54.03, -78.66) with Euclidean distances between colours of about 7 (between 6.32 and 7.11 see Table 1 in Appendix A for details). Color specifications for the blue stimuli as measured on the screen together with values of Euclidean distances are provided in Table A1 in Appendix A.

For *crveno* ‘red’ and *bordo* ‘dark red’, we used 11 red shades ranging from dark red (stimulus 1; CIELAB coordinates: 9.28, 19.24, 7.98) to medium red (stimulus 11; CIELAB coordinates 39.31, 60.76, 46.94) with Euclidean distances between colours of about 7 (between 5.76 and 8.01 see Table A2 in Appendix A for details). Specifications for red shades are given in Table A2 in Appendix A.

In both experiments, for both tasks, the screen background was gray (Table A1 and A2 in Appendix A).

**Procedure**

Both experiments consisted of two tasks: discrimination task and naming task. Naming tasks were performed second so participants would not be encouraged to use a naming strategy during the discrimination task. Each experiment took about 20 minutes per participant, with each of the two tasks taking about half of that time.

**Discrimination task**

Participants performed a simultaneous colour discrimination task (as in Winawer et al., 2007) with trials in both experiments made of colour square triplets (blue shades in Experiment 1 and red shades in Experiment 2, as presented in Figure 1a). Participants’ task was to decide which of the two bottom-squares (test or distractor) matched in colour the square presented above (target). When answer was the left bottom square participants were pressing C on the keyboard with their left index finger, while for the right square they were pressing N with their right index finger.
Colour pairs for the discrimination task were produced in the same manner for both experiments. It is important to emphasise that we had no previous data regarding the placement of boundaries between investigated plavo ‘blue’ – teget ‘dark blue’ and crveno ‘red’ – bordo ‘dark red’ categories or how much they would differ among participants. Consequently, we developed scales of colours that were used to cover possible variations in the placement of individual boundaries (scale and order of colours listed in Tables A1 and A2 in Appendix A; see also Figure 1b). We used colours 4 to 8 (as labelled in Table A1 and A2 in Appendix A) as targets and paired them with colours that were 1 (near pairs) and 3 steps (far pairs) apart on the scale (left and right) from the particular target square resulting in 5 (number of target colours) * 4 (near vs. far pairs left and right from the target colour on the scale) = 20 pairs per category boundary.

Each colour pair was presented 25 times during the task, which produced 25x20 = 500 trials per experiment. Test and distractors appeared equally often on the left and the right side.

Naming task

Presented in random order, each shade from the colour scale (blue shades in E1, red in E2) appeared alone in the middle of the screen. Participants performed a 2-Alternative-Forced-Choice Task (2AFC) – they had to categorise shades as plavo ‘blue’ or teget ‘dark blue’ (E1) and as crveno ‘red’ or bordo ‘dark red’ (E2). Participants answered by pressing the keyboard key representing the first letter of the colour category name (P and T in E1, C and B in E2). Naming tasks served to determine each participant’s linguistic boundaries (Winawer et al., 2007), i.e., locations on blue and red colour scales where the participants’ response changes from one to another linguistic colour category. To insure a more precise boundary location for each participant, each colour on the scale was presented eight times.
Results

Experiment 1 – the category effect in the discrimination of blue shades

Colour naming – analyses of boundaries. Figure 2 shows the data collected in the naming task – rows represent participants and columns represent 11 blue shades used in Experiment 1. The individual boundary placement represents the mode colour name of each participant and in Figure 2 is presented as a change in colour (darker colour represents the category teget ‘dark blue’). As it can be seen, participants’ plavo ‘blue’ – teget ‘dark blue’ boundaries fell between shade 5 and shade 8 (as labelled in Table A1 in Appendix A): for six participants the boundary was between shades 7 and 8, for five participants the boundary was between shades 6 and 7, and for three participants the boundary was between shades 5 and 6. Detailed results of the 2AFC task are presented in Figure B1 in Appendix B.

![Figure 2](image)

*Figure 2.* Results for colour naming task in Experiment 1. Rows represent participants, while columns represent 11 blue shades. Individual boundaries (the mode colour name of each participant) are marked as a change in colour, where darker colour represents the category teget ‘dark blue’.

