Russian *blues*: linguistic recognition of colors in bilingualism

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Language plays an important role in all facets of our lives, shaping our thoughts, thinking, and reasoning. The linguistic relativity hypothesis suggests that the specific structure and features of a language shape speakers' worldviews and cognition (Werner, 1994). For example, extensive variation in color naming and color terminologies across languages is one of these features that can shape color perception (Cook et al., 2005). Questions that have shaped the literature in this field ask for example how color is categorized across languages, or if there are any cross-linguistic differences in speakers' perception of a certain hue. To understand the variation of color terminology across languages, Berlin and Kay (Berlin & Kay, 1991) conducted a series of studies that surveyed the color vocabulary of 130 linguistic communities using color perception stimuli. The results showed how people report color in their languages, and demonstrated that if colors A and B exist, then color C (a combination of A and B) might be part of these speakers' linguistic repertoire. Even though Berlin and Kay received criticism for their experimental methodologies and data collection, their data revealed that color perception and categorization is based on linguistic features.

One key example of how languages differ in labelling colors comes from comparing Russian and English. Russian, unlike English, makes a lexical distinction between light-blue (“goluboi”) and dark-blue (“sinii”) indicating a difference in color recognition by native speakers of Russian (native language = L1). English instead refers to the different shades of blue with compound words consisting of an adjective and a noun as in light-blue or dark-blue. Therefore, while the boundaries for the Russian *blues* are lexically distinguishable and clear-cut, this is not the case for English. Recent research has evidenced the differences in color perception and color recognition in speakers of certain languages (e.g., Russian and

English). For example, Russian children learn the basic color words early in life, such as "goluboi" and "sinii", but they experience additional structural and functional brain changes with increased exposure to a second language (e.g., Paramei, 2005; Deluca et al., 2019).

The use of the different Russian *blues* in different contexts indicates a high level of language use and the mental representation of both hues. Winawer et al., 2008 worked on how the use of Russian *blues* reveals the effects of linguistic color discrimination and how color is perceived by a specific population of speakers. In Winawer et al., 2008, they administered a color classification task with twenty blue colors with the goal of determining each participant's linguistic color boundary within a range of blue colors. Critically, the results showed that Russian speakers were faster to discriminate between two colors that were not in the same color category (i.e., Russian) than if the two hues were in the same hue category (i.e., goluboi, sinii) showing the complexity of color categorization.

In sum, the current literature shows the differences in color cross-linguistically, but it does not provide an answer to how bilingual populations coexist with two or more languages with different color terminologies. To understand the relationship between how color categorization applies in bilingual contexts and how being immersed in a second-language (L2) environment modulates speakers' color perception, we designed a behavioral study that takes a new approach to linguistic recognition of color induced by bilingualism.

Rationale and aims

Language development and use are embedded in social interactions throughout life. In other words, language is not developed in a vacuum, but in a social context. Learning and speaking two languages is a known example of continuous life experience that induces neuroplasticity. Neuroplasticity refers to the brain's unique ability to change its structure to adapt to its environment through repetitive actions, and these neural changes have recently been elucidated with advanced technology, such as Magnetic Resonance Imaging (MRI)

(Keller & Just, 2016). For example, bilinguals' brains continuously experience structural and functional changes with increased exposure to a second language throughout their lifetime (Deluca et al., 2019). Being surrounded by a second language causes the cerebellum to become more responsive to experience-based restructuring, which is tied to the amount of exposure to the new language (Pliatsikas, 2020). Previous research also shows that this cognitive and neural flexibility is modulated by the level of exposure to a second language (Athanasopoulos et al., 2011). Even studying vocabulary words in a new language for twenty days can induce a measurable increase in gray matter volume and cause neuroanatomical changes in regions of the brain that make up the language control network (Legault et al., 2019).

It has been shown that individuals who move to a country with a language that uses different basic color terms than their native language are affected in the way they perceive colors based on the length of time in the new country, something which presents evidence for neuroplasticity in terms of perception (Athanasopoulos et al., 2010). Similarly, individuals whose first language is English and who learn Russian as a second language may experience neural restructuring that affects the way they perceive colors (Jie et al., 2018; Thierry et al., 2009).