Speeded discrimination – RT Analyses. Only the correct answers from the discrimination task were analyzed. To deal with outliers, for each participant, we replaced RTs above two standard deviations with the values at two standard deviations above the mean (Ratcliff, 1993).

We tested for category effect with the individual category boundaries measured in the naming task (as in Winawer et al., 2007). For each participant,
we analysed three colour pairs (as in Witzel & Gegenfurtner, 2016) around the individual colour boundary – one between-category pair (BC) and two within-category pairs (WC). Results of individual naming tasks (Figure B1, Appendix B) demonstrated that participants were fairly consistent with the *plavo* ‘blue’ – *teget* ’dark blue’ categorisation, so for the analysis, we chose colour pairs that were 1 step apart (near pairs) on the scale of shades (Table A1, Appendix A). For example, for Participant 1, BC pair consisted of shades 7 and 8, while WC pairs consisted of shades 6 and 7 and shades 8 and 9 (Figure B1, Appendix B). For each participant, RTs for chosen pairs were averaged.

To test the category effect, we averaged RTs for the two WC pairs and performed repeated-measures ANOVA with comparison type (BC/WC) as a factor. The main effect of comparison type was significant, $F(1,13) = 8.35$, $p < .05$, $MSE = .009$, $\eta_p^2 = .391$, showing that participants were faster in discriminating BC than WC colour pairs (Figure 3).

To analyse differences between single colour pairs we used the t-test for dependent samples. Average RT for BC pair (*plavo-teget*) was significantly shorter than WC pair *teget-teget*: $t(13) = 3.88$, $p < .05$ and WC pair *plavo-plavo*: $t(13) = 2.89$, $p < .05$ (Figure 4).

![Figure 3](image-url)
Figure 4. Average RTs for three colour pairs at and around individual boundaries. Stimulus pairs are: BC for *plavo-teget* pair, AB is WC pair *teget-teget* and CD is WC pair *plavo-plavo*. Actual shades differ across participants since we used individual boundaries. Error bars are SEM and * represent statistical significance on the $p$ level < .05.

In the same manner, as we analyzed RTs, we analyzed error rates for BC and WC comparisons. Repeated-measures ANOVA showed that the difference between BC and WC pairs was not statistically significant $F(1,13) = 0.22$, $p > .05$. Averaged error rates for three colour pairs at and around individual category boundaries are presented in Figure C1 in Appendix C.

**Experiment 2 – the category effect in the discrimination of red shades**

**Colour naming – analyses of boundaries.** Figure 5 shows the mode colour name of each participant (rows) for 11 red shades (columns) and the individual boundaries are marked as a change in colour. Participants’ *crveno* ‘red’ – *bordo* ‘dark red’ boundaries fell between shade 5 and shade 8 (as labelled in Table A2 in Appendix A): for three participants the boundary was between shade 7 and shade 8, for six participants the boundary was between shades 6 and 7, and for five participants the boundary was between shades 5 and 6. Detailed results of 2AFC task for each participant are presented in Figure B2 in Appendix B.
Figure 5. Results for colour naming task in Experiment 2. Rows represent participants, while columns represent 11 red shades. Individual boundaries (the mode colour name of each participant) are marked as a change in colour, where darker colour represents the category *bordo* ‘dark red’.

**Speeded discrimination – RT Analyses.** Data were prepared and analysed in the same manner as in Experiment 1. For each participant, three colour pairs (1 BC pair and 2 WC pairs) closest to the individual category boundary were analysed. Repeated-measures ANOVA showed the significant effect of comparison type (BC/WC): $F(1,13) = 22.95$, $MSE = .001$, $p < .001$; $\eta^2_p = .638$ – participants were significantly faster in the discrimination of BC pairs (Figure 6).
Figure 6. The category effect for participants’ individual crveno-bordo boundaries. WC is average RT for within-category comparisons, BC is average RT for between-category comparisons. Error bars show Standard Error of Mean (SEM).