In terms of color recognition and perception, past studies have investigated the following: how attention to color induces surround suppression of category boundaries (e.g., Fang et al., 2019; Liu & Carrasco, 2007); the color lexicon of various languages (e.g., Lindsay & Brown, 2014; Paramei, 2005; Paramei et al., 2014; Frumkina, 1984), label-feedback hypothesis[1] (Lypyan, 2012); cross-linguistic similarities in L2 cognate representation (e.g.,Paramei et al., 2016); how regions of the brain process color perception

[1] "The *label-feedback hypothesis* proposes that language produces *transient* modulation of ongoing perceptual (and higher-level) processing. In the case of color, this means that after learning that certain colors are called "green," the perceptual representations activated by a green-colored object become warped by top-down feedback as the verbal label "green" is co-activated" (Lupyan, 2012: 4).

(e.g., Siok et al., 2009); language-specific needs to communicate about different colors (e.g., Twomey et al., 2021); effects on language color discrimination (e.g., Winawer et al., 2006). While there is extensive research on neuroplasticity in the brain of bilinguals, there is a missing component in the literature in terms of how these changes can affect perception in the everyday life of bilinguals, such as in a color perception task.

Current Study

The goal of this behavioral study is to understand the degree to which knowledge of Russian coupled with English causes a change in color perception and a "temporary" conflict between the two languages. Specifically, the study aims to investigate 1) how being immersed in a dominant L2 environment affects color perception of bilingual speakers (i.e., Russian-English), and 2) to what degree speakers will be more linguistically dominant in one language and not the other while performing the cognitive control task (i.e., Stroop). In addition, the design of this study enables us to understand the influence of a dominant language on speakers' L1 or L2 outcomes in terms of color naming. The level of exposure to an L2 can dictate to an extent their performance on certain cognitive tasks, such as a color selection one.

Methods and Materials

Participants and Design

The study aims to recruit a total of 75 participants in the United States in various community detection areas where there is a high population of Russian-English bilinguals[2]. Specifically, 1.) participants must be native or heritage bilinguals (i.e., Russian, English) who acquired both languages before the age of six, and 2.) competent bilinguals (i.e., L1 English and L2 Russian) that learn Russian as a second language through instruction or exposure.

[2] Cities and states with a high population of Russians/Russian-Americans are Alaska, New York City, New England, Pennsylvania, Chicago, California, Florida, etc.

Additionally, the pool of participants must meet certain criteria to be eligible to participate. They must be between the ages of 18-35[3], and they must reside in the United States. Participants cannot have any prior knowledge of other languages, and they must not suffer color vision impairment since it affects the data results. Therefore, participants that speak other languages in addition to Russian and English are excluded from the study. To have a diverse sample, a list of participants was compiled from the summer 2022 Russian intensive program at *Hamilton Lugar School of Global and International Studies* in Bloomington, Indiana. Participants' demographics vary based on geographical location (e.g., home institution). The study is completely voluntary, but participants are offered course credit in exchange for their participation.

Measures

Color selection task

A color selection task is a method of data visualization used to collect certain types of information, such as patterns, metric values, emphasis, extrema, etc. For more information on a tasked-based color scale design, see Rheingans, 2000. The proposed study uses a sequence of various colors to determine, to an extent, what is the truest color of a specific hue to the participant. Each trial consists of a scale of seven blocks of color ranging from light to dark (e.g., dark green, red). The task is designed in FindingFive, a one-stop online platform that allows researchers to launch behavioral studies. A sequence of various colors was used to have a representative sample of the colors tested (i.e., target and non-target) varying in shades. Therefore, a total of six gradient colors were created from scratch on FindingFive (see figure 1 and figure 2 for task visualization and Appendix I for a full list).

[3] According to the 2021 U.S. Census, there are 886,038/2,407,434 Russians/Russian-Americans between the ages of 18 to 35 residing in the United States.