Again, we used *t*-tests for dependent samples to analyze differences between single colour pairs. Average RT for BC pair crveno-bordo was significantly shorter than WC pair bordo-bordo: *t*(13) = 2.41, *p* < .05 and WC pair crveno-crveno: *t*(13) = 3.89, *p* < .05. The results of *t*-tests are illustrated in Figure 7.

Figure 7. Average RTs for three stimulus pairs closest to individual crveno-bordo boundaries. Stimulus pairs are: BC for crveno-bordo pair, AB is WC bordo-bordo pair and CD is WC crveno-crveno pair. Actual shades differ across participants. Error bars represent SEM and * represent statistical significance on the *p* level < .05.
The analysis of error rates showed the significant effect of comparison type—participants made more mistakes when discriminating WC pairs ($F(1,13) = 5.38$, $MSE = .001$, $p < .05$; $\eta_p^2 = .292$). T-test for dependent samples showed that only difference between BC and one WC pair came close to statistical significance ($t(13) = 1.95$, $p = .07$; Figure C2, Appendix C).

**Discussion**

The analysis of participants’ reaction time showed category effects for both category boundaries investigated in this study—participants were faster when discriminating colour pairs that belong to different linguistic categories than the pairs from the same category, even though perceptual distances between colour pairs were controlled (see Tables A1 and A2 in Appendix A). Therefore, in this study, we demonstrated category effect between two Serbian colour categories for blue shades (*plavo* ‘blue’ and *teget* ‘dark blue’) and for the first time, we demonstrated category effect on the response times in the speeded discrimination of shades within the red part of the colour space (between Serbian terms for red and dark red – *crveno* and *bordo*).

According to our results, *categorical facilitation* appears to be a mechanism related to linguistic categories rather than the perceptual sensitivity (Witzel & Gegenfurtner, 2016). The distinction between the categories *teget* ‘dark blue’ and *bordo* ‘dark red’ is not directly connected to the low-level vision mechanisms as such, but reflects the specific way of linguistic categorisation of the colour space in the Serbian language. Also, these terms, according to original Berlin and Kay’s theory (1969), do not qualify as BCTs.

Prior to this research, several studies have shown categorical effects between colour categories beyond the inventory of 11 BCTs, such as studies conducted in Russian (Winawer et al., 2007) and Greek language (Thierry et al., 2009). However, these studies have explored categories that are considered to be BCTs in investigated languages, according to the measures obtained in tasks used for the determination of basicness, such as colour-elicitation or colour naming task (Corbett & Davies, 1995). Contrary to that, in our study, we have demonstrated the category effect for a category which, according to the measures obtained in the colour-elicitation task (see Part 1 of this study) cannot be unambiguously classified as basic for Serbian language (*bordo* ‘dark red’) and a category that seems to be a non-BCT according to all collected measures (*teget* ‘dark blue’).

If we look at the results of naming tasks we can observe a fair amount of consensus and consistency in participants’ classification of shades as *teget* and *bordo*. Even though an unconstrained naming task would provide more precise data, the results of 2AFC tasks used in this study (Figure B1 and Figure B2 in Appendix B) revealed both within- and between-participants agreement about the placement of the *plavo-teget* and *crveno-bordo* boundary, which indicates that Serbian speakers have distinctive representations of these categories.
The naming task in this study was not used as a measure of basicness (as for example in Lindsey & Brown, 2014; Paggetti, Menegaz, & Paramei, 2016), still we believe that observed consistency and consensus in the naming of teget and bordo further support the conclusions made in the Part 1 of this study regarding their high cognitive saliency for Serbian speakers.

Recent colour-inventory studies have shown that the colour terminology in modern languages is constantly evolving by revealing a number of frequently and consistently used non-BCTs (see for example Kuriki et al., 2017; Lindsey & Brown, 2014; Paggetti et al., 2016). We believe that results of our study indicate that salient non-BCTs identified across languages could also be investigated in the context of categorical facilitation. Not only that an additional insight into the saliency of those categories could be provided, but also the notion regarding the language-specific category effect could be further supported.