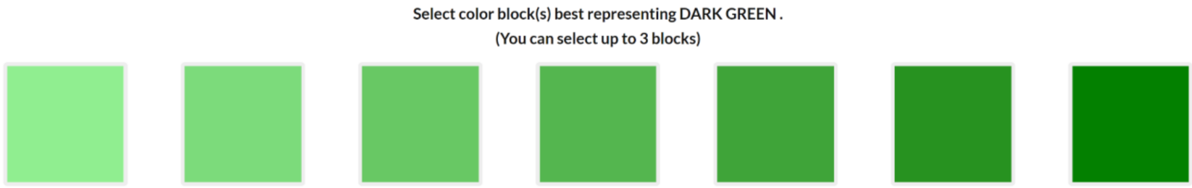

Figure 1

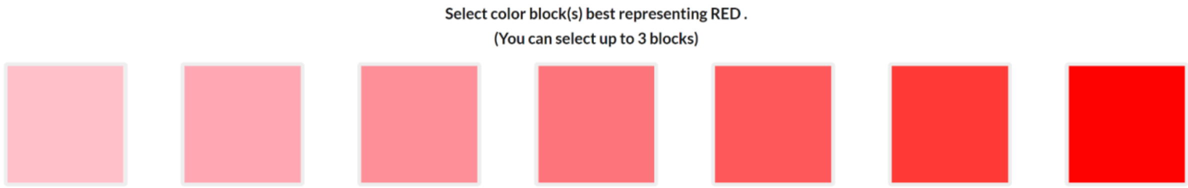

Figure 2

Stroop color task

The Stroop Color and Word Test was developed by John Ridley Stroop and published in 1935. Stroop's work revealed the presence of interference in participants when presented with a color word printed in an ink color that did not match the word. This caused participants to take more time to read those stimuli than the same color words printed in black ink (Stroop, 1935). The test involves one section where participants read color words that are printed in black ink, another section where participants name squares of certain colors, and an incongruent section where color words are printed in conflicting ink colors that do not match the word. Then, the participant must name the color of the ink (Scarpina & Tagini, 2017). In Dr. Stroop's original study, he used 5 different colors and 100 stimuli on each card, and he compared the time it took in seconds to read the stimuli from each card (Jensen, 1965). In the incongruent section, participants must suppress the more automatic task of reading the word to perform the less automatic task of naming the ink color, which creates cognitive interference and explains why the participants take longer to complete the incongruent section than the congruent sections (Scarpina & Tagini, 2017). This phenomenon is now known as the Stroop Effect and has been demonstrated many times in the literature (e.g., MacLeod, 1991; Scarpina & Tagini, 2017).

We use this test to assess the ability to inhibit cognitive interference that occurs when the processing of a specific stimulus feature (e.g., the color filling of a printed color word) impedes the simultaneous processing of a second stimulus attribute (e.g., the script of a printed word). The example below can help visualize how this task is shown. The Stroop effect is a delay in the reaction time between congruent and incongruent stimuli. In other words, the mismatch between the name of a color word (i.e., the filling of the word matches the printed color) and the printed one (i.e., the filling of a word does not match the printed color). An example would be the word green printed in red ink and not in green ink (see *figure 3 and figure 4* for a visual representation). In this study, we created a modified version of the Stroop test where the color word is presented to the participant in either a congruent or incongruent color.

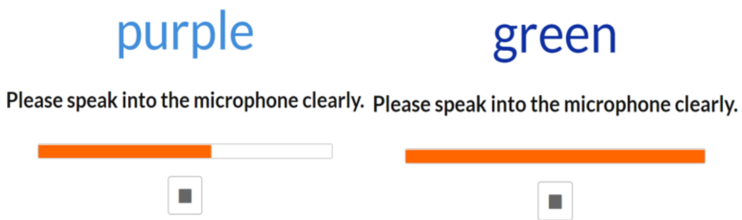

Figure 3

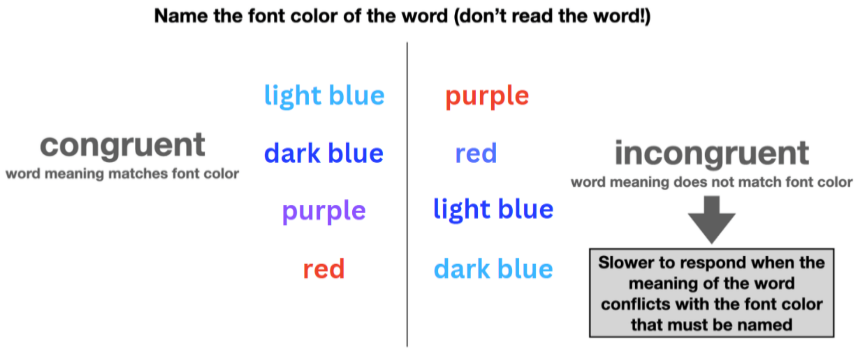

Figure 4

The study has two versions of the Stroop task (one in English and one in Russian). The difference between the two versions is the clear distinction in the blue colors and alphabets (i.e., from Roman script to Cyrillic script). See the example in *figure 5* of how both tasks are shown in FindingFive. Both versions are going to be counterbalanced in the sense that one participant will start with the Russian Stroop then English Stroop, and another participant will do the opposite. Additionally, the list of colors in both versions will be fully randomized.

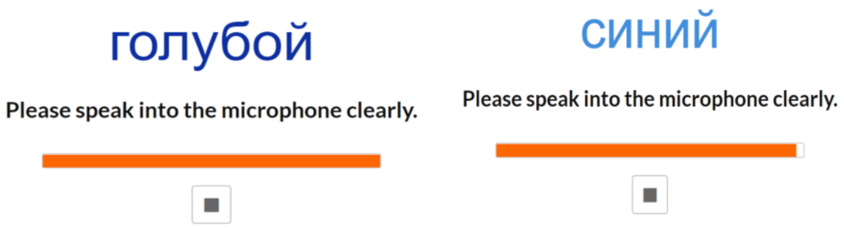

Figure 5

The Stroop task has a total of 120 trials subdivided into three different categories which are: 1) congruent, 2) incongruent non-language dependent, and 3) incongruent language dependent. The following table (figure 6) represents the total number of trials based on the categories and colors selected for the study.

FF Stroop Task

Task	PURPLE (P)	RED (R)	GREEN (G)	LIGHT BLUE (LB)	DARK BLUE (DB)
Congruent (N≈ 60)	12 P in P	12 R and R	12 G in G	12 LB in LB	12 DB in DB
Incongruent non-language dependent (N ≈36)	4 P in G 4 P in LB 4 P in DB	4 R in G 4 R in LB 4 R in DB	4 G in R 4 G in LB 4 G in DB	- - -	- - -
Incongruent language dependent (N≈24)	- - -	- - -	- - -	12 LB in DB	12 DB in LB

Figure 6

Language History Questionnaire (LHQ)

For this study, a short language history questionnaire was constructed based on current history questionnaires available in the literature (e.g., LHQ3, LEAP-Q). However, this study uses a set of questions that capture aspects of bilingual's demographic and languages (i.e., English, Russian), as well as whether participants considered English or Russian their native or foreign language(s). Demographic questions are open-ended that allow for multiple answers and the questionnaire will also ask participants to rate their proficiency level and describe their use of both languages. In addition to the basic demographic questions, participant will have to complete self-rating language proficiency level and use questions about their languages. These questions use a horizontal sliding scale where participants can select from one to ten to direct how confident they are in their responses. Appendix II provides all the questions from the LHQ and how they are displayed on FindingFive.

Procedure

The color perception study will be conducted fully online and asynchronously as it will be shared with multiple people across the United States to obtain a diverse sample in the responses and exposure to various Russian populations. The study takes 25 to 30 minutes to complete. Participants receive a link for one of the two versions of the study (i.e., Russian-English or English-Russian) via FindingFive to complete on a laptop or desktop since it records reaction time. Additionally, participants must give access to FindingFive to use their microphones. On the site, they will be prompted to read about the purpose of the study and general instructions. Next, they will be asked to complete an online consent form. Participants must select the “I agree to the above terms, and I give my consent” option. Once this is completed, they will be able to begin the study. The participants then proceed to complete the first task (i.e., color selection). In this task, they must select each box that they think corresponds to the color (in print) shown above. (See Appendix I for further clarification). After selecting one to three blocks, they must press confirm and the task will move to a new item.

Once the color selection task is completed, they proceed to complete the Stroop task. The instructions are presented on how the task works with an example. Participants received a trial practice of six words to familiarize themselves with the Stroop. The Stroop stimuli appear on the screen and participants must speak into the microphone clearly and the system will record their answer. A horizontal orange bar is shown in each trial that moves once there is a sound present. This ensures researchers that the software works properly. Once participants say their answer aloud, they must press the space bar. In the middle of the screen, they can see a message saying, “response received” and FindingFive will take three seconds to move to the next item. After completing the 120 trials in Russian or English, they will continue to perform the same task in the opposite language. After completing the Stroop task, participants will be prompted to the language history questionnaire where they will answer some questions about their demographics and linguistic background.

Discussion and Expected Results

The goal of this study is to examine whether differences in language, in this case, Russian and English, predict how bilinguals recognize color. Bilinguals' language use and exposure to an L2 can demonstrate how learning and being immersed in a second language environment with different basic color terms influence the way people process colors in their native language and affects performance on the Stroop test. Evidence of these changes would provide evidence that color recognition varies cross-linguistically.

As shown in previous literature, the Stroop effect involves the activation of the areas of the brain involved in color in color perception (i.e., the posterior dorsolateral prefrontal cortex), but not the ones involving word encoding. Specifically, the posterior dorsal anterior cingulate cortex is in control of the decision made (i.e., whether the participant says the incorrect answer [written word] or the correct answer [ink color]). As a result, the anterior dorsal cingulate cortex is in charge of evaluating whether the answer provided is correct or incorrect. Activity in this region of the brain increases when the probability of error is higher. For the present study, I hypothesize that those who have increased exposure to Russian will experience difficulties in their performance on the Russian Stroop test that involves the purposeful pronunciation of light and dark *blues*. Therefore, I expect to see a higher Stroop effect since FindingFive measures participants’ reaction time[4] during the task.