It is interesting to add that Holmes and Regier (2017) showed category effect between categories “warm” and “cool” using visual search task, and concluded that this effect can be found beyond basic categories of a particular language. Even though our results also show this effect beyond BCTs, we would like to stress an important difference between their work and our study. Namely, they investigated categories that are “superordinate” to the basic-level categories, which are being discussed as “proto-colour categories” emerging in the earliest stage of colour lexicon (Berlin & Kay, 1969). More importantly, according to Holmes and Regier (2017), none of the participants in their study reported using labels “warm” and “cool” for presented colours, which opens the question whether it can be concluded that categorical effect demonstrated in their study is at all linked with a linguistic distinction between those categories. Contrary to that, categories investigated in our study represent a finer linguistic partition of basic-level categories and are exclusively marked with language (in this case – Serbian). In other words, categories “warm” and “cool” and teget and bordo represent non-basic categories on a completely different taxonomic level. Hence, it is questionable if those categories are represented in the same way and whether they are accessed through the same mechanisms during a discrimination/visual search task. This is particularly important for the Direct language theory (Roberson & Davidoff, 2000), which argues that colour discrimination is under an online influence of some form of linguistic representations such as a label. A number of studies confirmed this hypothesis demonstrating the importance of verbal coding for category effect (Pilling et al., 2003; Suegami & Michimata, 2010; Wigget & Davies, 2008). According to the work of Holmes and Regier (2017), categories warm and cool are probably not accessed through an online labelling, the mechanism we cannot unambiguously exclude for teget and bordo categories investigated in the present study. Given the differences in tasks and colour sampling methods in the two studies (ours and Holmes and Regier, 2017), a valid conclusion for comparison of obtained measures (such as reaction times) is difficult to reach. However, by comparing categorical effects on three different levels of organization (proto, basic and non-basic categories), future studies might be able to answer the questions regarding mechanism(s)
underlying category effects and the role of attention and (online) language in those mechanisms.

Previous studies demonstrated category effects for error rates (e.g., Özgen & Davies, 2002) and reaction time (e.g., Roberson et al., 2008). Some studies (Witzel & Gegenfurtner, 2016) analysed both error rates and RT and found category effects for both dependent variables. Primarily, we were interested in RT, but we additionally analysed error rates. Our results did not show an expected categorical pattern of error rates for the crveno ‘red’– bordo ‘dark red’ boundary, while for the plavo ‘blue’ – teget ‘dark blue’ boundary it was not found at all, which we cannot explain at this point.

Our study was the first to address the placement of plavo ‘blue’ – teget ‘dark blue’ and crveno ‘red’– bordo ‘dark red’ boundaries for Serbian speakers, so we only investigated categorical effect based on individual category boundaries of each participant. Namely, our methodology was based on Winawer and colleagues (2007), whose participants performed naming task following the discrimination task. This experimental design has several advantages. First of all, by doing the naming task second, participants were not encouraged to use naming strategy or to focus on a category boundary, which enabled us to test whether investigated categories are spontaneously accessed during a discrimination task. Secondly, by using broader scope of shades in the discrimination task and determining the category boundary afterwards, we avoided the possibility that between-category pair produce better performance because it represents a centroid of three colour pairs around the boundary, which are usually used in the similar studies (for further discussion see Witzel & Gegenfurtner, 2016). However, based on the preliminary results regarding plavo ‘blue’ – teget ‘dark blue’ and crveno ‘red’– bordo ‘dark red’ boundaries provided by this study, we propose that future studies investigate category effects between blue and red categories in Serbian language using averaged category boundaries and compare results with individual ones obtained in this study.

As in a number of previous studies (for example Özgen & Davies, 2002; Zhou et al., 2010), we used CIELAB Euclidean distances in order to measure the distances between colour shades. Our measurements (Tables A1 and A2 in Appendix A) showed that distances between colour pairs slightly deviated from ideal, probably due to both production of colours on the screen and measurement technology that was used. For example, distance between blue shades 6 and 7 (Table A1 in Appendix A) was 7.11, while the distance between blue shades 7 and 8 was 6.65. However, this biggest perceptual distance did not coincide with the category boundary for each participant, so we believe that those, relatively small and unsystematic differences did not affect the observed category effect. In fact, for some participants (e.g., participants 1 and 3 in Figure B1 in Appendix B) this biggest perceptual distance was within category.

Recently, CIELAB system has been criticized as imprecise, and it was suggested that same CIELAB distances still might lead to observing differences in colour discrimination of different parts of the colour space (Witzel & Gegenfurtner, 2016). This is particularly relevant for our results since the reds were discriminated
more than 100ms faster than the blues, even though the distances between shades were similar. Consequently, obtained category effects could be reevaluated using different measures of control such as just noticeable differences (JNDs) between colour pairs, which have shown to be a good way of controlling colour differences in this type of studies (Witzel & Gegenfurtner, 2016).

**Conclusions**

Using colour-elicitation task in the Part I of this study (Jakovljev & Zdravković, 2018), we provided preliminary data regarding BCTs in Serbian language and showed that 11 most salient Serbian colour terms are 11 BCTs proposed by Berlin and Kay (1969). According to measures collected in this task, categories *teget* ‘dark blue’ and *bordo* ‘dark red’, which were in the special focus of this study, should be classified as salient non-basic colour terms. Still, the salience of mentioned terms seemed to be more similar to the salience of some BCTs than to other non-BCTs. The Part 2 of this study further confirmed high cognitive salience of these terms showing that both *teget* and *bordo* categories are salient enough to produce category effects in speeded colour discrimination task. However, additional data (e.g., naming consistency, naming consensus and determination of focal colours in an unconstrained colour naming task) is needed in order to draw a precise boundary between BCTs and non-BCTs in the Serbian language or, at least, to provide a deeper understanding of more subtle differences between “more or less basic terms”, which are being discussed by some authors in the field (Sutrop, 2001; Uusküla, 2007).

By showing the category effect not on one, but on two boundaries beyond the original inventory of 11 BCTs (Berlin & Kay, 1969), our study further support results showing that colour categories, which are exclusively marked with language can be accessed in tasks like colour discrimination (Athanasopoulos et al., 2009, 2011; Roberson, et al., 2008; Winawer et al., 2007). Therefore, our results support the notion of *categorical facilitation* stating that category effects cannot be a pure product of perceptual processes, but might be a product of higher cognitive mechanisms such as attention (Witzel & Gegenfurtner, 2016) or online verbal coding (Roberson & Davidoff, 2000).

To conclude, our results show that colour terms, which according to their frequency and cognitive salience indexes cannot be unambiguously classified as basic, can facilitate speeded colour discrimination.

**References**

Athanasopoulos, P. (2009). Cognitive representation of colour in bilinguals: The case of Greek blues. *Bilingualism: Language and Cognition, 12*(1), 83–95.

Athanasopoulos, P., Damjanovic, L., Krajcova, A., & Sasaki, M. (2011). Representation of colour concepts in bilingual cognition: The case of Japanese blues. *Bilingualism: Language and Cognition, 14*(1), 9–17.

Berlin, B., & Kay, P. (1969). *Basic color terms: Their universality and evolution*. Berkeley and Los Angeles, CA: University of California Press.
Bornstein, M. H., & Korda, N. O. (1984). Discrimination and matching within and between hues measured by reaction times: Some implications for categorical perception and levels of information processing. *Psychological Research, 46*(3), 207–222.

Corbett, G. G., & Davies, I. R. L. (1995). Linguistic and behavioural measure for ranking basic colour terms. *Studies in Language, 19*(2), 301–357.

Davson, H. (Ed.). (1962). *The Eye: The Visual Process* (Vol. 2). New York: Academic Press.

Drizvonikou, G. V., Kay, P., Regier, T., Ivry, R. B., Gilbert, A. L., Franklin, A., & Davies, I. R. (2007). Further evidence that Whorfian effects are stronger in the right visual field than the left. *Proceedings of the National Academy of Sciences, 104*(3), 1097–1102.

Franklin, A., Clifford, A., Williamson, E., & Davies, I. (2005). Color term knowledge does not affect categorical perception of color in toddlers. *Journal of experimental child psychology, 90*(2), 114–141.

Franklin, A., Drizvonikou, G. V., Bevis, L., Davies, I. R., Kay, P., & Regier, T. (2008). Categorical perception of color is lateralized to the right hemisphere in infants, but to the left hemisphere in adults. *Proceedings of the National Academy of Sciences, 105*(9), 3221–3225.

Franklin, A., Pilling, M., & Davies, I. (2005). The nature of infant color categorization: Evidence from eye movements on a target detection task. *Journal of experimental child psychology, 91*(3), 227–248.

Fuller, S., & Carrasco, M. (2006). Exogenous attention and color perception: Performance and appearance of saturation and hue. *Vision research, 46*(23), 4032–4047.

Gilbert, A. L., Regier, T., Kay, P., & Ivry, R. B. (2006). Whorf hypothesis is supported in the right visual field but not the left. *Proceedings of the National Academy of Sciences of the United States of America, 103*(2), 489–494.

Holmes, K. J., & Regier, T. (2017). Categorical perception beyond the basic level: The case of warm and cool colors. *Cognitive science, 41*(4), 1135–1147.

Jakovljev, I., & Zdravković, S. (2018). The colour lexicon of the Serbian language – a study of dark blue and dark red colour categories Part 1: Colour-term elicitation task. *Psihologija 51*(2), 197–213. https://doi.org/10.2298/PSI160521002J

Kay, P., & Kempton, W. (1984). What is the Sapir-Whorf hypothesis? *American anthropologist, 86*(1), 65–79.

Kuriki, I., Lange, R., Muto, Y., Brown, A. M., Fukuda, K., Tokunaga, R., ... Shioiri, S. (2017). The modern Japanese color lexicon. *Journal of Vision, 17*(3), 1–1.

Lindsey, D. T., & Brown, A. M. (2014). The color lexicon of American English. *Journal of vision, 14*(2), 17–17.

Mo, L., Xu, G., Kay, P., & Tan, L. H. (2011). Electrophysiological evidence for the left-lateralized effect of language on preattentive categorical perception of color. *Proceedings of the National Academy of Sciences, 108*(34), 14026–14030.

Özgen, E., & Davies, I. R. L. (1998). Turkish color terms: Tests of Berlin and Kay’s theory of color universals and linguistic relativity. *Linguistics, 36*(5), 919–956.

Özgen, E., & Davies, I. R. (2002). Acquisition of categorical color perception: a perceptual learning approach to the linguistic relativity hypothesis. *Journal of Experimental Psychology: General, 131*(4), 477.

Paggetti, G., Menegaz, G., & Paramei, G. V. (2016). Color naming in Italian language. *Color Research & Application, 41*(4), 402–415.

Pilling, M., Wiggett, A., Özgen, E., & Davies, I. R. (2003). Is color “categorical perception” really perceptual? *Memory & Cognition, 31*(4), 538–551.

Ratcliff, R. (1993). Methods for dealing with reaction time outliers. *Psychological bulletin, 114*(3), 510.

Regier, T., Kemp, C., & Kay, P. (2015). Word meanings across languages support efficient communication. In B. MacWhinney, & W. O. Grady (Eds.), *The handbook of language emergence* (Vol.87, pp. 237–264). West Sussex, United Kingdom: Wiley.
Roberson, D., & Davidoff, J. (2000). The categorical perception of colors and facial expressions: The effect of verbal interference. *Memory & Cognition, 28*(6), 977–986.

Roberson, D., Davies, I., & Davidoff, J. (2000). Color categories are not universal: replications and new evidence from a stone-age culture. *Journal of Experimental Psychology: General, 129*(3), 369.

Roberson, D., Pak, H., & Hanley, J. R. (2008). Categorical perception of colour in the left and right visual field is verbally mediated: Evidence from Korean. *Cognition, 107*(2), 752–762.

Roberson, D., Hanley, J. R., & Pak, H. (2009). Thresholds for color discrimination in English and Korean speakers. *Cognition, 112*(3), 482–487.

Rosch, E. (1999). Principles of categorization. *Concepts: core readings*, 189.

Suegami, T., & Michimata, C. (2010). Effects of Stroop interference on categorical perception in simultaneous color discrimination. *Perceptual and motor skills, 110*(3), 857–878.

Sutrop, U. (2001). The List task and a Cognitive Salience Index. *Field Methods, 13*(3), 263–276.

Thierry, G., Athanasopoulos, P., Wiggett, A., Dering, B., & Kuipers, J. R. (2009). Unconscious effects of language-specific terminology on preattentive color perception. *Proceedings of the National Academy of Sciences, 106*(11), 4567–4570.

Uusküla, M. (2007). The basic colour terms of Finnish. *SKY Journal of linguistics, 20*, 367–397.

Wiggett, A. J., & Davies, I. R. (2008). The effect of Stroop interference on the categorical perception of color. *Memory & cognition, 36*(2), 231–239.

Winawer, J., Withthoft, N., Frank, M. C., Wu, L., Wade, A. R., & Boroditsky, L. (2007). Russian blues reveal effects of language on color discrimination. *Proceedings of the National Academy of Sciences, 104*(19), 7780–7785.

Witzel, C., & Gegenfurtner, K. R. (2015). Categorical facilitation with equally discriminable colors. *Journal of vision, 15*(8), 22–22.

Witzel, C., & Gegenfurtner, K. R. (2016). Categorical perception for red and brown. *Journal of Experimental Psychology: Human Perception and Performance, 42*(4), 540.

Zhou, K., Mo, L., Kay, P., Kwok, V. P., Ip, T. N., & Tan, L. H. (2010). Newly trained lexical categories produce lateralized categorical perception of color. *Proceedings of the National Academy of Sciences, 107*(22), 9974–9978.
Leksikon boja u srpskom jeziku – studija kategorija tamno plave i tamno crvene boje.
Deo 2: Kategorička facilitacija sa nazivima za boje u srpskom jeziku

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U Delu 1 ovog istraživanja (Jakovljev & Zdravković, 2018), izolovana su dva frekventna i kognitivno zasićena ne-osnovna naziva za boje u srpskom jeziku: teget (tamno plavo) i bordo (tamno crveno), koji dele plavi, odnosno, crveni deo prostora boja. U ovoj studiji smo sproveli dva eksperimenta kako bismo dodatno testirali kognitivnu zasičenost ovih naziva ispitujući da li oni mogu da proizvedu efekte kategorija u zadatku diskriminacije boja. Dobijeni rezultati su pokazali konzistentnost i konsenzus ispitanika u vezi sa pozicijom granica između kategorija u plavom i u crvenom delu prostora boja, što dodatno pokazuje da govornici srpskog jezika imaju distinktivne reprezentacije ovih kategorija. Analiza vremena reakcije u zadatku diskriminacije pokazala je efekte kategorija – ispitanici su bili brži u razlikovanju parova boja koje pripadaju različitim lingvističkim kategorijama od onih koji pripadaju istoj kategoriji. Ovi rezultati po prvi put pokazuju efekat kategorija boja u srpskom jeziku kao i efekat kategorije na brzinu diskriminacije nijansi u crvenom delu prostora boja u bilo kom jeziku. Dobijeni rezultati govore u prilog stanovištu po kom je efekat kategorije povezan sa višim kognitivnim procesima, te može biti specifičan za jezik.

Ključne reči: kategorička percepcija boja, kategorička facilitacija, nazivi za boje u srpskom jeziku

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Appendix A

Scales of shades that were used to cover possible variations in the placement of individual boundaries: Tables A1 and A2

Table A1

| Colour | L    | A    | B    | ΔE  | x    | y    | Y    |
|--------|------|------|------|-----|------|------|------|
| 1      | 3.89 | 14.74| -27.07| .18 | .09  | 0.43 |
| 2      | 5.12 | 18.77| -31.78| 6.32| .17  | .09  | 0.57 |
| 3      | 6.68 | 23.23| -36.78| 6.87| .18  | .09  | 0.74 |
| 4      | 8.92 | 27.09| -41.82| 6.75| .17  | .09  | 0.99 |
| 5      | 10.92| 30.73| -46.85| 6.53| .16  | .08  | 1.25 |
| 6      | 13.24| 34.7 | -52.21| 7.06| .16  | .08  | 1.6  |
| 7      | 15.16| 38.84| -57.66| 7.11| .16  | .08  | 1.94 |
| 8      | 17.63| 42.23| -62.82| 6.65| .16  | .08  | 2.44 |
| 9      | 19.51| 46.33| -68.29| 7.08| .16  | .07  | 2.87 |
| 10     | 21.27| 50.59| -73.55| 6.99| .16  | .07  | 3.32 |
| 11     | 23.54| 54.03| -78.66| 6.57| .16  | .07  | 3.96 |
| W      | 100  | -2.56| -2.98| .31 | .32  | 100  |
| BG     | 39.6 | -0.26| -2.98| .30 | .32  | 11.01|

Note. W – white, BG – background; values are presented as measured on the screen by using X-Rite i1 Pro spectrophotometer and BabelColor Software. ΔE refers to the distance between colour and the preceding colour. The white-point (W) deviates from the nominal W (100 0 0) due to a small measurement noise, which can also explain different chromaticity observed in W and BG.

Table A2

| Colour | L    | A    | B    | ΔE  | x    | y    | Y    |
|--------|------|------|------|-----|------|------|------|
| 1      | 9.28 | 19.24| 7.98 | .50 | .32  | 1.04 |
| 2      | 11.66| 23.49| 11.28| 5.89| .53  | .32  | 1.36 |
| 3      | 13.99| 27.6 | 14.36| 6.11| .55  | .32  | 1.73 |
| 4      | 16.97| 31.68| 18.6 | 6.59| .57  | .33  | 2.3  |
| 5      | 19.89| 35.55| 22.29| 6.09| .58  | .33  | 2.96 |
| 6      | 22.58| 39.32| 25.7 | 5.76| .59  | .33  | 3.68 |
| 7      | 26.44| 44.57| 30.35| 8.01| .6   | .33  | 4.9  |
| 8      | 29.88| 48.7 | 34.26| 6.65| .60  | .33  | 6.19 |
| 9      | 32.98| 52.56| 38.22| 6.34| .61  | .33  | 7.53 |
| 10     | 36.07| 56.85| 42.82| 7.01| .62  | .33  | 9.05 |
| 11     | 39.31| 60.76| 46.94| 6.54| .62  | .33  | 10.84|
| W      | 100  | 2.28 | -2.56| .31 | .33  | 100  |
| BG     | 39.6 | -0.26| -2.98| .30 | .32  | 11.01|

Note. W – white, BG – background; values are presented as measured on the screen by using X-Rite i1 Pro spectrophotometer and BabelColor Software. ΔE refers to the distance between colour and the preceding colour. The white-point (W) deviates from the nominal W (100 0 0) due to a small measurement noise, which can also explain different chromaticity observed in W and BG.
Appendix B
Results of naming task for each participant: Figures B1 and B2

Figure B1. Results of 2AFC task for each participant in Experiment 1. Columns represent 11 blue shades, while rows represent participants’ answers to eight presentations of each shade. Boxes are coloured in darker shade if participants categorised the shade as teget ‘dark blue’.

Figure B2. Results of 2AFC task for each participant in Experiment 2. Columns represent 11 red shades, while rows represent participants’ answers to eight presentations of each shade. Boxes are coloured with darker shade if participants categorised the shade as bordo ‘dark red’.
Appendix C

Average error rates in Experiment 1 and 2: Figure C1 and C2

Figure C1. Average error rates for three stimulus pairs closest to individual plavo-teget boundaries. BC pair represents between-category plavo-teget pair, AB represents within-category teget-teget pair and CD represents within-category plavo-plavo pair.

Figure C2. Average error rates for three stimulus pairs closest to individual boundaries. BC pair represents between-category crveno-bordo pair, AB represents within-category bordo-bordo pair and CD represents within-category crveno-crveno pair. Difference between BC and AB pairs was not statistically significant ($t(13) = 0.73, p > .05$), while the difference between BC and CD pair came close to statistical significance ($t(13) = 1.95, p = .07$). Difference between two WC pairs was significant $t(13) = 2.32, p < .05$.