[4] Reaction time is the quickness with which a person responds to a form of stimulus. According to the Reaction Time Test, the average (median) reaction time is 273 milliseconds.

The color selection task can help have a better understanding to what marks the boundary between the hues of "goluboi" and "sinii" for Russian speakers and whether there is a "medium" blue color. The linguistic dominance of the two-participant population might show different results of the Stroop task. The following questions could be raised: 1) does learning English "weaken" Russians' (L1) perception of blue?, and 2) does learning Russian "strengthen" English-speakers' ability to determine color gradation. Data analysis will corroborate if there is a linguistic (dis)advantage of knowing and speaker Russian and English.

Conclusions and Future Directions

Color perception is a fascinating topic since the findings can show new layers of how people perceive color. The applications of color perception can be traced to other fields of research, such as neurobiology, philosophy, and psycholinguistics. Guy Deutscher in his 2010 book *Through the Language Glass*, demonstrates the complexity of color and how it varies from culture to culture and language to language. The present study aims to shed some light on the nuanced relationship between Russian *blues* and how the environment (i.e., the English language) interferences with participants' color perception. Originally, this study aimed to test an additional population of monolinguals residing in Russia, but the 2022 Russo-Ukrainian war hinders our ability to establish a participant pool in Russia. Testing this specific population would be a future direction for the study. Another future goal is to replicate this study in other languages and populations, such as Italian (*blu* and *azzurro*) and Spanish (*celeste* and *añil*). Additionally, depending on the results of the behavioral study, participants could be capped using non-invasive electroencephalography technology (EEG) to capture their brain activity while performing the various tasks presented.

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Appendix I

Select color block(s) best representing DARK BLUE .
(You can select up to 3 blocks)

Select color block(s) best representing PINK .
(You can select up to 3 blocks)

Select color block(s) best representing DARK GREEN .
(You can select up to 3 blocks)

Select color block(s) best representing LIGHT GREEN .
(You can select up to 3 blocks)

Select color block(s) best representing LIGHT BLUE .
(You can select up to 3 blocks)

Select color block(s) best representing RED .
(You can select up to 3 blocks)

Appendix II

Questions are displayed in the order participants see them.

Please type your age, in numbers, in the box.

Type your answer here:

Where is your country of origin?

Type your answer here:

Please type your gender in the box. (You may choose not to answer)

Type your answer here:

Where is your current country of permanent residence?

Type your answer here:

What is your highest level of education?

High School | Some College | Associate's Degree | Bachelor's Degree | Master's Degree | Doctoral Degree

Do you consider English your native language? This means the language you learned at birth or before the age of three.

yes no

Use the scale to describe how proficient you are i.e. how well you read in English. 1 being not proficient at all and 10 being highly proficient.

How confident are you in your response?

1 2 3 4 5 6 7 8 9 10

Use the scale to describe how proficient you are i.e. how well you speak in English. 1 being not proficient at all and 10 being highly proficient

How confident are you in your response?

1 2 3 4 5 6 7 8 9 10

Use the scale to describe how well you understand English when spoken. 1 not well and 10 being very well.

How confident are you in your response?

1 2 3 4 5 6 7 8 9 10

Use the scale to describe how much you use English in the context of Leisure and Entertainment, for example watching movies and tv shows, listening to music, etc. 1 being never and 10 always.

How confident are you in your response?

1 2 3 4 5 6 7 8 9 10

Use the scale to describe how much you use English in the context of academic settings, for example reading and writing in school. 1 being never and 10 always.

How confident are you in your response?

1 2 3 4 5 6 7 8 9 10

Use the scale to describe how much you use English specifically for reading. 1 being never and 10 always.

How confident are you in your response?

1 2 3 4 5 6 7 8 9 10

Now think about Russian. Do you consider Russian your native language? This means the language you learned at birth or before the age of three.

yes no

Use the scale to describe how proficient you are i.e. how well you speak in Russian. 1 being not proficient at all and 10 being highly proficient

How confident are you in your response?

1 2 3 4 5 6 7 8 9 10

Do you consider English your foreign language? That means the language you have learned/started learning/been exposed to after the age of 6?

yes no

Do you consider Russian your foreign language? That means the language you have learned/started learning/been exposed to after the age of 6?

yes no

Have you recently completed a placement test in Russian? If so, what was your level?

Type your answer here:

Are you currently enrolled in any Russian language courses? Or what was the last Russian course you completed? (Please list the course title/name)

Type your answer here: