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The Case of Lithuanians in Norway

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Master's Thesis in English Linguistics and Language Acquisition
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Abstract

Previous research has shown that having a different number of basic color terms across languages modulates speakers' color perception. Speakers of languages that have two labels for two color tones (e.g., *sinyj* and *goluboj* for dark and light blue in Russian) reveal a color category effect: they discriminate between these tones faster when they fall into two categories (one light blue and one dark blue) as compared to when they are from the same category (i.e., both dark blue). On the contrary, speakers of a language that has one basic color term for both of the tones (e.g., blue in English) discriminate the same part of the blue color continuum at the same speed. Basic color terms in Lithuanian and Norwegian divide the blue color spectrum differently. Norwegian, similarly to English, only has one basic color term for blue – *blå*, while Lithuanian, similar to Russian, has two basic color terms: *žydra* "light blue" and *mėlyna* "dark blue". The first aim of the current study was to examine whether experience with Norwegian can modify the color category effect in Lithuanian speakers of Norwegian (LN). Additionally, the previously reported color category effect in Russian speakers (Winawer et al., 2007) was expected in Lithuanians who live in Lithuania (LL), while Native Norwegians (NN) acted as a control group. LN participants self-reported being proficient in and exposed to their second language, Norwegian, in a variety of daily situations. A speeded color-matching task of blue stimuli that spanned the *žydra/mėlyna* boundary was employed to investigate color perception' differences between the three groups. In addition, one more color matching task was performed with verbal interference in Lithuanian for LL, in Norwegian for NN, and in both languages for LN to assess the role of the activated language in color perception. In line with previous research in Russian speakers (Winawer et al., 2007), we found that LL displayed a color category effect, while NN speakers tested on the identical stimuli did not show the same effect. Moreover, our results revealed that language in which the verbal interference task was performed affected color matching for LN. When the dual task was in Lithuanian, they showed the category effect like LL. However, when the same task was performed in Norwegian, LN did not show any categorical effect. These results demonstrate that (i) color categories in native language affect performance in a color matching task and that (ii) color matching is affected by bilinguals' activated language, with the color category effect being attenuated when second language is activated.

Keywords: Lithuanian, Norwegian, Linguistic relativism, color perception, categorization, verbal interference, bilingualism, discrimination, reaction time (RT), color category effect (CCE)

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Blue are the people here
That walk around
Blue like my corvette its in and outside
Blue are the words I say
And what I think
Blue are the feelings
That live inside me
(Jey, Ponte & Lobina, 1999)

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Above all, this thesis would not be possible without my wonderful participants in Norway and Lithuania. Ačiū/Tusen takk, I hope you had fun with my experiment and please continue contributing to science!

[1] Therefore, I use the pronoun "we" thoughout the thesis.

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List of Abbreviations

AoA	Age of Acquisition
BCT	Basic Color Term
CCE	Color Category Effect
L1	First Language
L2	Second Language
LL	Lithuanians in Lithuania
LME	Linear Mixed Effects
LN	Lithuanians in Norway
NN	Native Norwegians
SLA	Second Language Acquisition

1 Introduction

The way humans see colors is dependent on how an object absorbs and reflects wavelengths. Only a small electromagnetic field[2] can be perceived by the human eye, but it is enough to see millions of colors (The Science of How We See Color—And Why We Need Spectrophotometers, 2021). Yet, when we speak, write, and think, we categorize colors based on language-specific labels. Can differences of linguistic color categories' terminology across languages influence the way we perceive colors? The answer differs between two competing theories in language and color perception research, namely linguistic Relativism and Universalism. Linguistic relativism stems from the classic Whorfian hypothesis that argues that language shapes thought. In contrast, Universalism, based on the research of Berlin & Kay (1969), argues that color perception is universal and is not influenced by the languages we speak. The current work examined languages that differ in their linguistic color categorization: Lithuanian and Norwegian to address whether color perception of Lithuanian-Norwegian bilinguals will be universal despite that their first language (L1) and second language (L2) categorize color differently or will they perceive colors based on the "activated" language. Lithuanian has two basic color terms (BCTs) for blue: *žydra* "light blue" and *mėlyna* "dark blue" (Bimler & Uuskula, 2017), while Norwegian has only one - *blå* "blue"*.* Essentially, if languages with different linguistic categories affect color perception in monolinguals, then, what impact do languages have in bilinguals' color perception? We aimed to investigate whether language activation mode in bilinguals can momentarily alter the perception of blue colors towards the monolingual norms of that language. Particularly, we asked whether Lithuanian-Norwegian bilinguals induced into a monolingual Norwegian language activation mode will perceive blue colors like Norwegians or still like Lithuanians?

Many studies that have tested the classic Whorfian hypothesis were conducted on Indo-European languages such as English, Russian, Italian, Spanish, and Greek (Roberson et al., 2005; Gilbert et al., 2006; Winawer et al., 2007; Athanasopoulos et al., 2010; Bimler & Uuskula, 2014; González-Perilli et al., 2017). The present thesis involved Indo-European languages that, to our knowledge, were not previously researched on color category effects (CCEs): Lithuanian and Norwegian. Lithuanian is one of the two Baltic languages, the other being the neighboring language Latvian. Geographically, Lithuanian is also close to Slavic languages: Russian, Polish, and Belarussian. There are 3.1 million native Lithuanian speakers, most living in the Republic of Lithuania and about 200.000 speakers in other countries (Bilmer & Uuskula, 2017). In 2021, *Statistics in Norway* reported that there is a total of 40 632 Lithuanians residing in Norway.

Previous research (Winawer et al., 2007) has reported color categorization differences between Russian and English speakers within the blue color continuum. Since Lithuanian is historically, geographically, and linguistically close to Russian, we aim to conceptually replicate Winawer et al. study. Accordingly, the current MPhil thesis concentrates on blue color discrimination differences between Lithuanian and Norwegian languages and seeks to find out whether color labeling/categories differences result in perceiving colors distinctively. Moreover, our design will not only include speakers that have different

[2] from about 400 nm to 700 nm ("The Science of How We See Color—And Why We Need Spectrophotometers", 2021)

linguistic categories for blue color, but also active bilinguals whose two main languages categorize colors differently. We aim to contribute to the debate of whether and to what extent native and non-native languages affect the perception of color categories within the blue color continuum. The CCEs were investigated through behavioral tasks of color matching with and without verbal interference in Norwegian or Lithuanian.

In what follows, the thesis will, first, present the theoretical background on color categorization and perception, cross-linguistic variation, bi/multilingualism, and second language acquisition, then, we will explain the experimental design of the current study and will finalize with an analysis of the study's experimental data. An experiment was conducted involving three groups of participants: (1) Native Norwegians (NN), (2) Lithuanians in Norway (LN), and (3) Lithuanians in Lithuania (LL). The color matching tasks aimed to determine whether and if so, then to what extent: (i) there are differences of color perception between the three groups, (ii) whether these differences are modulated by a verbal inference task as shown in previous research for the monolingual[3] groups (i.e., Winawer et al., 2007)[4], and (iii) whether the activated language will alter the color perception for bilinguals.

1.1 The Present Study: Research Questions

There were three primary objectives of the current study. Since Lithuanian speakers have two BCTs for blue and Norwegians have only one, we aimed to find out whether this linguistic difference will result in perceiving colors distinctively. Therefore, we aimed to test this possibility in a color matching of blue colored stimuli and to find out whether speakers of Lithuanian and Norwegian show any cross-linguistic differences. The following research question was formed to satisfy the first aim of the study:

1. Do differences in BCTs between Norwegian and Lithuanian impact color perception for native speakers of these languages?

If there were differences in color matching task between these two groups, it would mean that, indeed, one's native language influences color perception. However, we also anticipated to evaluate whether experience with an L2 can influence color perception, just like the native language does. Since Lithuanians are the second largest immigrant group in Norway, Lithuanian-Norwegian bilinguals are numerous in Oslo and they were tested in addition to speakers who have Norwegian or Lithuanian as their L1 in Norway and Lithuania, respectively. In line with previous research on other languages (Witthoft et al., 2003; Thierry et al., 2009; Athanasopoulos et al., 2011), the level of users' proficiency and exposure in L2-Norwegian, age of acquisition, and time spent in Norway are likely to influence discrimination of *žydra* "light blue". Therefore, we excluded participants who were not proficient in and exposed to Norwegian enough (see Chapters 5 and 6). After selecting Lithuanian immigrants in Norway who were proficient in Norwegian, we aimed to assess whether their L1 color matching habits change because of their experience with the L2-

[3] LL and NN participant groups were not monolingual in a sense of knowing only one language. For the sake of simplicity, we refer to them as monolingual throughout the thesis, because they know only one of the target languages (Lithuanian or Norwegian) of this study and live in that language's environment.
[4] In Winawer et al. (2007) verbal interference has eliminated CCEs in monolingual speakers of Russian that have the light/dark blue boundary. However, we assumed that for bilinguals the language mode will influence the CCE depending on the activated language's linguistic categories for blue.

Norwegian. The following research question was formed to satisfy the second aim of the study:

2. Does experience with Norwegian in Lithuanian immigrants lead to matching blue stimuli differently from Lithuanians who live in Lithuania?

Speakers who have two BCTs for blue have been previously reported categorizing colors faster when they belong to different categories (one light blue and one dark blue) and slower when they belong to the same category (i.e., both light blues). Importantly, the reported effect was modulated with a dual-task paradigm. Verbal interference has been found to eliminate (Winawer et al., 2007), diminish or increase (Gonzalez-Perilli et al., 2017) the cross-linguistic effects. Accordingly, we investigated whether verbal interference could disrupt Lithuanians' performance on the color matching task in the current study. We formed the following research question to meet the third purpose of the study:

3. Does verbal interference attenuate cross-linguistic effects in the color matching tasks for Lithuanians in Lithuania?

If verbal interference can modulate the CCE for Lithuanians who live in their native language's environment and therefore are not exposed to foreign languages that much, how does the verbal interference affect the bilinguals? We were interested in whether and how the two languages affect color perception on-line, thus we aimed to test LN participants in speeded color matching tasks with verbal interference in both Lithuanian and Norwegian. The fourth research question was formed to discover whether Norwegian and Lithuanian will have different effects for bilingual participants once one of the languages is activated in the mind:

4. Does the language mode (activating Lithuanian or Norwegian), modulate color perception in Lithuanians living in Norway, who have different BCTs for blue in their two languages?

2 Cross-linguistic Categorization and Color Perception

2.1 Language and Thought

The world is full of various sounds, objects, events, and symbols that can be described by words. Human language faculty allows speakers to express their interpretation of the world through a complex linguistic system that stems from cognitive processes shared with other species (Malt and Wolff, 2010). Importantly, this linguistic system enables humans to communicate and provide tools for mental manipulation of knowledge (Gentner, 2003). It is commonly stated that the importance of language lies in communication with others although, according to Chomsky, language is primarily designed to think and interpret thoughts rather than communicate with others (Chomsky, 2015). Thus, even if we do not communicate with others, we are still thinking in a language. Malt and Wolff's (2010) *language-thought interface* offered the idea that each culture's language may portray the world in its unique way due to variations in the lexicons and encoding strategies. One example of this phenomenon that Malt and Wolff presents is that translators sometimes find it hard to transfer "the same" messages from one language into another without somehow adjusting its meaning.

Furthermore, word meanings are thought to be more diverse than general conceptual meanings. Every known culture appears to have a primary color-naming system of some sort. One line of research has focused on the universality of color categorization (Berlin and Kay, 1969), while many others have concentrated on exceptions and variants. Cross-linguistic research shows that one reason for it is that vocabularies partly depend on the community's physical and cultural environments. Thus, industrialized countries have more words to describe colors than speakers from traditional societies. In the present study, we focused on two languages that name the same part of color space differently (one color name in one language and two color names in another language) and aimed to find out whether this shapes the thought accordingly. Moreover, Malt and Wolff (2010) stated that the way different speakers name such concepts as space, body parts, motion, emotion, mental states, causality, and ordinary household containers differs greatly. According to Malt and Wolff, environment and physical surroundings alone are not a valid explanation to why there are so many of the cross-linguistic differences. The languages of interest in this study, Lithuanian and Norwegian, differ in the way they linguistically categorize blue color continuum even though both Lithuanian and Norway are industrialized countries, and their physical environments are not that different compared to, for example, the environmental difference between Himba speakers from Gabon, Africa[5] and English speakers from Great Britain.

2.2 Linguistic Relativism

Although human beings can see millions of color shades as recognized by the retina, color perception has been demonstrated to be categorical. It is known that languages have different linguistic categories to describe the color continuum, for instance, blue and green

[5] studied by Taylor, Clifford & Franklin (2013)

colors are linguistically categorized differently in Vietnamese and English (Kay & Maffi, 2008). Importantly, the question of whether the linguistic variation translates into stable differences in color perception when language is not involved is still open and will be discussed in the following paragraphs. Figure 2.1 illustrates a linear color interpolation from blue to green. The English language divides the continuum into two, where one part of the continuum is blue, and another part is green. Individuals might put a line in different places. Still, most probably, a speaker whose mother tongue is English or another language with one BCT for green and one BCT for blue will partition the continuum somewhere in the middle. However, some languages have one BCT for both green and blue ("grue"), such as Vietnamese.

Figure 2.1 Linear interpolation from green to blue. English and Vietnamese speakers categorize green and blue colors differently: English divided the green/blue continuum into two linguistic categories, while Vietnamese have one linguistic category for both.

The classic Sapir-Whorf hypothesis stands that "we view the world filtered through the semantic categories of our native language" (Regier & Kay, 2009, p. 1). Following the Whorfian hypothesis[6], the difference in linguistic color categories for green and blue in English and Vietnamese languages (Figure 2.1) would mean that Vietnamese speakers perceive colors differently. Another language, which our research in concerned with, Lithuanian, has two words to describe the blue color, namely *mėlyna* "dark blue" and *žydra* "light blue", which is different from English or Norwegian that only have one BCT to describe the same color space – blue or *blå* (Figure 2.2).

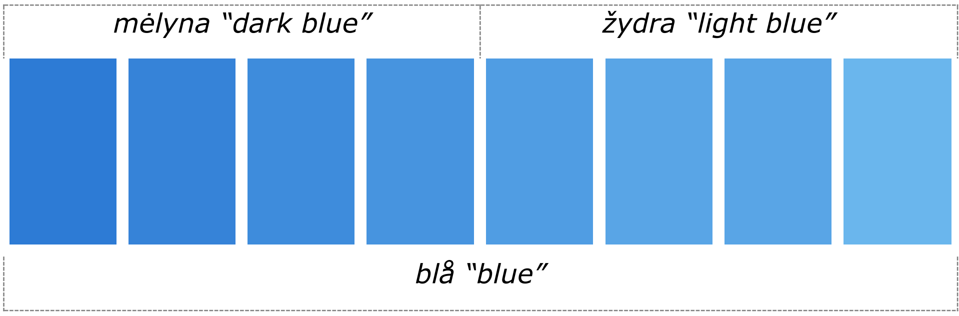

Figure 2.2: Linear interpolation from dark blue to light blue. Lithuanians have two distinct linguistic categories (*mėlyna* and *žydra*) within the blue color continuum, while Norwegian have only one (*blå*).

Remarkably, linguistic categories can constrain perception of concepts that refer to time, space, and color. The Dani language of a tribe in New Guinea can illustrate how different color naming patterns can be. The Dani language speakers have only two-color terms: *mili* which means black, but also refers to cool and dark shades, e.g., blue, green, and black, and *mola* "white" that also refers to warm and light colors, such as red, yellow, and white

[6] Whorf himself never proposed that language should affect color perception (Lupyan et al., 2020)

(Rosch Heider, 1971). The contrast between the Dani language and Indo-European languages, like English, raised the question of whether world languages are as universal as it has been believed. Hence, Sapir and Whorf are the names that stand for the two most defined claims of linguistic relativism. First, if there are structural differences between two languages, then there are also differences in the thinking habits that their respective speakers have. Second, through acquiring one's native language, one also develops a world view that is not easily changed in later life (Slobin, 1987). The first claim suggests a superficial linguistic difference between languages, like different alphabets, different sounds, word/phrase/sentence structures, and language use should affect our perception and/or cognition. However, this claim does not delve into the matter of how this can happen. The second idea is connected to perceptual differences and is more controversial. The controversy of the linguistic relativity hypothesis caused debates in linguistics, anthropology, philosophy, and psychology. At times relativism was rejected at all: "The idea that thought is the same thing as language is an example of what can be called a conventional absurdity" (Pinker, 1995, p. 57). Despite the criticism, many researchers are still working on the idea of language carving up the conceptual space in different ways.

2.3 Four Claims by Linguistic Relativists

According to Dedrick (2014), it is widely agreed that there are two versions of the Whorfian hypothesis: "the first is a strong version and claims that language determines or constrains mental operations. The second, a weak version, claims that language influences mental operations" (p. 274). In the studies that support *weak relativism*, language affected color perception, in both off-line similarity judgments (Davidoff, Davies & Roberson, 1999; 2000) and on-line perceptual discrimination (Winawer et al., 2007; Gilbert et al., 2006; Drivonikou et al., 2007). Off-line language effects can affect visual perception, but they do not modify the process of perception itself. Besides, the off-line language effect happens after the language processing routines have already been applied. In contrast, the on-line language effect occurs when perception has been affected in that specific moment, for example, by naming the colors (Lupyan et al., 2020). Winawer and the colleagues (2007) tested Russian and English speakers that differ in their linguistic color categories, namely Russians have two BCTs to describe shades of blue – *sinyj* "dark blue" and *goluboj* "light blue", while English uses single BCT – blue. All participants were tested in a forced choice color discrimination task, where Russians displayed a category advantage and English speakers did not. Noteworthy, Russian's category advantage was removed when they had to discriminate between shades of blue under verbal interference. It was claimed that verbal interference disrupted the use of language and therefore the category advantage in no interference condition occurred because language was involved on-line. Since the present study proposed to conceptually replicate the study on Russian blues by Winawer and the colleagues (2007), we were mainly concerned with the on-line language effects on color categorization. Briscoe (2020) divides the linguistic relativity theory further. He established four claims that are common among relativists:

1. Perceptual grouping, informativeness[7] and structuring of perceptual color space are universal. However, cultural and pragmatic color categorization are not universally constrained (Roberson et al., 2000;2005; Jameson, 2005). For instance, there is a practical need to communicate the distinction "between edible and non-edible fruits,

[7] Informativeness constraint, in color perception, refers to maximization of similarity of colors within category and minimizing similarity of colors between different categories (Gartner, 1974, as cited in Briscoe, 2020).

as well as from the distribution of shades in the natural and social environment." (Briscoe, 2020, p. 463)

Although, according to the first claim, salient colors constrain color concept formation, perceptual grouping and informativeness are rather loose restrictions on the construction of color categories (Roberson et al., 2000, as cited in Briscoe, 2020). When an individual is asked to match colors, there is no good way to limit the color space so that the matching of colors would stop at some point. Linguistic relativists do not answer the question on how hue, saturation, and lightness should be weighted in perceptual grouping (Jameson 2005, as cited in Briscoe, 2020). And grouping constraint implies that there has been a prior identification of color space. However, this problem is solved when a color task involves relative similarity: color x is more like color A than like color B. In this model, A and B are fixed and constrained upon assigning shades to categories (Dedrick, 1998, as cited in Briscoe, 2020). This is the model that we have adopted in the present study as well (see Chapter 5 for details). Additionally, the informativeness constraint assures that color systems will help speakers communicate about them but does not specify how many categories a system will contain (Briscoe, 2020).

2. Following Roberson et al. (2000) there are two steps in the conceptual development of colors. First, color categories are formed within the color boundaries that are specific to the color space of the observers, therefore the boundaries are not universal. Second, the best examples or foci of those color categories are taken out. (Briscoe, 2020)

The second claim has to do with *perceptual salience theory* which used to be associated with universalism (see Section 2.4). In perceptual salience theory, basic color concepts are formed by positioning boundaries in a color space centered on the "Hering primaries". The Hering primaries are black, white, unique yellow, unique green, and unique blue and are thought to be salient colors in vision before thought and language (Hering, 1878/1964 in Briscoe, 2020, p. 3). In contrast, the relativists claim that color categories start forming with setting up the boundaries in color space based on specific cultural reasons, environment, and language rather than based on Hering primaries (Briscoe, 2020).

3. Mental representation of colors is language dependent, and BCTs are the primary vehicles of conceptual color categories. Experimental research (Quine, 1973; Roberson et al., 2000; Davidoff, 2001; Roberson et al., 2005) "would suggest that there are no cognitive color categories that are independent of the terms used to describe them" (Roberson, 2005, p. 66, as cited in Briscoe, 2020).

The third claim is supported by research on patients with color naming impairments and subjects with no impairments who perform a color-matching task under verbal interference. In a verbal interference paradigm, participants are asked to rehearse words (i.e., number combinations) and match colors simultaneously. It was reported that such dual tasks may impair color perception selectively. The current study employed the verbal interference tasks to assess whether language interference will modify the CCE as demonstrated in the previous studies (Winawer et al. 2007, González-Perilli, 2017). Verbal interference is further discussed in Section 2.5. Besides, ordinary subjects who perform color matching with a verbal dual task act similar to aphasic patients in odd-color-out tasks (Lupyan, 2009 in Briscoe, 2020). An individual with impaired color naming cannot sort colored stimuli into groups (Roberson et al., 1999) nor judge which of the three objects differs from the other two in an odd-color-out task (Davidoff & Roberson, 2004). The results of ordinary individuals under verbal interference and color impaired patients form relativist arguments of why the color language may shape our conceptual space.

4. Experience of using a distinct set of linguistic categories, for instance, eleven BCTs in English, can make colors from the same category appear to be more similar to one another, and colors from different categories appear to be more different. In other words, color terminology "distorts perception by stretching perceptual distances at category boundaries". (Davidoff, 2001, p. 386 in Briscoe, 2020)

The fourth claim represents the strong version of linguistic relativism. As mentioned earlier, strong relativism suggests that color perception is categorical, and that language constrains color perception. Briscoe (2020) presented explicit evidence of why color perception is not categorical. For discussion on categorical perception concerning the current thesis, see Section 2.3.

2.4 Universal Color Categories

In the previous section, we discussed Briscoe's (2020) claims about linguistic relativism which are often contrasted with the universalist approach in literature. Indeed, relativists are primarily seeking differences in the way of cutting up the color space and are less concerned with creating a similarity system in which different languages assign labels to colors. In contrast, Berlin & Kay (1969) proposed a theory on the evolution of Basic Colour Terms (BCTs). Berlin & Kay proposed that color names in the world's languages are not assigned randomly but systematically. They argue that supporters of linguistic relativism are missing out on not making connections between languages. The latest version of the universalist view is the *Universality and Evolution model* (Kay, 2015; Kay & Maffi, 1999). This view suggests that humans have psychologically universal color concepts due to their perceptual salience[8]. The universal color concepts correspond to basic color terms (BCTs) and are simply reflected differently in a wide variety of languages. Hence, according to the universalists, color representation is not dependent on language in thought or perception (Briscoe, 2020, p. 2). Berlin and Kay (1969) changed ideas regarding the Whorfian approach quite drastically by testing 100 languages and finding the system behind the number of color terms a language has. They used standardized color stimuli of 329 color chips from the Munsell color system for gathering the data. The data was collected through two stages: first, informants were asked to list all the BCTs they knew in their native tongue. The data collectors were mostly using language that is native to the informants for instructions and minimizing the use of any other language. Second, every participant had to map both the focal point and the color name boundaries. To avoid taking expressions like *blond, salmon-colored, lemon-colored,* or *blue-green* as basic color terms, 4 criteria were established by Berlin and Kay (1969) for a color name to be considered a basic color name:

1. The color name is monolexemic.
2. Its signification is not included in that of any other color term.
3. Its application is not restricted to a narrow class of objects.
4. It must be psychologically salient for informants. This includes a. tendency for a color term to appear in the beginning of color names lists, b. stability of reference among informants and occasions of use, and c. occurrences between idiolects of all participants.

[8] In perceptual salience theory, the best examples of the color categories are based on the "Hering primaries", which are: black, white, unique yellow, unique green, and unique blue salient colors in vision (Hering, 1878/1964, as cited in Briscoe, 2020, p. 3).

According to Berlin and Kay (1969) even though different languages encode in their vocabulary's different numbers of basic color categories, a total inventory of exactly 11 basic color categories exists from which the 11 or fewer basic color categories of any given language are always drawn. Furthermore, if a language encodes fewer than 11 basic color categories, then there are strict limitations on which categories it may encode (Berlin and Kay, 1969, p. 2). In addition, BCTs evolve through time by incorporating more color terms but still in a constrained sequence. Essentially, the study's main finding was that there is a hierarchy in which languages express color. If one finds out how many basic terms there are in a language, the hierarchy will tell which colors the language distinguishes.

In languages with two color terms, those will necessarily be black and white (or their equivalents - dark and light). Then if a language has a third color name, it will be red. The following additions to the number of color terms can be from yellow, green, and blue. Next, if a language has a term for brown color, it will appear as the sixth color system. In addition, if there are still more words for colors in a language, those will be purple, pink, orange, and gray.

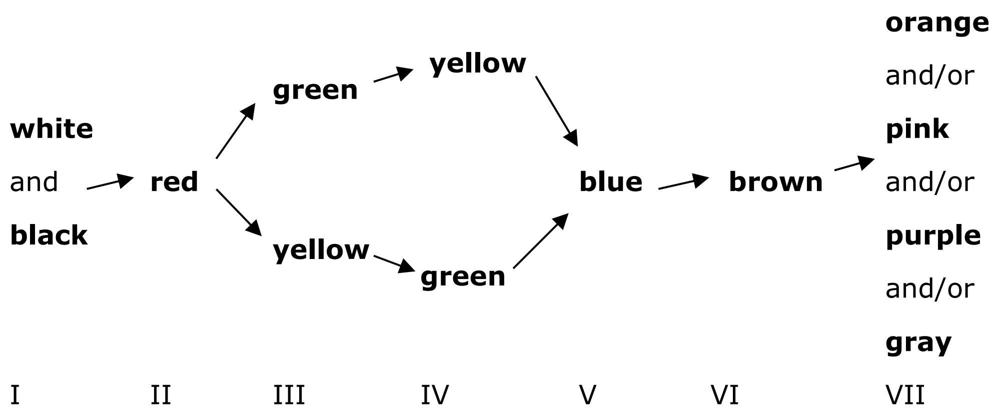

Figure 2.3: The listing of the basic color terms and their universal color categories. Adapted from Basic color terms: Their universality and evolution (p. 4) by B. Berlin & P. Kay, 1991, University of California Press. Copyright 1969 by The Regents of University of California.

Also, Rosch Heider's (1977) findings on focal versus non-focal colors strengthened the theory of universal color categories. Here, color is considered focal when it occupies a space in one of the color categories (in Figure 2.3) and represents the best example of that category. Rosh-Heider worked with English and Dani informants; the latter only have two basic color names in their language. The results outlined that focal colors are remembered more easily than colors outside of the 11 basic hues for both English and Dani speakers. Thus, the claim was that the colors might be hardwired into our color vision system and dependent on physiology rather than language. However, in 2000, Roberson et al. failed to replicate Rosch Heider's findings. The researchers claimed their findings to be supporting linguistic relativism. Moreover, Lucy and Shweder (1979) declare that Rosh-Heider's work overlooked the fact that color perception affects color memory. Focal colors are easier to look for in a color palette; therefore, they are more perceptually discriminable than the other colors. Thus, the linguistic relativity hypothesis was not discarded by the research of Rosch Heider.

In general, theories of color categorization differ in a variant of imposed language constraints on the formation of color concepts (Briscoe, 2020). The debate of universalist-versus-relativist over language and perception remains. More recently, studies that touch upon the Whorfian hypothesis moved from debating whether language shapes perception to seek observable factors involved in the process of language affecting perception

(Athanasopoulos & Casaponsa, 2020). Nonetheless, it is accepted that the views do not necessarily contradict each other, as in some sense, they are complementary. According to Martinovic et al. (2020), weak relativism "embraces the possibility of new BCCs (basic color categories) and their corresponding basic color terms specific to a given language, beyond the established 11" (p. 1). Moreover, researchers agree that perceptually salient colors do not support color naming patterns and that color categorization effects are relative to a specific language.

2.5 Categorical Color Perception

Categorical perception is warped in that differences between some objects that belong to different categories are highlighted, and differences between objects that fall into the same category are minimized (Goldstone & Hendrickson, 2010). Perceived continuums of similar colors or similar sounds are divided by boundaries and grouped into categories. The transition between two categories in the continuum is often referred to as a category boundary. In the Aristotelian categorization model, boundaries are clear and fixed, whereas, in cognitive linguistics, categories are less clear and can have fuzzy boundaries (Croft et al., 2004). Categorical perception also refers to "faster or more accurate discrimination of stimuli that straddle a category boundary" (Regier & Kay, 2009, p. 439).

In cognitive science, categorical perception presents how our higher-level conceptual and lower-level perceptual systems operate. Therefore, it provides some explanation of how cognition works in general. Typically, perceptual, and conceptual systems are separated by a point at which the information moves only from perceptual to the conceptual system and not the other way around. However, research revealed that categorical effects exemplify information moving both directions. Perceiving things categorically can help our perceptual systems transform sensory signals into internal representations in cognition. Goldstone & Hendrickson (2010) exemplify the linear signal transition as a staircase function. So, the increasing sensory signal does not affect perception until the signal reaches a certain point where the perception suddenly changes. While the flat portion of the staircase function is happening, different input signals have equivalent effects, but when the input from a different category occurs, the perception changes—treating a range of other stimuli as the same provides a mechanism that justifies equivalence classes.

Successively, equivalence classes provide humans with the formation of symbolic thought, which refers to the mental pictures of symbols (stimuli). The possible explanation why cognitive systems might be built with equivalence classes is that they are rather untrustworthy when it comes to judging superficial similarities or differences (Goldstone & Hendrickson, 2010). To illustrate, when perceiving two objects, we emphasize the differences between them to belong to different categories and minimize the differences that would put them into the same category. In other words, if we must place both stimuli in the same category, we will try to connect two stimuli, even if they have different apparent forms. However, even when we put two objects into the same category, we may not treat them as the same thing for all purposes (Goldstone & Hendrickson, 2010). Moreover, entities can be assigned to different categories in different contexts. Thus, if we create a category and name it "pets", cats and dogs will belong to this category, but if we make a category with the title "pets that meow", only cats will end up in this category.

According to Goldstone & Henrickson (2010), categorical perception can be learned, and the categories that we have formed or learned influence the way we perceive the objects surrounding us. In the theory of acquired distinctiveness, categories relevant for determining that category's members become distinctive in general. This theory is based on Lawrence's (1949) research with rats. In the series of experiments, rats were trained to discriminate between black and white colors and rough and smooth surfaces. Every time rats choose the stimuli that Lawrence wanted them to choose, they would get a reward. First, rats were trained to make black/white distinctions. The training phase was conducted as follows: when black shapes were presented, rats were rewarded for a left response, while when white shapes were introduced, the rats were awarded for a right response. In the second training, rats learned better because they already knew the black/white distinction. Therefore, if the stimuli are irrelevant for an earlier training phase, there is a deleterious effect on subsequent discrimination learning. The experiment with rats illustrates the way that the learned categorical perception works. The described impacts are expected in humans and provide structure for categorizing visual discriminations (Lawrence in Goldstone & Hendrickson, 2009).

Furthermore, gradual perceptual warping is thought to be a result of previously learned categories in humans too. Goldstone (1998) aimed to determine whether arbitrary new visual categorizations can be learned and whether they can be learned whether they shape perception. The stimuli that Goldstone used are given in Figure 2.4. First, the portrayed table was given to participants to train them to categorize brightness and size.

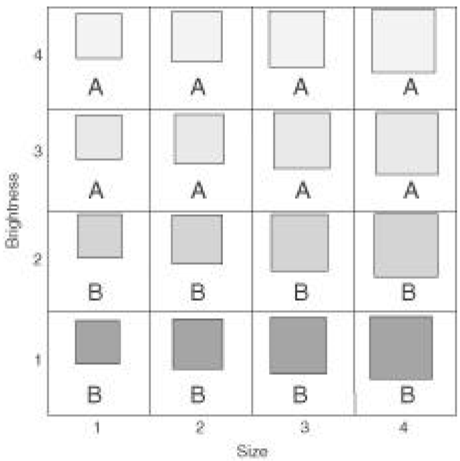

Figure 2.4: Stimuli used in Goldstone's study (1998). From "Categorical perception" by Goldstone and Hendrickson, *Wiley Interdisciplinary Reviews: Cognitive Science*, 1, p. 73. Copyright 2009 by John Wiley & Son s, Ltd.

After the categorization training, participants were given the same/different judgment task. In the task, either horizontally or vertically neighboring squares were presented, or the same square was repeated twice. Participants were asked to respond whether the two squares were identical on both their size and brightness or differed on either dimension. If dimension was relevant, participants' same/different judgments together with the entire dimension were more accurate than the same judgments of the participants for whom the dimension was irrelevant and the control group's participants who were not trained beforehand. Moreover, the subjects were the most accurate when the dimension values were at the boundary between learned categories (i.e., comparing values 2 and 3 on brightness). To conclude, research shows that when participants are taught a new category, it temporally changes their perception. (Goldstone & Barsalou, 1998; Ozgen & Davies, 2002).

2.6 Categorical Color Perception or Color Category Effect?

The categorical perception was first observed in sound discrimination (auditory). For instance, in English speakers, the sound discrimination was found to be easier for consonant pairs (i.e., /p/ and /b/) that cross the category boundary than for stimuli within the same category (i.e., Flege and Schmidt, 1995). Suppose color perception is like auditory perception. In that case, the shades that look more similar and have the same name should be harder to discriminate than more distant hues with different names, which "may cause us to perceive color in a more categorical way" (Lupyan et al., 2020, p. 4). For instance, Norwegian speakers do not assign different labels for lighter and darker shades of blue in their language and linguistically treat the whole blue color spectrum as the same. In contrast, Lithuanian speakers assign two labels to the blue color spectrum and divide it into two language-specific categories. For linguistic relativists, color category boundaries are distortions of continuous color space (Huette & Merced, 2016). As mentioned earlier, linguistic relativists assume that a linguistic difference of color language would translate into a perceptual difference.

However, Briscoe (2020), based on evidence by Roberson & Pak (2009), suggests that discrimination of color is categorical but not perceptual and occurs because of the post-perceptual naming strategy. Moreover, Briscoe (2020) exemplified naming strategy by category effect differences between Tarahumara and English speakers (Kay & Kempton, 1984). Notably, Tarahumara speakers do not have a blue/green boundary, similar to Vietnamese speakers mentioned in Section 2.1. All participants were given triads of colors within the blue/green color space and asked to select a color shade that was the least similar to the other two. English speakers often picked a color from that crossed the blue/green boundary, while Tarahumara speakers did not show a similar effect. Usually, this effect would be referred to as the categorical perception effect. Yet, Kay & Kempton (1984) refer to this effect as a naming strategy that gives advantage for speakers with a greater amount of color labels. In a color trial of their study, when an English speaker saw three color patches, they thought of a strategy that could be used to complete the task. One of the possible strategies would be applying labels to these colors. Once an English speaker realized that he or she can label the colors to complete the task, he or she noticed that two color patches (A and B) could be called blue, and the third patch (C) could be called green then. C is then selected as the most different patch. Tarahumara speakers do not use this strategy simply because of not having two different BCTs for blue and green (Briscoe, 2020). Moreover, Roberson et al. (2009) claim that the naming strategy effect, like the one found in English speakers vs. Tarahumara speakers, should be called a color category effect (CCE). We adopted this term in the present thesis as well.

Another account of cross-linguistic differences is that speakers of different languages learn to categorize colors based on their long-term experience of speaking the language is proposed by Lupyan et al. (2020). Learning[9] and using words such as Lithuanian *žydra* "light blue" and *mėlyna* "dark blue" provides a categorization practice that results in the gradual representational separation of the parts of the color spectrum to which the labels are applied. Different linguistic categorization patterns in Norwegian, using the generic term *blå* "blue", are expected to produce different discrimination patterns across the color spectrum (Lupyan, 2012). It does not mean that Norwegian participants will not have the capacity to distinguish light and dark blue colors, but, rather, that having two color labels will affect the performance of Lithuanians in terms of speed: they are expected to match

[9] in terms of acquired distinctiveness theory.

colors between categories faster than the colors within the same category. Lupyan (2012; 2020) refers to change of color representation over time as an off-line language effect. In Figure 2.5, (a) illustrates the off-line effect, where color patches are represented as steps of equal distance from each other. In contrast, on-line effects of color labels on color representations are portrayed in (b). Here, categorical effects occur by activating a verbal label (or BCT) on-line. The perceived color actives a BCT, which then warps the color representation in the moment (Lupyan et al., 2020)[10]. According to Lupyan (2020), the on-line labeling process is covert when color labels are automatically activated by perceptual inputs and can be "further exaggerated by overt labeling such as actively naming a color or reading/hearing a color term" (Lupyan et al., 2020, p. 6).

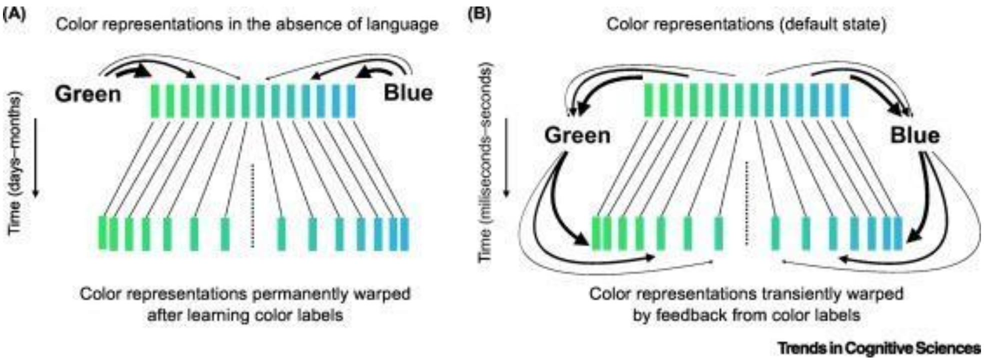

Figure 2.5: off-line (A) and on-line (B) effects of language on color perception. From "Effects of language on visual perception" by Lupyan et al., *Trends in cognitive sciences*, 24, p. 934. Copyright 2020 by Elsevier Ltd.

As presented in Figure 2.5, a stronger categorical representation of color patches is more expanded around the category boundary and in the middle of the category. According to Forder & Lupyan (2019), the expansions around the boundary and collapsing of the space within a category result in improved discrimination of atypical hues from more typical ones and in worse discrimination within the same category.

In 2016, Witzel & Gegenfurtner presented *categorical facilitation* - a weaker version of categorical perception. They tested categorical perception for brown and red, colors that have a boundary which is the least prone to "spurious effects of low-level mechanisms" (Witzel & Gegenfurtner, 2016, p. 540). First, they determined the boundary for red/brown through a color-naming task, and then they measured it for the just noticeable differences. The assumption was that if the effect is categorical just noticeable differences would decrease towards the boundary. However, the results did not confirm this assumption. Second, they measured the performance in reaction times (RTs) and error rates in a speeded discrimination task with color pairs equalized based on observed just noticeable differences. This resulted in slower RTs and error rates for identifying color differences in equal color pairs when the colors crossed the boundary. The results suggest that categories can only facilitate the identification of perceptual differences at the boundary. According to this approach, discrimination performance for colors that cross a category border should be better than for colors that belong to the same category when controlling for low-level sensitivity.

[10] In Figure 5, thicker lines denote the labels of "blue" and "green" that are stronger members of those categories than other blues and greens (Lupyan et al., 2016)

2.7 Behavioral Tasks Differences on Color Perception

What makes colors a suitable research domain is that the physical spectrum of light spans continuously, while color perception is often thought to be categorical (Lupyan et al., 2020). To get evidence for the Whorfian hypothesis, first, the two languages that differ in some linguistic features must be identified. Second, these differences need to be mapped onto differences in cognition or perception. Our study has selected Lithuanian and Norwegian languages that have different linguistic categories within the blue color continuum. In the studies of categorization and color perception participants are often asked to either name or match colors. In our study design both color identification and categorization tasks will be employed (see Chapter 5). Color naming tasks usually require participants to choose a color patch from the whole color palette and label it (Berlin & Kay, 1969) or mark color patches within some part of the color space (i.e., green-blue-purple space in Bimler & Uuskula, 2017). The methodology proposed by Berlin and Kay consists of two parts. First, *the list task*, also known as the term elicitation task, aims to find the most salient BCTs in a language. In this task, participants must make up a list of all color terms that they can recall within a limited time. Second, subjects are engaged in *the color-naming task* – they are asked to name the colors they saw. In this procedure, subjects were mapping verbal terms with the color stimuli in the color space and establishing potential boundaries of where the color categories begin and end. The responses determined a color naming pattern of a particular language. Furthermore, the most chosen color patches were elicited to be the best examples of BCTs by speakers of different languages. Typically, the best examples BCTs clustered in small regions of the palette, which was the main argument of why the color categories across languages are universal and constrained to a set of 11 color names (Kay et al., 1991; Kay & Maffi, 2000). Sometimes, a smaller number of color patches are selected by the researchers. In this type of investigation, the participants must name the chosen color patches with distinct BCTs from their language. To analyze color boundaries within the blue color continuum, Bimler & Uuskula (2017) asked speakers of six languages to sort color patches by similarity and to label the piles afterward. In data analysis, the researchers created an indicator of color term basicness, namely *clustering index*. The *clustering index* measured the expansion of light/dark separation and the weight of any category boundary between them within the blue color continuum. Clustering of blue stimuli confirmed "light blue" to be a separate basic color category for 4 out of 6 tested languages. Therefore, "light blue" shall be considered the 12th basic color category in the Berlin & Kay system for some languages, including Lithuanian.

Forced-choice designs will be referred to as color matching tasks. In a color matching task, the colors are already selected by the researcher; these are typically the colors surrounding the prototypes or the best examples of BCTs known from prior studies of color naming. Participants are asked to choose between three or two given colors. For instance, in Roberson & Davidoff's (2000) study, participants were shown a target color chip picked from a blue-green continuum. After the color chip was taken away and two new chips were presented. The participants had to indicate which of the two new chips matched the target chip shown initially. These two new chips were from the same category (both blue or both green) or different categories (one blue and one green. In addition, the two new chips were always normed so that colors within category and colors between categories were the same perceptual distance apart. The results showed that participants were more correct on trials between-category trials than those from within-category trials. Furthermore, Winawer and colleagues (2007) looked for categorical effects in Russian speakers. Russians, unlike English speakers, use BCTs for dark blue (*sinyj*) and light blue (*goluboj*). In this study, individuals saw three colored squares – one on the top and two on the bottom (Figure 2.6). The aim was to find which colored square of the two bottom ones was identical to the square on the top. Russian speakers were slower (measured by reaction times) to match colors when they belonged to the same category and faster when they belonged to different categories. English-speaking participants did not display the same cross-category effect.

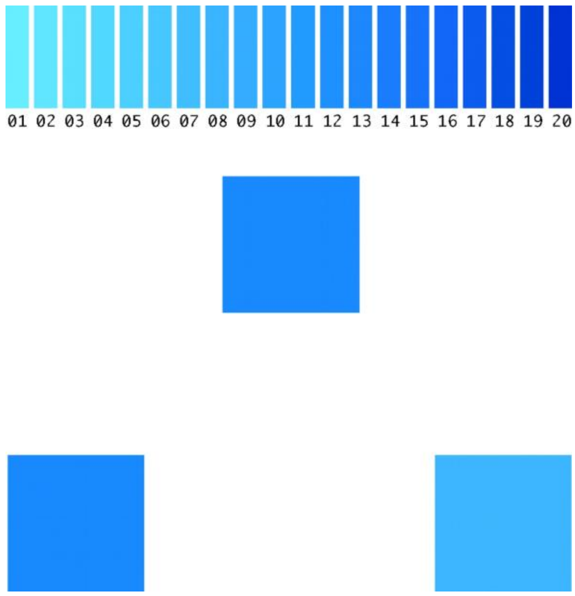

Figure 2.6: The design of Winawer et al. (2007) experiment, where a participant has to decide which of the two bottom colors is identical to the one at the top. From "Russian blues reveal effects of language on color discrimination" by Winawer et al., *Proceedings of the national academy of sciences*, 104, p. 7781. Copyright 2007 by National Academy of Sciences, U.S.A.

In fact, color discrimination and matching tasks can be modified by manipulating linguistic factors. Several studies have shown (Roberson & Davidoff, 2000; Winawer et al., 2007) that verbal interference tasks can make the cross-linguistic effects vanish. When dual task methodology is employed, participants are instructed to use language to perform a verbal task (e.g., rehearsing digit combinations) and perform the nonverbal perceptual/cognitive task (e.g., categorizing colors) at the same time (Athanasopoulos & Casaponsa, 2020).

In dual tasks, verbal interference disrupts the ability to use color language when matching colors. Color matching tasks together combined with verbal interference tackle the verbal rehearsal system (the phonological loop)[11]. The phonological loop allows subjects to rehearse stimuli verbally in short-term memory to store these stimuli in long-term memory (Athanasopoulos & Casaponsa, 2020). Crucially, it was claimed the phonological loop can no longer be adopted to process color stimuli that have verbal labels (Athanasopoulos & Casaponsa, 2020).

In Roberson and Davidoff (2000), subjects were presented with a target color square. After seeing the target as the verbal interference, subjects had to read words for five seconds and then were tested on the two test chips. It was found that the interference condition eliminated the advantage of between-category trials (or the CCE). Winawer et al. (2007) extended Roberson and Davidoff's study of color memory to on-line color judgments. As mentioned earlier, when language is involved on-line, color perception is being affected in

[11] This is based on the well-established psycholinguistic theory of memory by Baddeley (2003), where verbal information is encoded via a phonological loop.

that specific moment. In Winawer et al. 's (2007) study, Russian speakers were slower to match colors when they belonged to the same category and faster when they belonged to different categories. However, when the same task was performed under the verbal interference conditions, matching colors that belonged to the same category no longer took more time than the ones between categories. Thus, the CCE was not only not evident anymore, but also, it was reversed.[12] Another study by Gilbert et al. (2006) employed a verbal interference task that removed the categorical color perception effect found in the right visual field only. Moreover, it is often claimed that the left hemisphere is typically dominant for language (Briscoe, 2020).

Thus, the findings of dual paradigm studies reveal that CCEs are linguistic in their origin. In other words, the fact that verbal interference tasks eliminate the CCE can justify that this effect is linguistic and not due to cultural or environmental differences between native speakers of different languages (Regier et al., 2010). According to Winawer and Witthoft (2012), the interpretation that the elimination of the CCE is a result of categorical perception is possible, but also is unlikely. So, if CCE occurred because of perception being categorical then the way the color looks was modified only during the moments of color label access. Thus, BCTs are unlikely to influence the early perceptual processes, and the decision process is more plausibly affected by language. For instance, in a matching task, when two distinct colored squares are from the same linguistic category (e.g., they both are light blue), thinking of two distinct BCTs in a language is unlikely to guide a participant towards the correct answer. Yet, if color stimuli in a trial are noticeably having two different BCTs (e.g., one light blue and dark blue), then thinking of these BCTs may speed up memory or the comparison. Following this logic, rehearsing random words or digits interferes with assigning BCTs to the color patches and may eliminate one of the two strategies used for matching the colors. Winawer and Witthoft (2012) conclude that "verbal interference effects are more likely to reflect a role of color terms on decisions, strategy, and memory, rather than perception" (p. 5).

In accordance to Winawer and Wirrholf's claims (2012), Lupyan (2012) argues that verbal interference shows that the cross-linguistic effect observed without any interference was of language on language. Besides, as it is so easy to eliminate the CCE by the interference tasks, some researchers used it as an argument to claim that the Whorfian hypothesis must be false and superficial (Regier et al., 2010). According to Lupyan (2012), if CCE can be modulated by interference so easily, the question arises whether the effect of language warped perception in the first place? And if it did, why can these effects be "unwarped" so easily? Lupyan (2012) states that the answer has to do with linguistic influences on categorization and perception being superficial. Since CCE was disrupted by verbal but not visual interference, it might be the case that language was affecting the verbal process during the whole task. Ultimately, the cross-linguistic effect may be of language on language and not of language on perception (Gleitman, 2010, as cited in Lupyan, 2012). The assumption of language influencing language relies on two objectives. First, language is thought to be a "transparent medium" (Gleitman et al., 2004, p. 363, as cited in Lupyan, 2012). Transparent medium occurs when words map onto concepts that are independent words (e.g., Gopnik, 2001; Snedeker and Gleitman, 2004; Gleitman and Papafragou, 2005). Second, it is possible that because verbal and non-verbal processing is strictly separated, the verbal and non-verbal representations are too. In conclusion, cross-linguistic effects on color perception can be interpreted as both fragile and pervasive.

[12] According to Briscoe (2020), these findings are consistent with the earlier discussed Kempton and Kay's *name strategy theory* (p.16)

Therefore, it is yet unclear if language alters concepts and if the "altered concepts should persist regardless of how language is deployed on-line" (Lupyan, 2012, p. 3).

2.8 Basicness of "Blue" Terms in Lithuanian

In the current research project, we are focusing on Lithuanian color terminology for two main reasons: first, the Lithuanian color terminology is understudied, more precisely, to the best of our knowledge, Lithuanian blues were never investigated in a forced choice categorization task. Second, we have an opportunity to not only test Lithuanian speakers in their native language's environment, but also Lithuanian-Norwegian bilinguals and, therefore, to create an interesting experimental condition in which we aim to find out whether non-native language influences color matching over the native language. The base for the current study on Lithuanian blues comes from the evidence of categorical color perception reported in other languages that have a linguistic color boundary for light/dark blues. Greek (i.e., Athanasopoulos, 2009), Russian (i.e., Winawer et al., 2007), and Italian (i.e., Bimler & Uuskula, 2014) are few examples of languages that have two basic terms for the blue color and prove that eleven BCTs should not be considered as the limit in the Berlin-Kay generalization. The language of interest in the current study - Lithuanian - is a Baltic language that has a profoundly rooted language contact with Russian. Besides, Baltic languages belong to the Balto-Slavic branch of the Indo-European language family and are closest to the Slavic languages (Bimler & Uuskula, 2017). Similar to Russian, Lithuanian has two BCTs for blue, namely *žydra* "light blue" and *mėlyna* "dark blue." Notably, Russian *goluboj* "light blue" occupies a distinct area in color space that is not overlapping with the other BCT for the other blue color - *sinij* "dark blue". Thus, *goluboj* "light blue" has been recognized as the 12th basic color term (Paramei, 2005). Moreover, *goluboj* "light blue" and *sinij* "dark blue" are not hyponyms (Bimler & Uuskula, 2017). Despite the fact that Lithuanian was not investigated in color matching experiments before, Bimler & Uuskula (2017) reported that *žydra* "light blue" is a BCT, similar to Russian *goluboj,* therefore, the 12th BCT in Lithuanian. In the following paragraphs, we report Bimler & Uuskula's results to better understand the investigation of the Lithuanian blues in the present thesis.

Bimler & Uuskula (2017) tested Lithuanian and five other Indo-European languages to determine whether the color names that describe light shades of blue in these languages can be considered BCTs. Colored papers from the green-blue-purple color continuum (the Color-Aid Corporation (CAC)) were fitted on 55 plywood tiles and used as the stimuli. The participants in the study had to sort these tiles so that the similar tiles would belong to one group. There were no indications of how many groups should be created. After, each group of tiles had to be given a name. In addition, the respondents were asked to name each tile as the tiles were shown one by one in random order (Bimler & Uuskula, 2017).

Figure 2.7 revealed the multidimensional scaling solution for Lithuanian data. The symbols in the given map mark modal term and the sizes of the symbols illustrate how unanimously participants agreed on nominating a single term for that specific color tile (Bimler & Uuskula 2017). A high level of *žydra* "light blue"/ *mėlyna* "dark blue" clustering was observed as these two terms revealed highest agreement among participants (Bimler & Uuskula, 2017). *Mėlyna* "dark blue" cluster occurs to be "particularly compact, with good agreement on how to name its tiles" (Bimler & Uuskula, p. 374, 2017). However, that participants' responses on how the BCT for light blue - *žydra* is applied were more varied, as the cluster is more expanded.

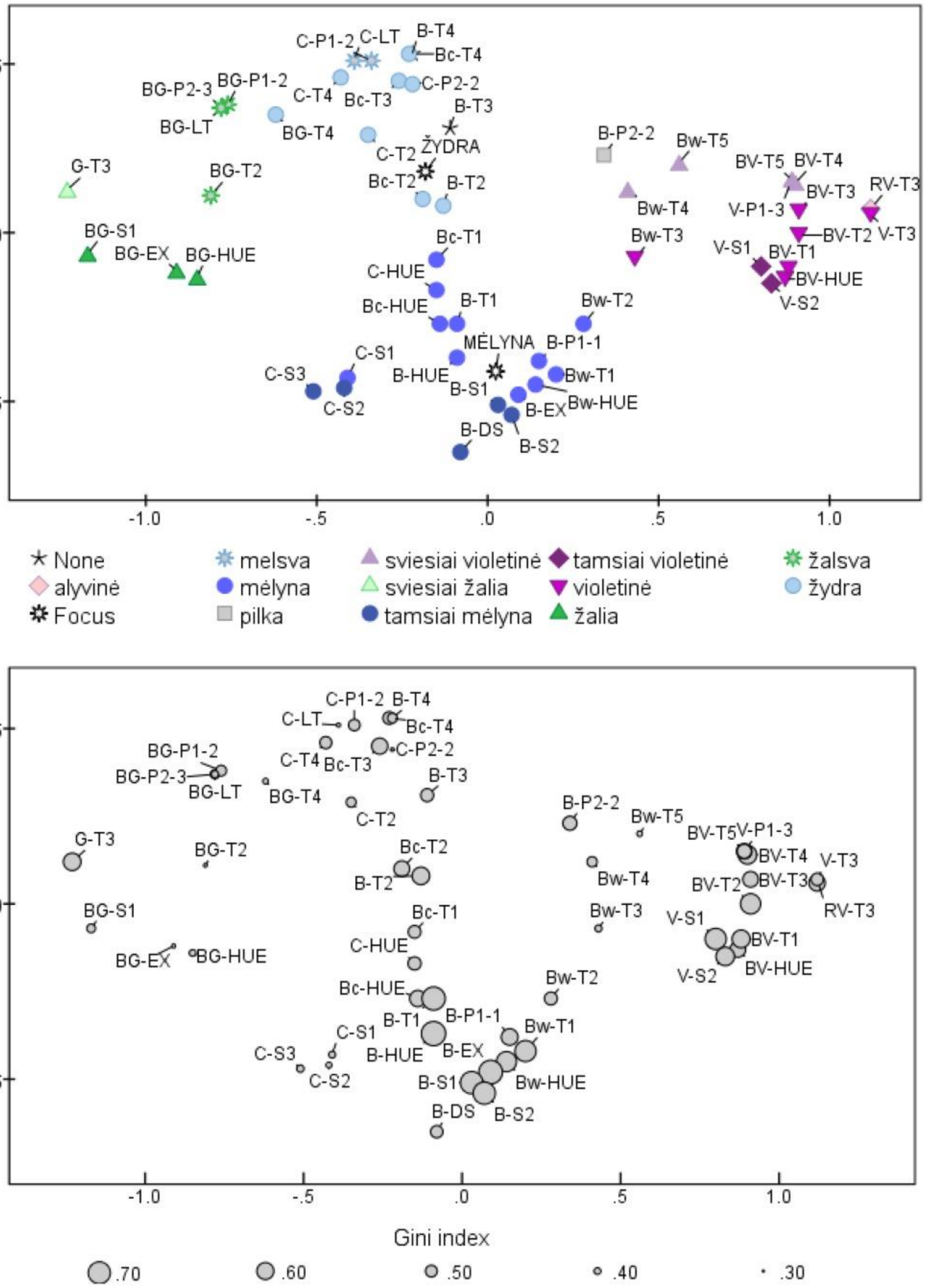

Figure 2.7: Two-dimensional map for Lithuanian blue colors displaying clustering of tiles for *mėlyna* and *žydra* suggesting that most participants grouped these tiles in separate groups and gave the same name for it. Symbols that can be seen on the map and in the legend indicate the color names and the corresponding color tiles. From "A similarity-based cross-language comparison of basicness and demarcation of "blue" terms" by D. Bimler & M. Uuskula, Color Research and Application, 42, p. 371. Copyright 2016 by Wiley Periodicals, Inc.

Table 2.1 presents the results of the pile-naming. For Lithuanians, the main term in both naming tasks was *mėlyna* "blue," accounting for 21% of all terms used (rank 1). In detail, *mėlyna* was dominant for the six tiles: Bc-Hue, B-Hue, B-T1, Bw-T1, B-Ex and B-P1-1

(Figure 2.8). The most dominant examples of *mėlyna* were B-EX, B-Hue, Bc-Hue, and Bw-Hue. This indicated that the location of focal *mėlyna* is significantly lighter than the Italian *blu* and Russian *sinyj* "dark blue". Consequently, *mėlyna* is close to Italian and Russian light blues: *azzurro* and *goluboj*. Furthermore, *Šviesiai mėlyna* "light *mėlyna*" (rank 5) was mentioned less frequently than *žydra* "light blue". *Žydra* "light blue" was marked for 8.1% of terms. Most subjects used both colors labels: *žydra* and *mėlyna*, therefore these terms should not be considered synonymous. Bc-T2 and Bc-T3 accounted for more than half the choices of good prototypes for *žydra.* Also, *žydra* was further adapted to *šviesiai žydra* "light *žydra"* by some participants further suggesting that *žydra* should be regarded as a BCT (Bimler & Uuskula, 2017).

Table 2.1: Color-term usage from 50 Lithuanian participants for tiles and piles. Adapted from "A similarity-based cross-language comparison of basicness and demarcation of "blue" terms" by D. Bimler & M. Uuskula, *Color Research and Application*, 42, p. 371. Copyright 2016 by Wiley Periodicals, Inc.

		Tiles			Piles		
Term	Gloss	n_T	Size	Frequency (%)	n_P	Size	Frequency (%)
mėlyna	Blue	49	6.1	11.8	37	14.2	20.7
tamsiai mėlyna	Dark blue	46	3.0	5.5	19	8.5	6.4
žydra	Light blue	44	3.7	6.4	23	9.0	8.1
violetinė	Purple	43	3.6	6.0	38	11.0	16.4
šviesiai mėlyna	Light *mėlyna*	33	3.2	4.2	13	10.2	5.2
žalsva	Greenish	33	2.5	3.2	10	8.1	3.2
tamsiai violetinė	Dark purple	33	2.4	3.1	6	5.0	1.2
šviesiai violetinė	Light purple	31	3.5	4.3	6	5.7	1.3
melsva	Bluish	29	3.6	4.1	9	11.2	4.0
alyvinė	Lilac	24	2.5	2.4	14	7.5	4.1
šviesiai žalia	Light green	24	1.8	1.7	5	6.0	1.2
elektrinė	Electric blue	20	2.6	2.0	7	7.9	2.2
žalia	Green	20	2.0	1.6	30	6.3	7.5
šviesiai žydra	Light *žydra*	18	3.2	2.2			
pilka	Gray	17	1.1	0.7	9	2.0	0.7
dangiška	Sky-blue	15	2.9	1.7			

2.9 Cultural and Etymological Roots of the Words *Žydra* and *Mėlyna*

As discussed in the previous section, it is now clear that *žydra* and *mėlyna* are two distinct BCTs[13] in Lithuanian. However, it is still unclear why Lithuanians use two terms and English or Norwegian speakers, for example, use only one. According to Bimler & Uuskula (2017), Lithuanian has two BCTs for blue because of its contact with Russian. Indeed, there is a spread of bilingualism and code-switching with Russian, especially in older Lithuanian generations. Lithuanian color naming patterns likely occur because of exposure to novel

[13] The Lithuanian blues might overlap in the blue color continuum judging from Bimler & Uuskula (2017) results.

categories in Russian or through second/third-language acquisition[14]. Thus, such linguistic communities as Lithuanian exposed to another language historically have incorporated a distinction into their own color terminology (Bimler & Uuskula, 2017). However, the younger Lithuanian generation is not exposed to Russian very much. Besides, the placement of Lithuanian *žydra/mėlyna* boundary differs significantly from Russian *goluboj/sinyj*. First, it is not such a clear cut because the two colors may overlap for some speakers, and second, the boundary appears on the lighter end of the continuum. The exact colors used in the present study are given in the Chapter 5. The difference between the Russian and Lithuanian boundaries within the blue color region may indicate that there are other reasons for having the two BCTs and language contact with Russian is not the only rationale. Historical, cultural, and etymological analysis can detect the sources of the words. In this section, we provide the etymology of the two Lithuanian blues and few examples of how the 12th BCT in Lithuanian was used in the texts of the first writers who wrote in Lithuanian. Additionally, Lithuanian blues will be compared to Russian ones.

Since Lithuanian is historically related to Russian, the reasons for the light/dark blue color boundary in Russian shall be considered. According to Paramei (2005), the two Russian blues differ in their connotations in cultural and religious contexts. Thus, *Goluboj* has cultural and religious functions that resulted in its separation from *sinyj*. In accordance with Paramei (2005), the new religion might have brought a new color scheme from Greece. The New Testament in Greek language was not directly translated from Greek to Russian, but rather adopted in the original translation from Greek to Old Church Slavonic. In the religious contexts and the Orthodox paintings, blue was a dominant color of fabrics and clothing in biblical people. Thus, saint Mary was often painted in dark blue attires to show suffering and grief, while *goluboj* "light blue" was used for the background to represent "God's epiphany" (Paramei, 2005, p. 31). Moreover, the Orthodox Church shares similar beliefs with the other Christian churches, therefore it is possible that the two blue color names were adopted by the speakers of other languages through the religious contexts. Lithuanians converted from paganism to Christianity in 1387, and the first Lithuanian texts were printed in around 1503. These texts were prayers, and the two blue color words were not evident in them. It is hard to pin down when the words *žydra* and *mėlyna* were formed and whether religion was the reason for their occurrence, but it might have been one of the reasons. The following examples show the usage of *žydra* "light blue" in the Lithuanian texts of the first writers that wrote in Lithuanian language.

1. ... kuris lino žiedo spalvos, šviesiai mėlynas, dangiškas: Saulelė rieta per skaistitelį **žydrą**, kaip nušluotą dangaus skliautą.

   … which is the color of a linen blossom, light blue, heavenly: The sun rises through a **light blue** swept dome of the sky.

2. Jeigu yra debesys geltoni, šviesi i **žydrì**, ta jau žinok, ka būs pagada.

   If the clouds are yellow, bright, and **light blue**, you should already know that the famine will happen.

3. Dangiškai **žydros** jo akys apvestos tamsiais antakių lankeliais.

[14] It was compulsory to learn Russian as a second language in schools during the Soviet occupation (1940-1990). The older generations (i.e. those born in ~1980 and before) are therefore fluent in it. Nowadays, English is a compulsory second language and only ~40% of middle schoolers learn Russian as their third language. The other 60% choose to learn German or French (Žemaitis, 2020)

Dark eyebrow bows surround his heavenly **light blue** eyes.

4. Beveik visų akys **žydros** ir, žiūrėdamos į kitą žmogų, jos šviečia kaip dangaus ar jūros prisiminimai.

   Almost everyone's eyes are **light blue** and when they look at another person, they shine like memories of heaven or sea. (Lietuvių kalbos žodynas [Lithuanian dictionary], 2020)

The examples of how the BCT *žydra* was used in the old Lithuanian texts suggest that *žydra* "light blue" mainly describes objects found in nature, such as the sky, clouds, and the sea. Moreover, it is often used to describe blue eyes of a person. According to Frumkina (1999), Russian term for *goluboj* "light blue", serves the same function in modern times as Russians cannot describe blue eye color and the common color of sky without using the color name for light blue (Frumkina, 1999, as cited in Paramei, 2005). Moreover, a recent study by Josserand et al. (2021) suggests that speakers in the areas with more sunlight are more likely to speak languages (i.e., Vietnamese) that have only one BCT for both green and blue - "grue". Another finding was that living near a lake as well as in a larger society, increases the chance of having a separate word for "blue" (Josserand, as cited by O'Grady, 2021). To conclude, the environment might also affect color labeling.

Etymologically, most of the BCTs are secondary so that their meanings are derived from other words that name other concepts or objects. For example, in English, orange is not only a color term but also a fruit. Moreover, Polish[15] BCT for blue - *niebieski* was derived from the noun for the sky - *niebo*. Regarding the findings of Berlin and Kay (1969), even if less industrialized cultures have fewer color terms than more industrialized civilizations, they divide the color space in similar places. Thus, it can be speculated that many years from now, the number of BCTs in the world's languages that are less industrialized now will increase too. According to Kabasinskaite (based on a personal conversation, 2021) Lithuanian adjective *žydras* "blue" does have a clear etymological root. Still, many sources speculate that the word is derived from the verb *žydėti* "to bloom", similar to such words as *tikras* "real" derived from the verb *tikėti* "to believe." Specifically, the suffix "*ras"* in adjective *žydras*, is derived from the verb *žydėti* "to bloom." Suppose *žydras* came from the verb that means blooming. In that case, it can be hypothesized that the primary word's derivations were expressions similar to *žydintis mėlynai* "blooming blue" or *žydintis dangiškai* "blooming sky-blue." However, following Kabasinskaite, this approach is problematic for two reasons. One is that historically the occurrence of the verb *žydėti* "to bloom" is late. Another reason is that when the Baltic language was spoken, the word formations with the suffix *-ra-* were not very common. It was typical of the Proto-Indo-European language. Besides, both terms for the color blue in Lithuanian often describe more than one color. For instance, Daukantas[16] used the word *žydra* "light blue" to describe violet color too (*Lietuvių kalbos žodynas* [Lithuanian dictionary], 2018).

The BCT *mėlyna* "dark blue" has a more straightforward etymological trace. Previously *mėlyna* "dark blue" simply meant dark. In the neighboring Baltic language, Latvian *melns* means black, and in Greek, *μελας* (*melas*) means dark or black. Therefore, it is an old word that first meant dark and black and later was developed into other words to describe darker

[15] that are from a neighboring country to Lithuania.
[16] Simonas Daukantas (28 October 1776 – 6 December 1864) is credited as the author of the first book on the history of Lithuania written in the Lithuanian language.

colors, such as *mėlyna*. Moreover, it is evident that the adjective *mėlynas* was used in the times of the Baltic parent language. According to Kabasinskaite, *mėlyna* was also a word in the Proto-Indo-European language. Regarding the Proto-Indo-European language, Mažiulis (1988) speculates that the derivation of *mėlyna* can be made from the verbal stem *$melh_2$- that means 'to smash, to grind' and the suffix *-ina-*. Following this speculation, the primary meaning of the word *mėlyna* was "smashed, darkened." However, to Kabasinskaite, this speculation seemed rather vague.

3 Second Language Acquisition Effects on Color Perception

3.1 Color Terms Acquisition in L1

It is often claimed that color terms are challenging to learn (i.e., Shatz et al., 1996). Therefore, color naming language develops late in first language acquisition. However, the age of color terms acquisition is constantly decreasing in the literature, with 2 years of age being the earliest (Mervis et al., 1995, Shatz et al., 1996). Regardless of L1, children appear to follow similar patterns in their color naming pattern development. Children tend to learn words from their caregivers. The evidence shows that the variance of the earliest children's vocabularies specific to color terminology is correlated with their mother's vocabularies (e.g., Andrick & Tager-Flusberg 1986). Thus, color categories and their boundaries are learned and might be shaped by the culture that surrounds the child (Bornstein, 2007).

Skelton and colleagues (2017) found that infants respond to novel hues, indicating that their recognition memory dissects the color continuum into red, yellow, green, blue, and purple categories. Moreover, the results revealed that infants' categorical divisions aligned with common distinctions in color labels across languages (Skelton et al., 2017). Thus, Skelton et al.'s (2017) findings advocate for color categorization in language being partially biologically constrained. In contrast, acquiring a L2 and its color naming patterns is impacted by biological and environmental factors and differences between the L1 and L2 and other languages one speaks.

3.2 Language Transfer and Attrition

This section explores a variety of concepts in second language acquisition (SLA), including language transfer and attrition. Moreover, ways of how cross-linguistic variation in color lexicons are impacting bi/multilingual minds will be discussed. SLA research contributes to the discussion on language influencing thought by "comparing the psychological reality of linguistic categories in the L1(s) and in the languages learned later in life, with automaticity being one of the key indices of such reality" (Pavlenko, 2016, p. 597).

Recent research manifests that bi/multilinguals do not use either of their languages the way monolinguals do. Besides, according to Cook (2003), most adults in the world are learners or users of a second language; therefore, monolinguals are exceptionally hard to find. A bilingual speaker is not simply two monolinguals' minds put into one: the relationships between languages in a multilingual user's are more complex and interactive in nature. As multilingualism is an inevitable phenomenon today, a great deal of research has gone beyond analyzing only two languages of a speaker to looking at all the languages that one may know. It was widely discussed that bilinguals and multilinguals do not have entirely isolated systems for each of their languages. Still, instead, all the languages interact with one another in the brain. For instance, if we look at a third language (L3), it may be influenced by transferring some linguistic concepts to the L2, by the L1, or both. Also, exposure to a foreign language can make one gain language skills through linguistic transfer. It can make one experience the loss of some linguistic aspects in the other language too. As bi/multilinguals can have very different language backgrounds and experiences, factors such as the context of the acquisition, language proficiency, age of acquisition, and length of language use shall be considered. These factors have been shown to have a strong relationship with similarity scores in Spanish-German bilinguals (Boroditsky et al., 2003). According to Pavlenko (2016), proficiency in a language is then seen as an outcome of perceptual changes.

3.2.1 Transfer

Transfer plays an important role in L2 learning as learner's use of L2 is influenced by their first language. Typically, at the initial stage of L2 learning L2 is more prone to interference or negative transfer from L1, as L1 system transfers and is used to process L2 (Weinreich, 1953). One of the obvious, and often considered negative, examples of language transfer is a "foreign accent", where the phonology in a L2 have similarities to languages learned earlier. Language transfer can be influenced by linguistic, psychological, individual, or contextual factors. Language distance is one of the linguistic factors which determines how similar or distinct languages are. For instance, it is speculated that Indo-European languages came from the same protolanguage, and they are somewhat similar, while, for example, Japanese and English did not; therefore, they are very distant languages. Language groups within Indo-European languages, such as Germanic and Slavic, also classify them as distant or close. In *Linguistics across Cultures*, Lado (1957) proposed the contrastive analysis hypothesis that accounts for the idea that learning a foreign language that is very different from one's native tongue can be more difficult:

> the student who comes in contact with a foreign language will find some features of it quite easy and others extremely difficult. Those elements that are similar to his native language will be simple for him, and those elements that are different will be difficult. (p. 2)

Lado implied that if L1 and L2 are different in some aspects, a negative transfer is likely to occur. He explained that when a speaker acquires an L2, the routines that were established while using the native tongue must be replaced. Thus, language features with low acceptability value are referred to as the negative transfer of interference. On the other hand, high acceptability features are considered positive transfer (Treffers-Daller & Sakel, 2012). As previously suggested, transfer can also be positive. One example of a positive transfer is when a speaker uses cognates from languages that are close to each other. Cognates are words from different languages, but of the same origin, for instance, Norwegian *hus* and English *house*. On a positive note, some findings show that the most contrastive differences of languages do not cause learning difficulties as items that are only slightly different or slightly similar lead to the most problems. Languages' similarities generate the most confusion and negative transfer (Ringbom & Palmberg, 1976; White, 1991). Researchers that follow Chomskyan *principles and parameters* favor Lado's (1957) theory as well. They argue that setting a parameter for the same principle in L1 and L2 when these languages are similar causes positive transfer from the L1 to the L2. And errors are more likely to occur when the parameter settings are different (Saville-Troike & Barto, 2017).

Furthermore, behaviorists consider transfer a source of common errors and interference in the foreign language, because the mother tongue's "habits" are deeply set in a speaker's mind. According to Bergen (2012), one reason why learning a L2 can be difficult is the commitment that a person makes as a child to view a world in a way that the first language allows. More precisely, "the commitment one made to a particular cutting up of the world" that "is hard to let go of" (Bergen, 2012, p. 194). Language transfer is an important phenomenon when a foreign language learner attempts to transfer linguistic patterns of L1 to the L2 usage. Many studies have focused on L1 influence on the other acquired language, while the reverse effect is less researched. L1 categories are often thought to be stable and, therefore, in automatic processing, they are often favored over the L2 categories (e.g., Pavlenko, 2014). Pavlenko (2016) suggests people who grew up speaking only one language or bilinguals speaking languages that are deeply related typologically will mostly realize their L1 categories in their native language. Indeed, languages learned at an early age tend to trigger memories, imagery, affective processing, embodied simulations, and implicit knowledge of situations to which they apply. Whereas, if the language is learned later in life, this is not the case (Bergen, 2012; Keysar, Hayakawa, & An, 2012, as cited in Pavlenko, 2016). However, if a speaker is exposed to the foreign language more and achieves higher proficiency, L2 categories can destabilize the L1 patterns. For instance, English and Russian speakers perceive and express certain kinds of causal interactions differently (Wolff and Ventura, 2009). Wolff and Ventura (2009) found that learning L2 Russian for Americans can have consequences for the underlying conceptual system. These learners showed more variability in L1 English attribution of causality after living in Russia for only six months. Another study by Kartushina & Martin (2019) revealed that intensive 2-week L3-English use impacted vowel production in both L1 and L2 for Spanish-Basque bilinguals. Notably, linguistic transfer can go beyond the interaction of L1 and L2 and the theory of multi-competence by Cook (1991) investigates the relationship between all the languages in the mind. Therefore, an L3 may influence an L2 or an L1. For instance, Wrembel (2011) has shown that L3 production of stop consonants in voice onset times is affected by both L1 and L2. L2 learners often experience major difficulties in producing non-native speech sounds. In conclusion, transfer defines the linguistic patterns moving from one language to another. It is not restricted to only two languages and can move both forwards and backward. Significantly, learning a new language with a distinct linguistic pattern can change or at least contribute to the way one views the world.

3.2.2 Attrition

Yet, there is a danger of linguistic patterns disappearing when a speaker uses an L2 more frequently on a daily basis. Specifically, immigrants that are less exposed to L1 might experience attrition of L1 concepts. Language attrition indicates loss of language skills and is usually explained as the non-pathological decrease in a language that an individual had previously acquired or a malfunction in the relationship between the languages (Kopke & Schmid, 2004). Schmid (2014) refers to attrition as the phenomenon of L1 change and L2 interference. One practical example of language attrition would be an adopted child. From the moment of entering the L2 environment, a new family in a different country, an adopted child is isolated from their L1. In the cases like this, L1 loss can be irremediable (i.e., Ventureyra, Pallier & Yoo, 2004). Contrary, for late adult bi/multilinguals, usually, attrition does not mean vanishing one of their languages. In phonology, for instance, some aspects of language accent can change because of living in an L2 environment, while the others will remain. A study of a Dutch-English bilingual subject and her Dutch monolingual monozygotic twin introduced a uniquely controlled setting for making observations on this phenomenon. In both experiments of the study by Mayr, Price & Mennen (2012) the bilingual twin showed attrition in some features of a native-like L1 accent, but not in all features distinct to Dutch. Moreover, Kartushina & Martin (2019) reported that early Spanish-Basque bilinguals' vowel production of L1 and L2 was influenced by intensive 2-week use of L3-English. However, once the learners were back to their L1 country, their vowel production was back to the norms, which indicated that changes in production are reversible. Furthermore, Vulchanova's et al. (2020) findings on first-generation Spanish immigrants in Norway suggest that living in the L2 environment (for Spanish immigrants in Norway) can pressure deictic referential systems of L1 to change. Additionally, in Athanasopoulos & Kasai (2008) study, Japanese-English bilinguals had been shown to have altered their similarity judgements of countable objects and non-countable substances. Their similarity judgments were close to those of monolingual English speakers. It was confirmed that increased proficiency in L2 is the best predictor of the degree to which these bilinguals will shift their concepts.

3.3 Multi-competence of Color Terms in the Mind

The theory of multi-competence essentially means "knowledge of two or more languages in one mind" (Cook, 1991, p. 1). Multi-competence theory brought into question how bi-/multilingualism affects cognition or perception. If the L1 linguistic categories can constrain and shape the way we perceive time, space, and colors, then what happens when we learn that our L2 has a different categorizing pattern? Speakers that use more than one language as subjects in a study can offer an opportunity to examine whether human cognitive representations are static or dynamic when exposed to a new language. To explore the cognitive and perceptual differences between monolinguals and bi/multilinguals, the researchers test speakers of more than one language on the domains in which cognitive or perceptual differences have been shown to occur between monolinguals of distinct languages. A myriad of studies has been conducted on the effects of learning two languages on speakers' color perception. Caskey-Sirmons and Hickerson (1977) found that L2-English bilinguals from different linguistic L1 backgrounds have shifted their L1 color terms prototypes towards the English prototypes. In the context of attrition of color categories, research shows evidence of such attrition in obligatory color contrasts decrease in Greek-English bilinguals (Athanasopoulos, 2009). Another study by Athanasopoulos et al. (2011) reports that increased usage of English in Japanese-English bilinguals resulted in worse distinction of different shades of blue as two different colors, as they are in the Japanese linguistic system. These and many other findings conclude that exposure to a new language and culture might change color perception patterns (Cook, 2016). The changes in perception or cognition can also be seen in the physiology of the brain. Learning a new concept in a foreign language can lead to changes in the brains' physical structures. Kwok et al. (2011) found that learning newly defined and named color terms of green and blue for only 2 hours increases the volume of gray matter in the left visual cortex.

It was established that experience with a foreign language can change L2 user's color perception. Yet again, it is difficult to say in what way does it change. Understanding of how L1 language attrition and L1 transfer operate in L2 learners is crucial. According to Athanasopoulos et al. (2011), investigations on linguistic relativity principle have shown that speakers whose languages categorize colors in different ways tend to "display variable cognitive behavior, sometimes resembling monolingual speaker of their L1, sometimes resembling monolingual speaker of their L2, but most of the times falling somewhere in-between" (p. 10). In multi-competence theory, there are more variants of bi/multilingual thinking. L2 speakers can have "a single set of ideas in mind, more than one set of ideas, a merged set from different languages, or a new set of ideas unlike the sum of its parts" (Cook, 2003, p. 2). These different variants of the minds of bi/multilinguals shall be considered when looking into speakers of languages that cut the color continuum in different places. Cook (2016) explained a possible explanation of how speakers see colors, depending on how many and which languages they speak. It is exemplified by the research of Athanasopoulos (2009). Figure 3.1 illustrates, hypothetically, how a monolingual native speaker of a language that recognizes two distinct colors of blue, for example, Greek *ble* "light blue" and *ghalazio* "dark blue" (Athanasopoulos, 2009). At some point in their lives, these speakers acquire a language that has only one word to describe the whole blue color continuum, for example, English blue. Following Cook (2016), we describe four possible scenarios for L2 users' change in conceptual representations of colors. We will report these scenarios following their example of Greek-English bilinguals and complement it with Lithuanian-Norwegian speakers' case.

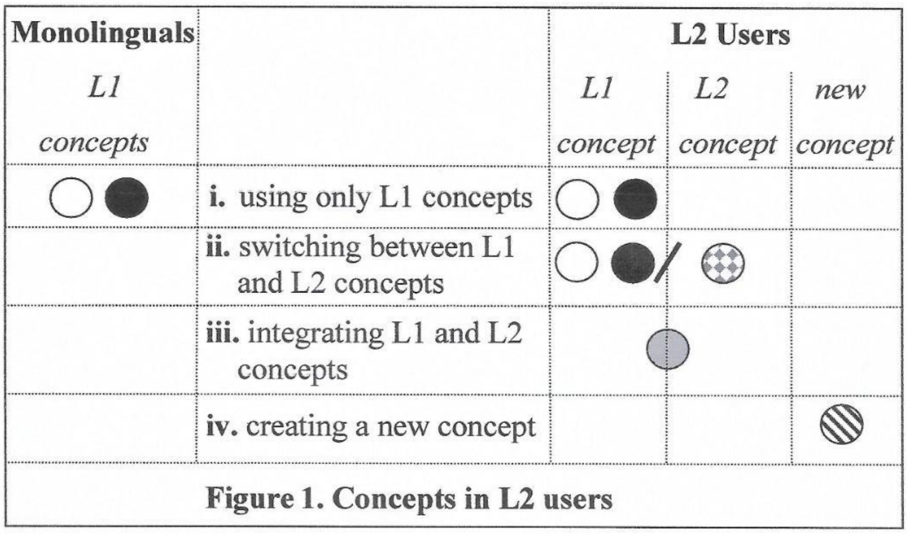

Figure 3.1: Concepts in L2 users. From "Transfer and the relationship between the languages of multi-competence" by V. Cook, *Crosslinguistic Influence in Second Language Acquisition*, 24, p. 35. Copyright 2016 by Walter de Gruyter GmbH.

i) The first scenario is entitled the one-concept scenario. In a one-concept scenario, speakers do not perceive colors differently when they learn a new language. The same concept from L1 is used across all the languages regardless of which they are using. For instance, Greek bilinguals will still cut the blue color continuum into *ble* and *glazario* in their mind, even if they use English single blue term. Similarly, a Lithuanian person who has learned Norwegian will still think in terms of two colors equivalent to *žydra* and *mėlyna* even when using the Norwegian word *blå*.

ii) The second scenario is referred to as the double-concepts scenario. In the double-concept scenario, L2 users switch concepts according to the language they are speaking. Thus, when they speak their first language, they are using L1-related concepts and when they speak their second language, they are using L2-related concepts. In this model, bilingual minds hold two sets of concepts. So, the Greek-English bilingual speaker will cut the blue color continuum into two parts when using Greek, while they will think in terms of one blue when speaking English. Similarly, a Lithuanian-Norwegian speaker will think in terms of two blues when using Lithuanian but only one blue when speaking Norwegian.

iii) The third model is a one-integrated-concept scenario. Following the third scenario, the speakers endorse a single concept that combines the L1-related and L2-related concepts. This sort of thinking differs from monolingual native speakers of both languages. In other words, a Greek-English speaker will create a new concept of blue in their mind which is a compromise of Greek two blues and English one blue. Similarly, a Lithuanian-Norwegian speaker will have neither the two Lithuanian blues nor the single Norwegian blue but a color that is a compromise between the two.

iv) The fourth scenario is called the original concept scenario. The final possibility is that L2 users conceive a new concept that is not intermediate between the L1-related and L2 concepts as something different. Here, The Greek-English speaker will not think of blue color continuum as cut into light and dark but would create an original blue concept. Same for Lithuanian-Norwegian speakers - they will not think of blue in terms of the dark/light difference but might have a blue that is characteristic of neither language. This scenario is seen in the study of Athanasopoulos (2009) in which Greek-English L2 users have a concept of *ghalazio* "light blue" that is lighter than for Greek monolinguals.

The given models illustrate four different scenarios of the relationships between L1 and L2 color concepts for Greek-English and Lithuanian-Norwegian L2 users. In the first scenario, the user remains not affected by the L2 concepts, in (ii) the user switches between the L1 and the L2 concepts, and in (iii) the L1 and the L2 concepts are combined so that the L2 user does not think like an L1 user of either language. Thus, (ii) and (iii) scenarios incorporate linguistic concepts' transfer and attrition that were previously discussed. The (ii) scenario also exemplifies concept switching that we did not discuss previously. According to Bialystok (2008) bilinguals and L2-learners deviate from monolinguals because they switch between different languages' codes all the time. When an L2 user is concentrated on only one of the languages, the other language still influences the language in use, and the transfer moves both directions between the languages in the mind (Cook, 2008).

However, the last scenario (iv) is different from the first three. In the fourth model, something is created that is not predicted by the relationship between L1 and L2: a new concept has been created. According to Cook (2016), "the interesting problem for [second language acquisition] "research is describing things that cannot be anticipated from the given, the cases when 2+2=5" (p. 35). Therefore, not only measuring L2 user on a monolingual standard is not giving a fair result, but also combining L1 and L2 in one L2 speaker is "inadequate as the unique constructs of the L2 user elude an analysis built only on the L1 and L2; comparison is not enough" (Cook, 2016, p. 35).

4 The Present Study: Hypotheses

The "basicness" of two Lithuanian BCTs for blue was reported by Bimler & Uuskula (2017), where *žydra*, Lithuanian term for "light blue", was confirmed as a BCT. In the present study, we aimed to investigate Lithuanian blues in a color-matching task. In line with previous research (Roberson & Davidoff, 2000; Winawer et al., 2007), we assumed that native speakers of languages with different linguistic categories for color will perform on color matching tasks differently. Besides, recent research has indicated that bilinguals with languages that differ in grammar and lexical categories may adapt their L1 mental representations to those matching monolingual speakers of their L2 (i.e., Athanasopoulos, 2009). The current study aims to extend this line of research to the domain of color perception in native Lithuanian speakers who live in Norway and use L2 Norwegian in their everyday life. Lithuanian differentiates the blue color continuum into a darker shade called *mėlyna* and a lighter shade called *žydra,* while Norwegian does not. It is expected that Lithuanian-Norwegian bilinguals' performance in the color matching task will be affected by both their L1 Lithuanian and L2 Norwegian. In contrast, native Norwegian speakers and Lithuanian monolingual speakers are expected to match colors in line with the linguistic categories existing in their L1 since they live in the L1 environment.[17]

The current thesis project will conceptually replicate the design of Winawer et al. (2007): the color-matching task will require low memory demands, and the results will focus on on-line language effects. In line with the study on Russian blues, we expected that for Lithuanians, when the matching target and the alternate color belong to categories referred to with different words (one belongs to the category of *žydra* and another belongs to the category of *mėlyna,* between-category color exemplars), it will be easier to match colors, and the response times are expected to be shorter. However, if both colors represent one color word (within-category color exemplars), the trial is more challenging, and response time is expected to be longer. In accordance with the Russian blues study's results (Winawer et al., 2007), we also expected the effect of color distance to be present for all our participants, as colors that are near each other in the color continuum are harder to discriminate than color that are far from each other, see Chapter 5 for details.

Besides, studies have shown that the cross-linguistic effects can be modulated by verbal interference. Winawer et al. (2007) reported that verbal interference reversed the CCE while, Gonzalez-Perilli et al. (2017) noted that verbal interference increased the CCE. These findings suggest that language activation mode can momentarily influence color perception. A verbal interference task will be employed in the present study to examine whether the CCE will be affected the "active" language. *Multi/bi*linguals usually make sure that they use just one target language and suppress the irrelevant languages, for example, when having a conversation. The aim of performing the verbal interference task in the two target languages for the Lithuanian speakers of Norwegian in Norway is to evaluate whether the language currently being "active" modulates the categorical perception response. In the verbal interference task, monolingual groups of Lithuanians and Norwegians will act as controls. The theories formed by relevant research provide an essential background for the hypotheses of the current study. Three null hypotheses and

[17] The control group was recruited in Lithuania to check whether their responses in the experiment differ from Lithuanians' who live in Norway and, therefore, are exposed to L2 Norwegian daily.

their alternative hypotheses were formed for the two task conditions with and without verbal interference:

1. **H0:** The differences in linguistic categories for the blue color in Lithuanian and Norwegian will not result in significant CCEs in terms RTs between the Lithuanians in Lithuania (LL), Lithuanians in Norway (LN), and Native Norwegians (NN) participants' groups in the color matching with no verbal interference.

   H1: Differences in linguistic categories for blue color between Lithuanian and Norwegian will result in differences in RTs: Lithuanians (LL and LN) will be slower to match shades of blue within the same category (both *mėlyna* or both *žydra*) than between categories, while NN will not show similar CCE.

2. **H0:** RTs in the color matching task under verbal interference will not be affected by the differences in linguistic categories, therefore there will be no differences in the two monolingual groups (LL and NN) between the RTs in the matching without and with the verbal interference condition.

   H2: Following the previous research (i.e., Winawer et al., 2007), the verbal interference task will affect the CCE in terms of RTs: LL will no longer be faster to discriminate blue colors between the categories (one *žydra* and one *mėlyna*) and slower within the category (both *žydra* or both *mėlyna*) as they will be matching all the color in similar speed; NN's color matching results will not be affected.

3. **H0:** RTs of LN under verbal interference will not be influenced by the language in which the color-matching task will be performed (Lithuanian vs. Norwegian), because their ability to use language will be disrupted.

   H3: The language in which verbal interference will take place for LN, will affect their CCE in one of the three possible ways, based on four Cook's (2016) scenarios presented in Section 3.3: 1) the CCE will occur in both languages for LN, as they will strictly use linguistic categories relative to their L1 (*žydra* and *mėlyna*), 2) the CCE will not occur under verbal interference in L2, because this language has only one linguistic category for blue (blå). In contrast, CCE will occur once the task will be displayed in L1, because this time LN will be thinking in terms of the two linguistic categories in L1, and 3) the CCE's will only occur to some extent in both L1 and L2, as LN will be integrating color categorization of both languages into one concept while matching colors. *H0* was found for monolingual Russians in Winawer et al. (2007).

5 Methods

5.1 Participants

A total of 112 participants[18] took part in the study; they were divided into three groups: (1) native Norwegian speakers (NN), (2) native Lithuanian speakers living in Norway (LN), and (3) native Lithuanian speakers living in Lithuania (LL). The former two groups were tested in the *BabyLing* laboratory at the Department of Psychology at the University of Oslo, whereas the latter group was tested in the laboratory at the Kaunas University of Applied Engineering Sciences (Kaunas, Lithuania). For the sake of simplicity, we referred to participants who were native speakers of one the target languages (LL and NN) as monolingual and to participants who knew both languages (LN) as bilinguals, even though all the participants knew more than one language. The material, the laptop, the screen, and the programs to run the task were exactly the same across the two labs in Oslo and Kaunas. The testing rooms between the university are very similar: small rooms, with no windows and dimmed light.

5.1.1 Lithuanians living in Lithuania

The first group consisted of 41 native Lithuanian speakers [*Lithuanians living in Lithuania*; henceforth (LL)]. There were 8 males and 33 females, with a mean age of 32 years (32±8.87; *M*±*SD*, ranging from 17 to 45). The subjects were native Lithuanian speakers living in Kaunas. Out of 41 participants, 37 reported knowing English, and 25 reported knowing Russian. Also, some participants documented knowledge of German, and Polish (Appendix 7). English, German, and Polish only have one BCT for blue, while Russian has the light/dark blue color distinction.

5.1.2 Lithuanians living in Norway

The second group consisted of 36 native Lithuanian speakers [*Lithuanians living in Norway*; henceforth (LN)]. All LN subjects reported using Norwegian in their everyday lives and in all major language-use settings including listening, speaking, writing, and reading. 4 LN subjects were excluded from the analyses, because of low proficiency and lack of exposure to Norwegian (see Appendices 3 and 4 for details). 1 LN subject was excluded because it was impossible to determine their light/dark blue color boundary as all the colors in the identification task were identified as *mėlyna* "dark blue", see Section 6.2 for details. Lithuanians recruited in Norway were first generation immigrants. Out of 31 remaining participants there were 4 males and 27 females, with a mean age of 33 years (33±7; *M*±*SD*, ranging from 19 to 49). Their ages of Norwegian language acquisition varied between 5 and 43 years of age, where the mean acquisition age was 24 years. The proficiency and exposure to Norwegian also varied, as illustrated in the Appendices 3 and 4. Moreover, all LN participants reported knowing English. The mean age of acquiring English was 10.2 (ranging from 6 to 26). Out of 36 participants, 25 reported knowing Russian (7.8, ranging from 0 to 26). They also reported knowing other languages (Appendix 6).

[18] The sample size was constrained by the available resources and the MPhil thesis time frame.

5.1.3 Native Norwegians

In the third group, there was a total of 35 participants that consisted of 14 males and 21 females, with a mean age of 25 (25.26±4.29; *M±SD*, ranging from 21 to 33). The subjects were *Native Norwegian* speakers living in Oslo*,* henceforth (NN). Crucially for our study, none of the Norwegians reported knowing languages that cut the blue color continuum into two. The languages that they reported knowing were French, German, Swedish, Danish, Arabic, Spanish, and Macedonian (Appendix 8). To the best of our knowledge, all the reported languages have a single-color term for blue.

5.1.4 Differences in age

We performed three t-tests to see if the differences in age between the participant groups were statistically significant. First, the ages of Lithuanians who live in Lithuania and Lithuanians who live in Norway were statistically not different [t = 0.26197, df = 69.078, p= 0.7941]. Second, Norwegians (NN) age differed significantly from Lithuanians who live in Norway (LN) [t = 4.9853, df = 46.555, p<0.001], and Lithuania (LL) [t = 4.5523, df = 59.738, p<0.001]. This is likely due to the fact that most of the Norwegian participants were students from the University of Oslo, while Lithuanians presented a more varied general population.

5.2 Stimuli

Before starting the project, we considered using the same stimuli as in Winawer et al. (2007) for Russian, which were kindly provided by the authors. However, following the initial piloting that aimed to identify the "ideal" *žydra* and *mėlyna*, in Lithuanian, the resulting colors did not match the original Russian terms for blue *goluboj* and *sinyj*. Consequently, we created our own stimuli, after having assessed, in a different sample of 105 native Lithuanian speakers, the prototypical light and dark blues, *žydra* and *mėlyna*. The study was implemented as an online survey, where participants had to identify the two ideal colors, representing *žydra* and *mėlyna* from the Munsell color chart, favored by many researchers in the field (i.e., Kay et al., 1991; Regier et al., 2005). The World Color Survey stimulus palette based on the Munsell color chart is given in Figure 8.

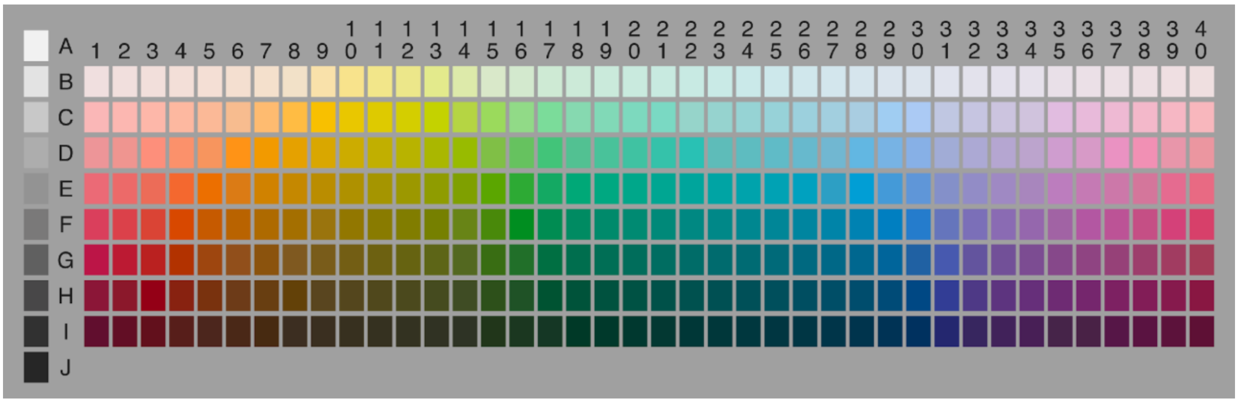

Figure 8.: Munsell color chart. From http://www.icsi.berkeley.edu/wcs/data.html

Out of 105 responses, the most frequently chosen color squares for each blue color were converted into Munsell values, namely, 5PB 5\12 for *mėlyna* (36 responses) and 10B 7/8 for *žydra* (25 responses). The remaining respondents picked other colors. The first number in the Munsell notation represents the hue or color (i.e., 5PB). The second number that is followed by the slash symbol (/) stands for the value (i.e., 5), which determines how light or dark the color is. The last number in the notation stands for chroma, which determines how weak or strong the color is (i.e., 12). The text version of the Munsell color chart with the explanations on how to read it can be found at the World Color Survey data archives. The detailed information about the two prototypes as identified by Lithuanian speakers is given in Table 5.1.

Table 5.1: The color data of the two prototypes for blue color in Lithuanian

MĖLYNA (dark blue)	**ŽYDRA** (light blue)
5PB 5\12 Munsell Color system	10B 7/8 Munsell Color system
sR = 45.955	sR = 106.814
sG = 123.726	sG = 182.830
sB = 213.821	sB = 237.650
CIE-L*ab = 51.576 8.129 -52.944	CIE-L*ab = 71.596 -8.211 -34.486
CIE-L*Ch(ab) = 51.576 53.564 278.729°	CIE-L*Ch(ab) = 71.596 35.450 256.608°
CIE-L*uv = 51.576 -26.501 -82.650	CIE-L*uv = 71.596 -33.175 -54.167
CIE-L*Ch(uv) = 51.576 86.794 252.222°	CIE-L*Ch(uv) = 71.596 63.519 238.514°

To create our stimuli, we interpolated the two color chips chosen as the two prototypical blue colors by Lithuanian participants, using the following procedure. First, the prototypes' Munsell values were converted into the RGB color space by a color converter (Werth, n.d.). However, when interpolation is performed in RGB color space, the colors in the middle of the color continuum appear to be greyish. In addition, RGB color space does not represent how humans perceive colors (Zucconi, 2016). Thus, RGB values of the prototypes were further converted to values in the *Cielab* color space on the *easyrgb* website (IRO Group Limited, n.d.) Finally, the *Cielab* values were then used for the interpolation using the chroma.js library tool on *GitHub* (Aisch, n.d.). The twenty-step color interpolation between the two prototypes resulted in very similar steps judged too hard to discriminate between them when compared to the interpolated grid used in the Russian blues study (i.e., Winawer et al., 2007). Therefore, instead of having the prototype colors as the first and the last steps in the continuum, we decided to place them as 3rd and 18th steps, to have additional 2 colors on each extreme of the continuum. To clarify, we interpolated the colors between the two prototypes into 16 interim steps. Thus, in Table 5.2, the 3rd step on the continuum is the prototype of *žydra* "light blue", and the 18th step is the prototype of *mėlyna* "dark blue".

Table 5.2: Chroma.js interpolation. Correct lightness + Bezier interpolation

	L (lightness)	**c (chroma)**	**h (hue angle)**
1	74.099	32.685	253.843°
2	72.847	33.697	256.103°
3	71.523 (71.596)	34.438 (35.450)	257.997° (256.608°)
4	70.237	35.640	260.446°
5	68.908	36.466	262.202°
6	67.532	37.422	263.604°
7	66.240	38.770	265.782°
8	64.904	39.705	267.369°
9	63.567	41.222	269.101°
10	62.227	42.226	270.583°

11	60.890	43.815	272.190°
12	59.506	44.941	273.351°
13	58.171	46.593	274.867°
14	57.069	47.266	275.323°
15	55.738	48.966	276.795°
16	54.321	50.218	277.724°
17	52.997	51.976	279.143°
18	51.587 (51.576)	53.269 (53.564)	280.084° (278.729°)
19	50.496	54.577	280.655°
20	49.075	55.918	281.543°

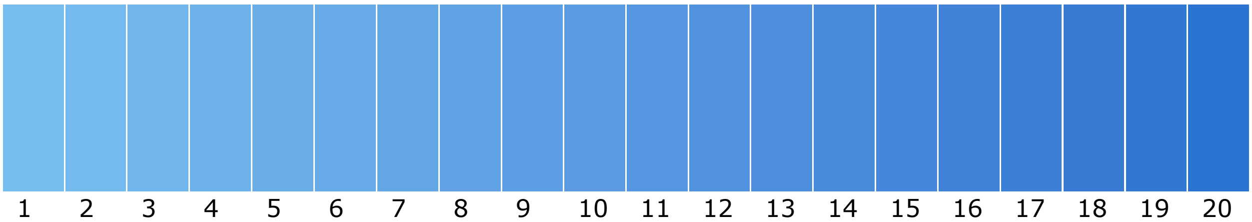

Figure 5.1: Linear color interpolation of the blue color used in the current study. Lithuanian prototype of *žydra* is at the 3rd step, and the Lithuanian prototype of *mėlyna* is at the 18th step

Each distinct color patch in the color continuum from 1 to 20 (Figure 3) is an equidistant color step. The steps were combined to make far and near color comparisons for the color matching tasks. Near color comparisons consisted of one target color and one alternating color, that is two color steps away from the target stimulus. In far color comparison, alternate colors were four color steps away from the target color. For instance, if the target color was *blue 1,* it was combined with *blue 4* to make a near color comparison. Whereas, to make a far comparison trial, *blue 1* was combined with *blue 6*.

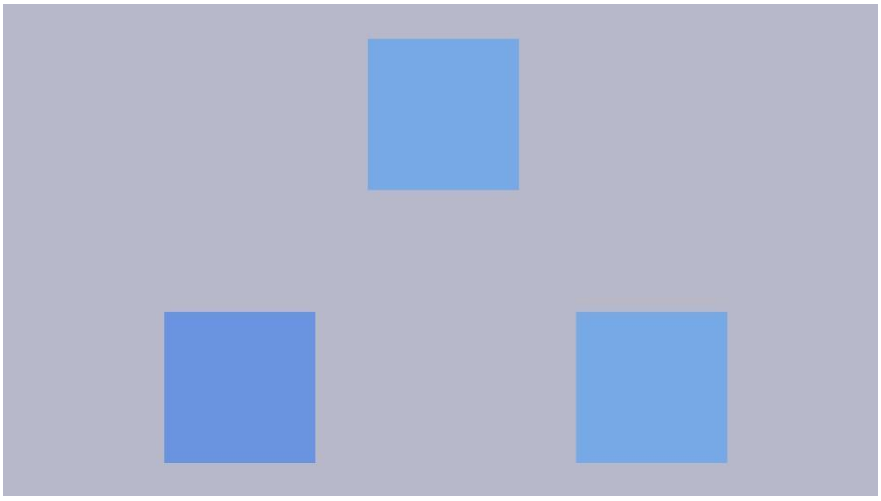

Figure 5.2: An example of one color matching trial (far comparison) in which participants were asked to match the top colored square with one of the bottom squares

5.3 Procedure

The participants were recruited through personal network, social media and flyers distributed at the University of Oslo and at the Kaunas University of Applied Engineering

Sciences. Lithuanian participants in Norway were recruited with the help of the Lithuanian embassy, various expat communities, clubs, and social media groups. Those participants, who expressed their will to take part in the study, provided their emails that were used in the email communication. In the first e-mail, participants received a document consisting of all the necessary information about the study and the consent form. The consent form is provided in Appendix 1. They were informed that their participation was voluntary, what the participation entails and what to expect during the experiment. Participants were told that their personal information would be kept confidential, secured, and destroyed after completing the project.

This study was approved by the NSD (reference number 476510) in September 2020. Native Norwegian and Lithuanian speakers living in Norway were also informed that after the study was completed, they would get a chance to win a 400 kr gift card as a token of appreciation. Subjects in Lithuania were reimbursed with gift cards. Participants randomly drew out which gift card they will get: 15 participants got 10-euro worth gift cards, 10 participants received 7-euro worth gift cards and 10 subjects got 5-euro worth gift cards. The rest of the participants (6 subjects) volunteered free of charge.

Finally, all participants were informed that the study would consist of two parts. The first part required them to fill out a self-reported language proficiency questionnaire that was administered using *Nettskjema (*Norwegian web-based survey platform). The consents of participation were collected electronically at the beginning of the questionnaire. The second part required taking part in a 30-minute-long behavioral experiment that took place in the laboratories in Oslo and Kaunas (see Section 5.1).

5.3.1 Materials

The behavioral tasks were performed in a laboratory to ensure that all participants completed the tasks on the same computer, screen and within the same light conditions. The room where the experiment took place was quiet and had deemed lights. The same Dell UltraSharp™ U2412M monitor was used throughout the study to display stimuli, both in Norway and in Lithuania. The chosen monitor has IPS technology, which ensures an accurate display of colors and ensures consistency across a broad viewing angle (*Dell U2412M | Dell Croatia*, 2021). Nonetheless, the subjects viewed the screen from approximately 75 cm, and they were instructed to stay in the same position during the whole examination[19].

5.3.2 Language experience questionnaire

The Language and Social Background Questionnaire (LSBQ; Anderson, Mak, Keyvani Chahi, & Bialystok, 2018) was translated into Lithuanian and Norwegian, adapted, and used to measure participants' language experience. Participants were asked to fill in the questionnaire online before coming to the experiment. The questionnaire contained three sections (Appendix 2). The first section gathered information on gender and age. LN were asked, in addition, how long they have been living in Norway. The second section assessed which language(s) the participant can understand and speak, where the language(s) were learned or acquired, and at what age. Moreover, subjects had to self-rate their proficiency in speaking, understanding, reading, and writing in every indicated language, where 0 indicated no ability at all, and 100 indicated native fluency. The exposure to the languages participants knew was also measured. We asked participants to self-rate the frequency of speaking, understanding, reading, and writing, where 0 was never and 4 indicated all the

[19] If a participant changed their head's position, the color distribution was barely affected by it.

time. The third part of the questionnaire was not used in the analysis as it was developed for bilinguals and weighed only two languages, while most of the participants reported knowing more than two languages and it was unclear to which language they are referring to when answering questions in the third part of the questionnaire. A copy of this background questionnaire is provided in Appendix 2.

We aimed to only select proficient L1-Lithuanian speakers of L2-Norwegian therefore we adapted and used the excel spreadsheet that counts bilingualism scores provided by Anderson et al (2018). Since our participants reported knowing more than two languages, we adapted the excel spreadsheet to only measure proficiency and exposure to the L2-Norwegian. Self-reported levels of Speaking, Understanding, Reading, Writing) and Writing Frequency (where 0 indicates no time spent and 4 indicates all the time) were used as the variables to measure proficiency. Speaking, Listening, and Reading frequencies (where 0 indicates no time spent and 4 indicates all the time) as well as Years lived in Norway and Age of Acquisition were used as the variables for calculating the exposure to Norwegian. Appendix 5 provides an example of how we computed the proficiency and exposure scores. To exclude those participants who were not fluent in Norwegian, the cut off values were derived. If the participant 's overall proficiency and exposure scores were lower than the cut-off values, the participant was excluded from the study. The cut-off value depended on This resulted in the loss of four LN subjects (Appendices 3 and 4).

5.3.3 Behavioral color-matching experiment

Participants were tested in the dim-lighted room. The experiment involved three behavioral tasks: a color matching task without verbal interference, a color matching task with verbal interference, and a color identification task. The LN were asked to perform the task with the verbal interference condition twice, once in Lithuanian and once in Norwegian. The participants' categorical judgments on colors were tested following the design of Winawer et al.'s (2007) study. The sequence of the tasks was the same for all the participants: 1) they performed a color matching task without interference, 2) the same task was performed under verbal interference (for LN in Lithuanian first and in Norwegian second), and 3) they were asked to perform the color identification task. The tasks were run using the DMDX software developed at Monash University and at the University of Arizona by K.I.Forster and J.C.Forster. This software was adopted to precisely time the visual stimuli of colors and allowed us to measure reaction times (RTs) in millisecond accuracy.

5.3.3.1 Color Matching Task

Color matching task 1 aimed to compare LL, LN, and NN participants' discrimination of light and dark blue shades. On each trial, participants saw one color square on the top of the screen and two color squares on the bottom of the screen (Figure 5.2). Participants had to choose, by pressing a key on the keyboard, which of the two bottom squares matched the top square best. The side of the matching color was counterbalanced. The order of trials was randomized across participants. Participants were instructed to answer as quickly as possible. There were 64 color trials, and each trial was repeated twice (in total 128 trials). Reaction times (RTs) from the color trial on-set until a participant responded (pressed the right or left shift key button) were used as a measure of the speed of color discrimination. After participants responded, the next color trial was displayed immediately. Participants always had 3 seconds to answer and if they did not provide a response by pressing left or right shift key within the given 3 seconds, the color trial would automatically change into a new one. There were no breaks in between the trials and the cross sign (X) was not displayed at the beginning of each trial.

5.3.3.2 Color Matching Task with Verbal Interference

Task 2 was identical to the task 1 but this time it was performed with verbal interference, following the Winawer et al. (2007) study's design. For LN, the verbal interference task was performed, separately, in Norwegian and Lithuanian. The verbal interference condition required memorizing and silently rehearsing, for 8 trials in a raw, a combination of numbers, while simultaneously completing, on each trial, a color discrimination task. Each combination of numbers consisted of 8 random digits. Participants had to listen to a recording of the digits while looking at a blank computer screen. When the recording was over, the color matching trials started automatically. After the completion of the 8th color trial, on the 9th trial, a participant saw two different 8-digit combinations on the left and right sides of the screen. One combination was the one that was played at the beginning of the 1st color trial, whereas another combination, differed by one digit. Participants had to choose the correct combination by pressing the left and right shift buttons on the keyboard. Then, on the next, 10th trial, participants would hear, again, a new combination of numbers and would have to pass 8 color discrimination trials following by a forced-choice number identification trial, and so on. Importantly, the combination of numbers would always be heard in one language, either Lithuanian or Norwegian for LL and NN, respectively. LN passed the task in both languages. Similarly, to the Task 1, there were 64 color trials, and each trial was repeated twice. In addition, there were 16 digit trials and 16 trials when participants listened to the recordings of the digit combinations while looking at a blank computer screen. There was no break after the recordings of the digits and the color trials were displayed immediately after the recordings were over. As in the task 1, the color trial was present until the response to it was given. Participants always had 3 seconds to choose the right color (in color matching trials) or the correct digit combination (in forced choice digit trials) by pressing left or right shift buttons on the keyboard. If they did not provide choose the digit or color within the 3 seconds, a new recording of a new digit combination would be played automatically. There were no breaks in between the trials and the crosses (X) were not displayed at the beginning of each trial.

5.3.3.3 Color Identification Task

After completing color matching tasks with and without verbal interference, each participant was examined, in an additional color identification task to replicate the procedure of Winawer et al. (2007) study. In this task, 20 stimuli of light and dark blue shades (Figure 5.1) were shown to the participants (twice each) in a random order. Subjects were asked to decide whether the color square on the screen is *žydra/lyseblå* or *mėlyna/mørkeblå*. Two stickers with the words *žydra/lyseblå* and *mėlyna/mørkeblå* written on them were attached to the left and right shift keys. All three groups of participants performed this task. Data from this task was used to determine participants' individual category boundary for the blue color continuum from light to dark. The location of the individual category boundary for each participant will be used in the analyses.

5.4 Data Analysis

We adopted a similar analysis pipeline as in the previous studies (e.g., Winawer et al., 2007, Martinovic et al., 2020). The statistical analysis of the identification task was performed in MATLAB (The MathWorks, 2010). Color matching tasks' analyses were performed in R (R_Core_Team, 2016), using packages: *gtools* (Warnes, Bolker, & Lumley, 2015), *lme4* (Bates, Maechler, Bolker, & Walker, 2015), *doBy* (Højsgaard & Halekoh, 2016), *lsmeans* (Lengh, 2016, and *effsize* (Torchiano, 2020). The following section includes an in-depth analysis and discussion of the results.

6 Results and Discussion

This chapter presents the data collected during the color matching experiments. We explain how it was analyzed and report the results derived from the analysis. First subchapter describes identification of the individual color boundaries for each of our participants. Subsection 6.2 was dedicated for the color matching tasks. In the first part of this subsection, we describe the data units that had to be discarded before the analysis. Further we explore the overall trials accuracy, the model that we used for the statistical analysis, and how we reported the statistical significance. The subsections 6.3.6. and 6.3.7. report the results of the color matching tasks with and without verbal interference. Further, we discuss our findings in the Subsection 6.4. In the discussion we focus on the results of the two behavioral tasks, unexpected obstacles, and limitations of the current study. The last subchapter provides advice for the further research as well as describes our contribution to language science.

6.1 Identification Task

First, there was a need to determine each subject's linguistic color boundary within the continuum of the blue color stimuli that were used in this study. As it was mentioned in Section 5.2.3., the identification task was performed to determine each subject's boundary as the transition point in the categories. Each color from the color continuum (Figure 5.1) was shown twice. If the cut in the color continuum was not clear or was placed between two stimuli, then, similar to previous research (Winawer et al., 2007; Martinovic et al., 2020), we always chose the longer reaction time (RT) to decide on the individual boundary. In detail, we adopted the following rules to disambiguate the boundary: first, in cases when a color was identified as *lyseblå/žydra* on one trial and as *mørkeblå/mėlyna* on the other, we favored longer RT to determine which color that was. Second, occasionally the first color identified as dark blue was followed by several colors identified as light blues. If these light blues that occurred after the first dark blue had shorter RTs, the boundary remained at the first color identified as dark blue. However, if these light blues had longer RTs (than the first dark blue in the continuum), we chose the next dark blue that had longer RT. As stated in previous research, longer RT indicates that participants spent more time thinking about the classification of that colored square; therefore, it is more reliable (Bornstein, 1984, p. 46, as cited in Winawer et al., 2007). One LN participant was excluded because their performance on the identification task did not show any boundary as all the colors were identified as *mėlyna*.

We visualized the data of the identification task across the three participant groups in Figures: 6.1, 6.2 and 6.3. 18 colors from color 2 to 19 are plotted on the x axis. The first color was always identified as *žydra/lyseblå* and the last color was always identified as *mėlyna/mørkeblå*. The light blue circles stand for colors that were identified as *žydra/lyseblå*. Dark blue circles stand for colors that were identified as *mėlyna/mørkeblå.* The dashed lines mark the individual boundaries. A total 2140 data points (107 participants x 40 categorizations each) were obtained for the analysis of the identification task. Reaction times (RTs) were averaged over two trials for each stimulus.

The participants of the three groups cut the given blue color continuum differently. *Žydra/mėlyna* boundary was 8.84±2.33 (*M*±*SD*, range 4-13) for LN participants and

9.05±2.38 (*M±SD*, range 4-14) for LL participants. For NN participants the *lyseblå*/ *mørkeblå* boundary was 12.51±2.43 (*M±SD* ranging from 9 to 17). Out of 41 LL, 15 participants had a clear cut between light and dark stimuli. 12 LN out of 31 and only 8 NN out of 35 had a clear boundary. By clear cut we mean that colors consistently, one after another were identified as light, and once stimulus was identified as dark, the rest of the colors were consistently identified as dark only.

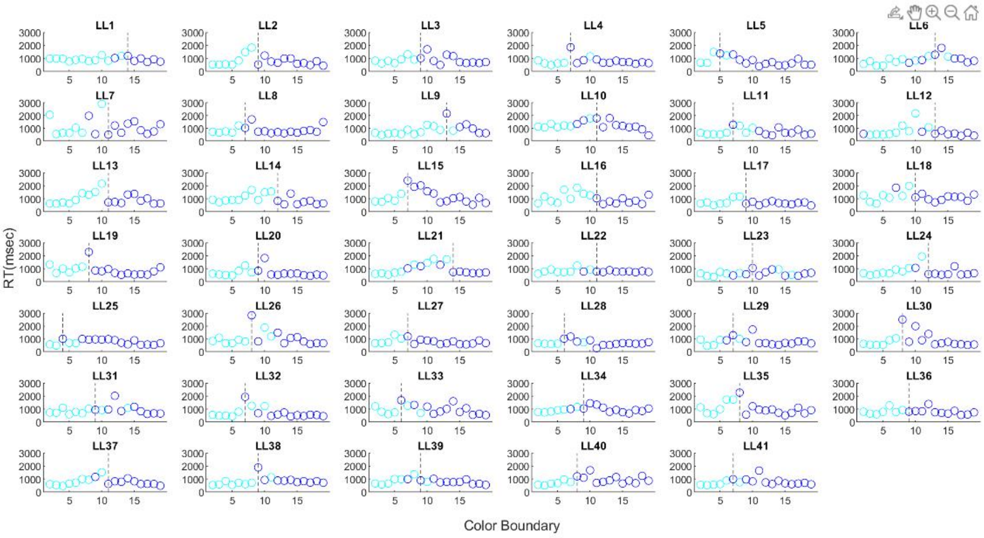

Figure 6.1: Individual color boundaries for Lithuanian speakers who live in Lithuania

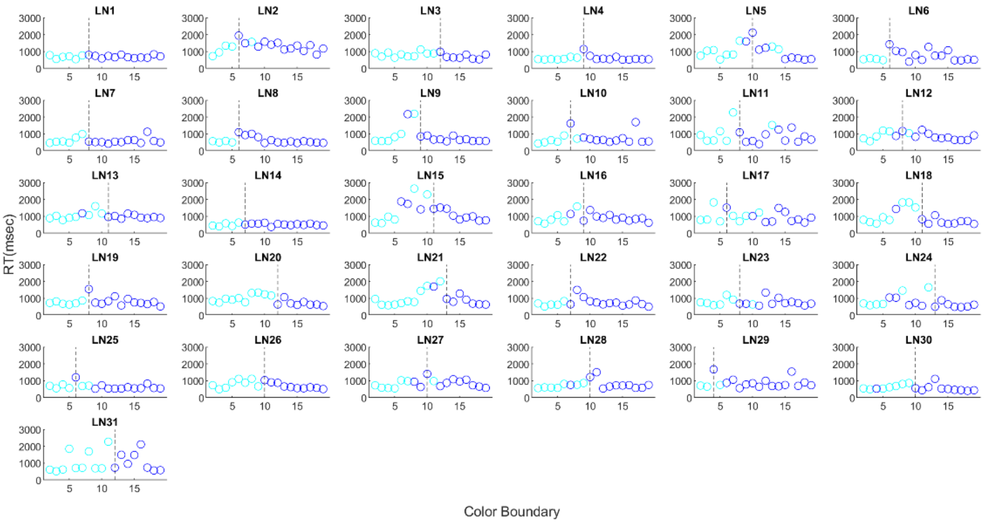

Figure 6.2: Individual color boundaries for native Lithuanian speakers who live in Norway.

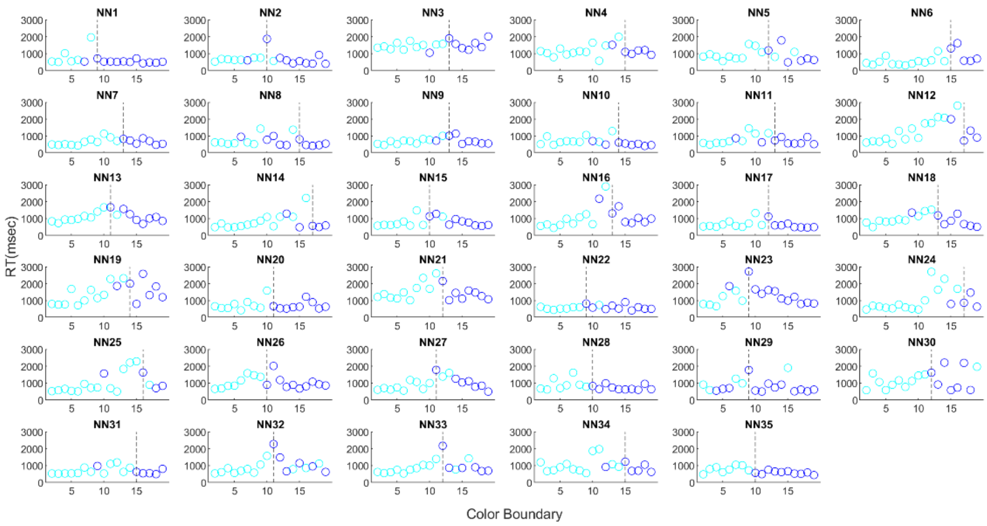

Figure 6.3.: Individual color boundaries for native Lithuanian speakers who live in Norway.

6.2 Color Matching Tasks

For the analysis of the matching task, we followed the approach applied by Winawer et al. (2007). Data for each subject were analyzed based on their individual color boundary. So, the trials were named within-category if the stimuli fell on the same side of that participant individual boundary (e.g., both *žydra* or both *lyseblå*) and were called cross-category if they fell on the opposite sides of the boundary or if one of the two stimuli was on the boundary. The ten near-color and the ten far-color comparisons closest to that subject's boundary were included in the analysis. Analyzing only color comparisons that are the closest to the individual boundaries provided an analysis based on subjective category boundaries (Winawer et al., 2007).

6.2.1 Trial exclusion

In the matching task on Russian blues (Winawer et al., 2007), the response timeout was not limited, but all the trials that took more than 3 seconds were discarded. This resulted in a loss of 25 % of trials. In the present study, therefore, subjects' time to answer was limited to 3 seconds on each trial. The limit of 3 seconds likely speeded up our participants, unlike in the previous study (Winawer et al., 2007), where participants had no time limits to answer. The participants were instructed that they had 3 seconds to answer, therefore, trials with no answers within the 3-second response window were excluded[20]. Also, we excluded all the reaction times (RTs) that were shorter than 250 msec, in line with previous research. Furthermore, trials were excluded if the responses to color matching trials were incorrect, since including incorrect color matches data would result in an analysis that would not be adequate (Balota & Chumbley, 1984, p. 353). A total of 18.13 % of color trials were excluded because of incorrect color choice. After the incorrect color data elimination, a total of 25676 trials were left for the further analysis. Analogously to the

[20] In the previous research (i.e., Martinovic et al., 2020), the cross-category data analysis was based on at least two discrimination pairs, and within-category data analysis was based on at least three discrimination pairs for each participant. However, as we had time constraints on the time outs (3 second for each trial) which was not present in the previous research, we have decided to not apply the latter exclusion criteria.

original paper (Winawer et al., 2007), when the color matching was performed with the verbal interference, we analyzed the data excluding the eight color matching trials preceding the wrong answer in the interference blocks. In this analysis 35 % (1643 out of 4708 trials) of the color trials surrounding individual boundaries were excluded because of incorrect response to the numbers in the interference block.[21] After all the incorrect data elimination, a total of 3065 trials were left for the final analysis.

6.2.2 Accuracy

Unlike in the previous study (Winawer et al., 2007) the three groups differed in their trial accuracy. Out of 3968 trials of color matching in no interference condition, 3281 (82.69 %) were matched correctly by LN participants. Out of 3968 observations for color matching of LN with verbal interference in Lithuanian, colors were matched correctly 3306 times (83.31 %) and 3370 times (84.93 %) when verbal interference was in Norwegian. The task with verbal interference in Lithuanian was performed first. For LL participants, out of 5248 trials, 4128 (78.65 %) were answered correctly in color matching without interference and 4268 (81.32 %) trials when the task was displayed with verbal interference. For NN participants, out of 4480 trails, 3695 trials (82.47 %) were answered correctly when the task was performed without interference and 3564 (95.27 %) when the task was performed with verbal interference.

As mentioned previously, we also removed color trials that preceded incorrectly identified combination of numbers in the verbal interference task. Because of the different number of participants, the three groups had different numbers of digit combinations to answer: NN had to remember 560 digit-combinations, LL: 656, and LN: 496 x 2 (in Lithuanian and in Norwegian). NN answered 157 digits' trials incorrectly, LL: 232, and LN: 182 (in Lithuanian) and 184 (in Norwegian).

6.2.3 Analysis model

In the original study (Winawer et al., 2007), the authors modeled their statistical analysis in separate 2 x 3 x 2 repeated measures ANOVA models for two language groups with factors of distance, category, and condition. Importantly, Plonsky (2011) stated that there is a tendency to use ANOVAS in L2 language acquisition research which may have shaped research practices in favor of factorial designs. At times, methods other than the factorial ones (i.e., ANOVA) are more suitable (Plonsky, as cited in Cunnings, 2003, p. 370). We used a Linear Mixed Effects (LME) model, instead, in line with the more recent study on Russian blues (Martinovic et al., 2020), in order to take between and within-participant variability into account. In our study the LME model was the most appropriate, because it allows missing data points. For instance, some participants might have answered all the trials around their color boundary correctly, while others answered only 75 % or less correctly, so the remaining 25 % were not used in the analysis, and therefore can be considered as missing data points. Also, as it was explained previously, the individual boundaries differed, thus not only did participants have different number of trials, but also the selected trials were not the same. Hence, it means that we selected an inconsistent number of color trials for each participant. Generally, the LME model is similar to a simple linear regression model that contains fixed effects reflecting the mean intercept and mean slope(s). The intercept is the predicted value of the dependent variable when all the independent variables are 0 and the slope reveals how much one factor can be expected

[21] Since there was a significant loss of the data, we have also performed an exploratory analysis of RTs for color trials when the responses to the interference stimuli were not given or incorrect together. The effects in the exploratory analysis were similar to the ones in the present analysis.

to change as the other factor increases. Despite missing data points, the repeated measures LME model computes variability between and within participants or participants groups. Moreover, the LME includes both fixed effects and random effects (Mcternan, 2021). Since our study is concerned with the reaction time (RT), it is beneficial to use the LME model which allows for continuous dependent variables. Importantly, when other models are used, it may be assumed that the different pieces of data are independent, while mixed effects models are specifically designed to tackle these relationships between cases. Random effects, such as subject IDs and language for bilinguals in our study, in mixed-effects analyses can recognize random effects structures that arise during random population sampling (Cunnings, 2012).

The R package of the current statistical analysis was *lme4* (Bates, 2005), which provided the needed functions for running mixed-effects models. We used *lme()* function to perform regression in which observations can also be correlated as it is part of repeated-measures designs (Miles, 2012). In the cases where LME model showed a significant effect of an interaction between two factors, we performed pairwise comparisons with *lsmeans ()* function from *lsmeans* (Lengh, 2016) package in R. For example, when language's interaction with category was statistically significant, we wanted to see which language (i.e., Lithuanian or Norwegian) was driving that interaction. Lastly, we used the *anova ()* function of *lme4* package to get a summary of the main significant effects.

6.2.4 Datasets and detailed analysis

To perform a statistical analysis in R, we split all the data into three datasets, and generated three LME models. The first dataset consisted of data from color matching task without interference. All three participant groups (LL, NN, LN) were included in this dataset. With the first model we aimed to assess whether there were differences between the three language groups (Norwegian (NN), Lithuanian (LL), or both (LN)) in reaction times (RT).

The second dataset contained the data with the verbal interference task of monolingual groups LL and NN. This dataset was used to examine whether there were differences between native Norwegian and native Lithuanian speakers in color matching under verbal interference in their respective languages.

The third dataset contained bilinguals (LN) data from the color matching with verbal interference task in both Lithuanian and Norwegian languages. We used this data set for the model, in which we compared how bilinguals performed on the task in Lithuanian and in Norwegian.

All three datasets were then fitted with LME models in R, where the dependent variable was RT. It was necessary to avoid positively skewed ratios and to have data of normal distribution, therefore RTs were log-transformed for the LME model (Wolfe, 1998). The repeated measures analysis was performed based on the following factors, each with two levels: category, distance, and language. The interactions between language and category, language and distance, category and distance, as well as the three-way interaction between language, category and distance were included in the models.

6.2.5 Statistical significance

Three null hypotheses for the two task conditions with and without verbal interference were formed and explained in the Section 4. Once the null hypotheses were tested through three linear mixed effects regression models, *anova ()* function in R was used to compute the hypotheses' significance values: the sum of the square of variation (Sum Sq), the mean square (Mean Sq), degrees of freedom (DF), F-values, and the p-values were reported in the summary tables for each model. The P-values stand for statistical significance of the phenomenon being tested. It provides an estimate of the likelihood that the results occurred coincidentally. Low p-values (< 0.05) suggest evidence against the null hypothesis, presenting, for instance, the differences between the participant groups in one or several of the factors (language, category, or distance) as significant. Higher p-values (> 0.05) indicated that there was no significant difference between the data of the groups or of the two languages for LN, in other words, there was no proof against the null hypotheses. The degrees of freedom (DF) and the F value refer to the number of independent values in the statistical distribution and the F-value. Moreover, to show the effect size of the main effects the Cohen’s d value was reported. These independent values were considered to derive the result. In the rest of this chapter, degrees of freedom will be presented in the LME summary tables from Num DF to Den DF, then the F value will be given, the p-values will be referred to as p and Pr(>F) (in the summary tables of the statistical models), and Cohen's d values will be referred to as d.

6.3 Results of the Color Matching Task without Interference

For the first LME model, we compiled the data for LL, NN and LN from the color matching task without verbal interference. We assumed that Lithuanians (LL) and Norwegians (NN) activated their native languages when hearing the recording of the task instructions in their respective native languages. Also, LN participants were expected to activate their mother tongue – Lithuanian, since the instructions of the no interference condition were given in their L1. We aimed to compare speakers of Lithuanian and Norwegian and to investigate whether there were any differences between the LL, NN, and LN. To model the analysis for the first task we used the given formula, where the reaction time (RT) was a dependent variable:

```
log(RT) ~ language + category + distance:category + language:category +
      distance + language:distance + language:distance:category
                          + (1 | subject_ID)
```

The fixed factors were language, category, and distance and their interactions. We included interactions between distance and category, language and category, language and distance, category and distance, and finally a three-way interaction between language, distance and category together[22]. LME model revealed that there were two significant main effects: 1) of color distance (near/far) and 2) of color category (within/between). Two significant interactions were observed: language X category and language X distance (see Table 6.1 for details).

Table 6.1: LME model’s summary for the three groups when the task is displayed without verbal interference.

Factor/Interaction	Sum Sq	Mean Sq	Num DF	Den DF	F value	Pr(>F)	
language	0.0672	0.0336	2	104.12	0.5992	0.551	
category	1.1505	1.1505	1	2014.24	20.5237	<0.001	***
distance	7.5714	7.5714	1	2008.24	135.0648	<0.001	***
category:distance	0.0038	0.0038	1	2008.53	0.0674	0.795	
language:category	0.4567	0.2284	2	2014.37	4.0739	0.017	*
language:distance	0.5761	0.2881	2	2008.29	5.1386	0.006	**

[22] Barr et al. (2013) suggested that including all posible factors and interactions in the statistical models is the “best practice” for linear mixed-effects models.

language:category:distance	0.0981	0.049	2	2008.59	0.8749	0.417

The significance effect of distance indicates that all subjects were faster at far-color matching than near-color comparisons. In other words, all participants were faster when the two colors were far from each other and slower when they were close to each other (Figure 6.5). Category was another significant main effect [for LL: d=0.202, for LN d= 0.301] suggesting that participants were faster when the two colors were on the opposite sides of the boundary (one *žydra/lyseblå* and one *mėlyna/mørkeblå)* and slower when the colors were within the same category (i.e., both *žydra/lyseblå)* (Table 6.1).

Overall, there was no significant effect of language in no verbal interference condition, indicating that whether participant was a speaker of Lithuanian, Norwegian or both did not change the time it took participant to decide on the matching colors. However, language interacted with distance (Table 6.1). The *post hoc* analysis of the language X distance interaction revealed that the effect of distance was the strongest for LL [1418.97±444.98 vs. 1195.46±350.56 msec, near color vs. far color; *M*±*SD*] and the weakest for NN [1368.05±375.60 vs. 1257.99±315.59 msec; *M*±*SD*], while LN were somewhat in the middle [1326.74±399.83 vs. 1153.35±322.97; *M*±*SD*]. This finding indicated that having the two linguistic categories for blue may have altered the perceptual distances between colors for Lithuanians who live in Lithuania (LL), while for Lithuanians in Norway (LN), who used languages with different linguistic categories every day the perceptual distances in perceptual space were impacted by both their L1 and L2 (see Section 6.6 for details).

Critically to our hypothesis, category interacted with language too. Namely, both bilinguals (LN) [1310.736±393.84 vs. 1199.37±355.25 msec, within vs. between; *M*±*SD*] *and* Lithuanians in Lithuania (LL), it was a less significant [1359.74±419.45 vs. 1275.866±411.53 msec vs., within vs. between; *M*±*SD*], while for Norwegians (NN) neither color category nor language X category interaction were statistically significant, as illustrated in Figure 6.4. In other words, having two BCTs for light and dark blue (for Lithuanian speakers) impacted their perceptual decision time, and suggested the CCE, not present for participants having a single BCT (Norwegian speakers).

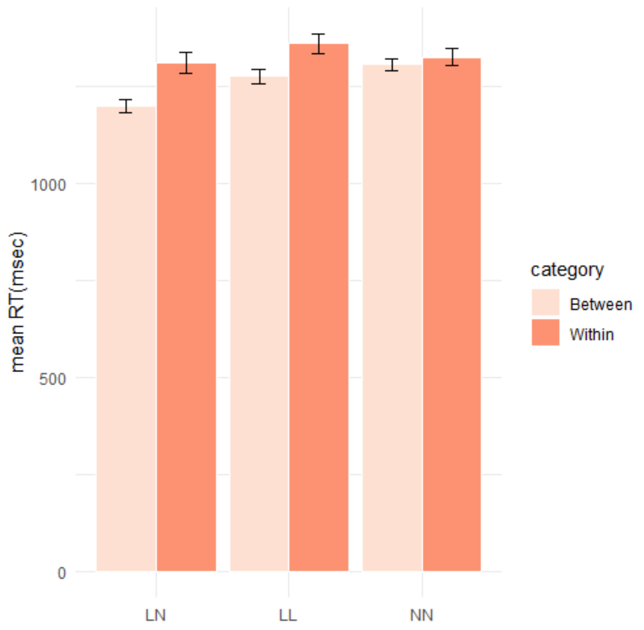

Figure 6.4: CCE for LL, and LN in no interference condition

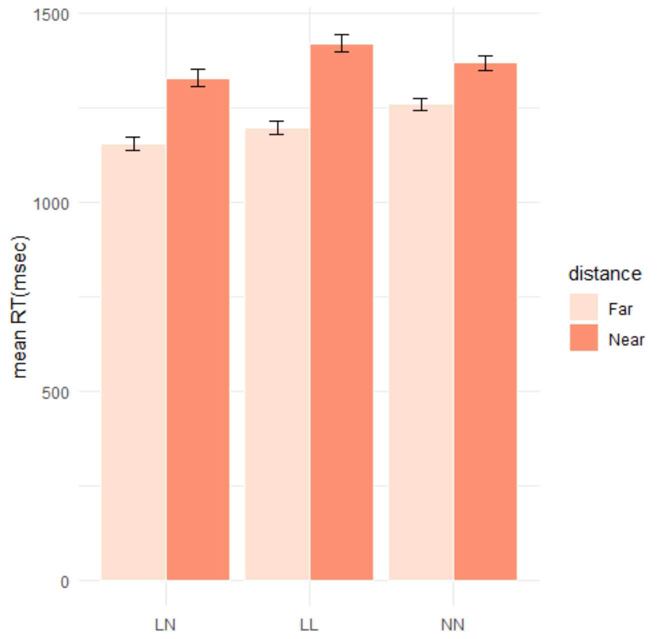

Figure 6.5: The effect of distance among the three language groups (LN, LL, and NN)

6.4 Results of Color Matching with Interference

Identical LME model as for the no interference condition was used for the analysis of the color matching task with verbal interference:

```
log(RT) ~ language + category + category:distance + language:category +
        distance + language:distance + language:distance:category
                    + (1 | subject_ID)
```

This time the participants were divided into two groups: (1) monolingual participants who used only one of the target languages: Lithuanian (LL) or Norwegian (NN), and (2) Lithuanians who lived in Norway and used both languages (LN). Accordingly, data of each group was entered into a separate model. Language in model (2) is the language in which the interference was conducted during the experiment, and hence is a within-subject factor as opposed to a between-subject factor in model (1)).

Table 6.2: LME model (1) summary for Lithuanians (LL) and Norwegians (NN)

Factor/Interaction	Sum Sq	Mean Sq	Num DF	Den DF	F value	Pr(>F)	
language	0.0907	0.0907	1	103.11	1.2751	0.261	
category	0.1886	0.1886	1	1725.58	2.6502	0.104	
distance	5.3167	5.3167	1	1695.51	74.704	<0.001	***
category:distance	0.0736	0.0736	1	1692.52	1.0342	0.309	
language:category	0.1888	0.1888	1	1723.59	2.6523	0.104	
language:distance	0.2119	0.2119	1	1695.74	2.9771	0.085	.
language:category:distance	0.6465	0.6465	1	1692.51	9.0834	0.003	**

For the model (1), there was a significant effect of distance indicating that monolingual participants (LL and NN) were both faster when colors were far, then when they were near.

Further, a significant three-way interaction of language X distance X category was observed (Table 6.3). To investigate what caused this interaction, we performed a *post hoc* analysis which revealed that the facilitatory effect of category was significant only in LL when the two colors of a trial were near, so near colors crossing the category were answered faster than near colors within the color category. NNs' RTs for far and near comparison did not differ between within-category and between-category trials (Table 6.3). To summarize, the main finding in the three-way interaction, was that having two linguistic categories for blue color for LL, impacted their time to match colors: near blue shades within the same category were matched slower than near blue shades that crossed the category boundary.

Table 6.3: The three-way interaction between language category & distance in the color matching task with interference of LL and NN reported in Mean RTs and SDs

	Near		Far	
	Between	Within	Between	Within
Lithuanians who live in Lithuania (LL)	957.88 (331.06)	1036.71 (345.25)	873.09 (280.23)	863.43 (246.56)
Norwegians who live in Norway (NN)	1046.71 (370.88)	1022.71 (336.51)	923.94 (319.35)	944.87 (338.26)

The main aim of the present research project was to investigate whether the "active" language can momentarily alter bilinguals' color perception. Model (2) was adopted to test this possibility. Data for the LN participants was analyzed separately, because they performed the task with verbal interference in both languages: Lithuanian and Norwegian. In the model (2), analysis of the color matching under verbal interference, we aimed to examine whether RTs of LN would be affected by the language in which they had to perform the color matching task with verbal interference. For LL and NN analysis language was a between-subject factor, while for LN analysis language was a within-subject factor. We used a similar model for LN as for the other two groups, only language was added as a random effect this time, because as it was reported in the language background questionnaire, LN participants' proficiency and exposure to the two languages varied. In other words, we did not want to ignore the possibility that for some participants language will have stronger effect while for others it will have a weaker effect. We used the following model (2) for the LN data investigation:

```
log(RT) ~ language + category + language:category + distance +
category:distance + language:distance + language:distance:category
+ (1 + language | subject_ID)
```

The main aim of the present research project was to investigate whether the "active" language in bilingual mind can momentarily alter their color perception. Model (2) was adopted to test this possibility. Data of the LN participants was analyzed separately, because they performed the task with verbal interference in both languages: Lithuanian and Norwegian. In the model (2), analysis of the color matching under verbal interference, we aimed to examine whether RTs of LN would be affected by the language in which they had to perform the color matching task with interference. For LL and NN analysis language was a between-subject factor, while for LN analysis language was a within-subject factor. We used a similar model for LN as for the other two groups, only language was added as a random effect this time. LN proficiency and exposure to the two languages varied as it was reported in the language background questionnaire, therefore we did not want to ignore the possibility that for some participants language will have stronger effect while for others it will have a weaker effect. We used the following model (2) for the LN data investigation:

```
log(RT)~ language + category + language:category + distance +
category:distance + language:distance + language:distance:category +
(1+language|subject_ID)
```

Model (2) revealed that under verbal interference condition for LN, category and distance were significant, main effects (Table 6.4). The significance effect of category, similarly as in the no interference condition, indicated that LN displayed a CCE: they matched colors between categories faster than colors within category. Moreover, the effect of distance indicated that LN matched far colors faster than near colors, in spite of the language (Lithuanian or Norwegian) of the verbal interference.

Crucially, language interacted with category (Table 6.5) indicating that once the verbal interference was in Lithuanian bilinguals were faster when the colors were between categories and slower when colors belong to the same category. However, when the task was in Norwegian CCE was not significant anymore as bilinguals were of a similar speed in both situations (within and between). This key finding confirmed that linguistic categories of the "activated" language affect color perception. The differences of bilinguals' RTs in both languages are reported in the Table 6.5. Figure 6.7 illustrated the interaction between category and each "activated" language.

Table 6.4: LME model (2) summary for LN (bilinguals) under verbal interference

Factor/Interaction	Sum Sq	Mean Sq	Num DF	Den DF	F value	Pr(>F)	
language	0.0133	0.0133	1	33.39	0.1734	0.68	
category	0.3334	0.3334	1	1267.88	4.3547	0.037	*
distance	4.1199	4.1199	1	1275.8	53.8156	<0.001	***
language:category	0.319	0.319	1	1281.86	4.1664	0.041	*
category:distance	0.097	0.097	1	1267.15	1.2669	0.261	
language:distance	0.0263	0.0263	1	1280.69	0.3438	0.558	
language:category:distance	0.0014	0.0014	1	1271.62	0.0185	0.892	

Table 6.5: Mean RTs and their standard deviations for LN participants in the color-matching tasks with verbal interference in Lithuanian and Norwegian

	Between	Within
Verbal interference in Lithuanian	877.37 (313.41)	941.41 (336.52)
Verbal interference in Norwegian	916.74 (352.28)	902.64 (304.05)

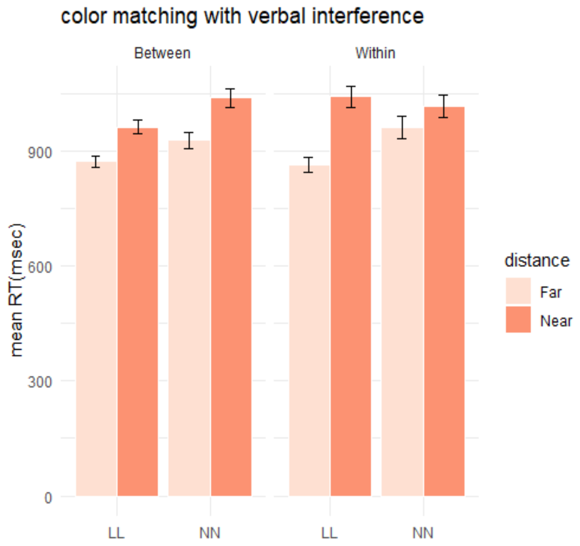

Figure 6.6: LL and NN participants under verbal in their respective native languages

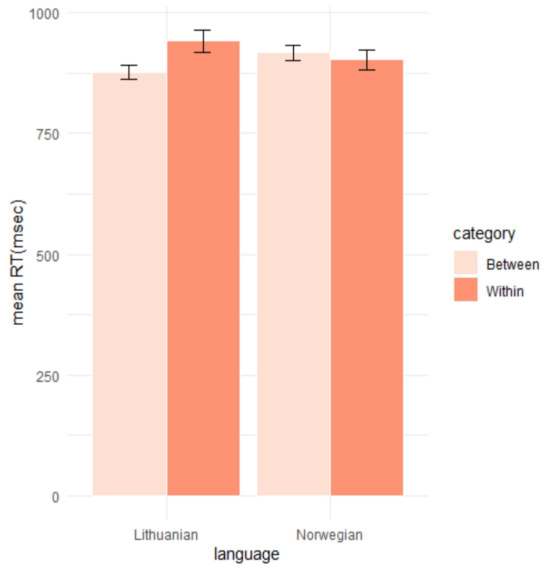

Figure 6.7: CCE for LN participants under verbal interference in Lithuanian (left) and no CCE in Norwegian (right)

6.5 Discussion

In the present study we compared speakers of two different languages on the identical blue colors' stimuli in a color identification and color matching tasks in order to examine whether L2 can influence color perception the same way as native language does. Noteworthy, Lithuanian has two BCTs to describe the blue color continuum, while Norwegian has only one which means that *žydra*, the Lithuanian term for light blue, does not exist in Norwegian. Our study's design attempted to conceptually replicate parts of a previous investigation on the two Russian blues in which monolingual speakers' color perception was affected by the linguistic categories in their respective languages (Winawer et al., 2007). Based on the previous research, we assumed that native speakers of Lithuanian and Norwegian, languages with different linguistic categories for color, will display differences in the color matching task. That is, colors between two categories (one light blue and one dark blue) will be matched faster and colors within the same category (i.e., both dark blue) will be matched slower by Lithuanians, while Norwegians will match all colors in similar speed. A previous study on color categorization and bilingualism (Athanasopoulos, 2009) indicated that bilinguals with languages that differ in lexical categories shift their mental representations of those categories towards monolingual speakers of their L2[23]. To address this hypothesis, we not only tested native Lithuanian and Norwegian speakers, but also Lithuanian-Norwegian bilinguals (LN). The present study attempted, therefore, to answer four questions: (1) do speakers of Lithuanian and Norwegian show any cross-linguistic differences in the color matching task, within the blue color continuum?, (2) does experience with and use of Norwegian language in Lithuanian immigrants lead to changes in color matching for the *žydra* "light blue" - the BCT that does

[23]Although study on Greek blues (Athanasopoulos, 2009) is exploring bilingualism, we followed the research design tested on Russian speakers (Winawer et al., 2007) because Lithuanian is geographically and linguistically closer to Russian.

not exist in Norwegian?, (3) does the verbal interference for LL and NN modify monolinguals' performance in the color matching task?, and (4) whether the active language (either Lithuanian or Norwegian) in the verbal interference task will affect bilinguals' performance on color matching? Specifically, whether activated Norwegian will remove the cross-linguistic effect in Lithuanian-Norwegian bilinguals, because this language categorizes the blue color continuum with a single BCT - *blå.*

In addition, we tested all participants' color identification to access their individual color boundaries. The purpose of determining individual boundaries was to only analyze color matching trials that were closest to the individual boundaries of each participant.

6.5.1 Color identification task

The results of the color identification task align with the relative color boundary approach/theory. Specifically, the area near individual color boundaries was difficult to categorize, as it represents a distortion in human perceptual space (Huette & Merced, 2016). The graphs of individual boundaries given in Figures 6.1, 6.2, and 6.3 showed that the reaction times (RTs) around the light/dark blue were longer. Also, at times participants were undecisive where exactly the boundary was. Importantly, because, presumably, monolingual LL operated with the two labels for blue more frequently than bilingual LN, LL were more balanced with the two categories, in other words, for them the color boundary was the closest to the middle of the blue continuum. For Norwegians this task showed more scattered color identification, because the colors are from the same category for them, they can only rely on lightness to identify them. These results are suggesting that LN may be integrating color concepts of both languages in their mind (see Section 3.3 for details), because their identification of blue differed from the LL.

6.5.2 Color matching tasks

6.5.2.1 Summary of the results

Overall, the results of the current study of Lithuanian blues suggests that language influences thought, and therefore supports linguistic relativism over universalism. Both Lithuanian groups (LL and LN) displayed a color category effect (CCE) under no verbal interference, while for Norwegians did not display a CCE. Additionally, under no verbal interference, for both Lithuanian groups language interacted with category. Thus, having two BCTs revealed differences in color perception. When the task was performed with verbal interference, there was a significant three-way interaction of language X category X distance for the monolingual groups, which revealed that LL were slower than NN when the colors were near and within the same category (both dark or both light, two color steps away from each other) which supports the assumption that thinking of these colors as the same (having the same BCT) made it harder to see the differences between them, therefore it took more time to categorize which resulted in longer RT. Noteworthy, this was the case when colors were the most visually alike. In this situation, Norwegians categorized colors similarly to when they were near and between the dark and light blue categories, plausibly because in Norwegian language all the stimuli had the same BCT – *blå*. Finally, in the verbal interference condition, bilingual Lithuanians' color perception was affected by the language in which the verbal interference was displayed, once the task was in Lithuanian, it activated L1 in the bilingual mind and a CCE was observed. However, when L2-Norwegian was activated, LN did not demonstrate a CCE. This is the key finding of the present study which indicated that "active" language can shape color perception on-line.

6.5.2.2 Color matching without verbal interference

Regarding color matching, we found that, without verbal interference, Lithuanian speakers who live in Norway (LN) had stronger CCE than Lithuanian speakers in Lithuania (LL), while Norwegians did not show any CCE at all. The finding of the CCE for Lithuanians (both LL and LN) supports the relativist notion of language influencing color matching. For LL and LN, the blue color continuum splits into two parts - light and dark, because of the two BCTs in Lithuanian. Specifically, when two distinct color stimuli were from the same linguistic category (i.e., they both were *žydra* "light blue"), Lithuanians (LL and LN) were "trapped" in trying to decide on which side the target color is, therefore the reaction times (RTs) were longer for Lithuanians. In this scenario, having two BCTs interfered with the Lithuanian's performance on the color categorization task. Yet, if the color stimuli in a trial were noticeably sampled from two different BCTs (one *žydra* "light blue" and the other *mėlyna* "dark blue"), then thinking in terms of the two BCTs and assigning them, speeded up perceptual comparison and helped to answer faster (Winawer and Witthoft, 2012). For NN, the colors in the same continuum are all named with one BCT, and whether the target color is within the category or between the two categories is less relevant for them. Further, Norwegians did not show a CCE under no interference condition, which was expected since their language does not have a light/dark blue boundary. The evidence of the color matching task without interference agrees with the previous research on the Russian blues (Winawer et. al., 2007). Lithuanians displayed a CCE similarly to Russians, while Norwegians did not, similarly to Americans.

In line with our hypothesis, Lithuanians who live in their native language's environment and use it as their main language get more practice with the use of two BCTs of blue, and therefore their color matching should be influenced by their mother tongue more than for Lithuanian bilinguals in Norway. However, both Lithuanians groups had significant CCE in our results indicating that attrition of L1 categories was not observed in LN. Following the attrition research, exposure to Norwegian for Lithuanians would result in weaker categorization of *žydra* "light blue". The question of why bilinguals who were expected to have altered their Lithuanian color categories displayed a strong CCE may be answered by research on bilingual advantage. The rationale behind the previous research on bilingual advantage is that bilinguals have a unified system in which both languages are permanently active rather than having two separate compartments for each language in the mind (Kroll, Bobb, & Hoshino, 2014). In fact, the effect size of category was larger for LN than for LL (see Section 6.3 for details). The everyday practice of activating one language over the other for bilinguals may have helped them to suppress Norwegian, when they had to perform the color matching task in Lithuanian. Prior to the color matching task without interference Lithuanians heard the recording of the task instructions in Lithuanian. In comparison, even though Lithuanians who live in Lithuania know other languages they do not experience inhibiting one language over the other as much as Lithuanians who live in Norway do, as they use L2-Norwegian on a daily basis. Therefore, when LL were asked to match blue colors, they did not necessarily think that in order to perform on the task better they had to activate their native or, in fact, any language. To put it simply, the task of matching-colored squares without interference did not require a LL participant to think in terms of linguistic color labels or language in general. If the use of two labels for LL was inhibited needed further analysis. Winawer et al (2007) offered the idea that to know if the CCE was displayed because of language, we needed to detect whether CCE is removed by verbal interference (see Section 6.5.2.3 for details). In contrast, we argue that for LN the task instructions activated their mother tongue which suppressed the use of L2-Norwegian color categories and stronger CCE was observed (than for LL), because active bilinguals were used to suppress one language over the other.

What concerns the second language acquisition research, it is beyond our study's design to acknowledge whether LN have transferred their native language's color categories into the Norwegian language system in their mind, but the fact that the CCE was significant in LN suggests that the light/dark blue boundary is not fading away[24] because of the Norwegian language daily use. Moreover, additional analysis is required to answer which scenario of the four in Cook's (1991) multi-competence theory LN speakers would align with. Nonetheless, since the results of the color matching task without interference revealed a weaker CCE for LL than for LN, we speculate that LN participants were strictly following color concepts of their native language and were suppressing the L2-Norwegian concepts which would align with one-concept scenario (the first scenario). In this scenario, a Lithuanian who has learned Norwegian would still think in terms of *žydra* "light blue" and *mėlyna* "dark blue" even when using the Norwegian BCT *blå*.

With the findings of color matching task without verbal interference we rejected the first null hypothesis and accepted the *H1* as we found differences in color matching between Norwegians (NN) and Lithuanians (LL and LN). Namely, having linguistic categories for light blue (*žydra*) and dark blue (*mėlyna*) result in color category effect for Lithuanians.

6.5.2.3 Color matching with verbal interference

Previous research by Winawer et al. (2007) also found that verbal interference negated CCE in Russian speakers. Under verbal interference, Russians became faster in matching colors within category and slower when colors belonged to different categories. Our results did not align with the previously reported effects of the verbal interference. Crucially, we did not observe the same disruption of CCE in Lithuanians in Lithuania (LL). In detail, the CCE was eliminated in the far color trials (four equidistant color steps apart), but not in the near color trials (only two equidistant color steps apart). Crucially, with the results of the two monolingual groups (LL and NN) we did not fully reject the second null hypothesis (explained in Section 4), because LL displayed a CCE in near color comparisons. So, when colors were near and within the same category, LL matched them slower than near colors from two categories. However, LLs' RTs in far comparisons did not differ between within-category and between-category trials. This can be considered as only partial elimination of the CCE. Moreover, LN under verbal interference in Lithuanian remained faster when colors belonged to different categories and slower when they belonged to the same category, similar to the pattern observed in the no interference condition.[25] In line with English speakers in Winawer et al. (2007), verbal interference did not include Norwegian's color matching.

According to Briscoe (2020) the fact that verbal interference negated the CCE in Russian blues' study (Winawer et al., 2007) supports the dual code model that stands for language being the main factor driving the color matching. Thus, verbal interference of rehearsing number combinations and matching colors at the same time, in theory, should eliminate the strategy of using language (thinking in terms of linguistic categories for colors). This is an argument for language being "activated" in the color matching task without verbal interference (Winawer and Witthoft, 2012). In other words, it is claimed that the CCE found in the color matching without the dual task was because a Russian participant was thinking

[24] No language attrition was observed.
[25] We may have found a similar disruption if the task in our design would not have had three-second time out, as it did not in Russian blues study (Winawer et al., 2007).

in terms of the two linguistic color categories for blue while he or she was matching the colors and this thinking was disrupted when the task was displayed with verbal interference. Moreover, Regier et al. (2010) interpreted verbal interference's elimination of the CCE (in i.e., Winawer et al., 2007) as a linguistic effect in nature and not due to cultural or environmental differences between native speakers of different languages.

However, Winawer and Witthoft (2012) also noted that there was a possibility that the CCE was found under no interference because Russian participants' early perceptual processes were shaped by their two BCTs for blue. If this was the case, "it would require color appearance to be altered only during those moments when one is accessing the [color] labels" (Winawer and Witthoft, 2012, p. 5). Our finding that bilingual Lithuanians in Norway match colors differently depending on which language is the verbal interference displayed (discussed in the further paragraphs) suggested that, indeed, colors can momentarily be perceived differently depending on which language is "activated" on-line. Moreover, Gonzalez-Perilli et al. (2017) reported that, in fact, CCE can be increased or diminished by the verbal interference for speakers of different Spanish dialects. We did not analyze whether the CCE was diminished or increased by the verbal interference, because our design had a 3 second time out on every trial, including when participants had to choose the correct digit combination and it speeded up participants considerably. Also, this effect did not reach statistical significance in the investigation on Spanish blues. Nonetheless, our results aligned with Gonzalez-Perilli et al. (2017) study, because the CCE was not eliminated by verbal interference for LN and only partially eliminated for LL. Noteworthy, the finding of verbal interference not eliminating the CCE is unusual and the theoretical interpretations about the dual task as well as the color categorization study designs may have to be adapted accordingly.

We interpret that the Whorfian notions of L1 shaping color perception stands. Moreover, not only language but also cultural and environmental differences between Lithuanians and Norwegians might be the reason of the absence of the complete CCE disruption in our study. Pavlenko (2016) hypothesized that effects of L1 categories are "particularly strong in people who grow up speaking a single language or typologically related languages with long histories of language contact" (p. 598). In fact, most Lithuanians of older generations grew up speaking both Lithuanian and Russian that both have two linguistic categories for blue. Noteworthy, most of Lithuanian participants in our study also reported being proficient in Russian. Further analysis is be needed to access the proficiency in and exposure to Russian in Lithuanians of the present study to investigate whether speaking two languages that both have two BCTs for blue affect the color perception is such a way that the CCE cannot be eliminated with the verbal interference as easily as for, for example, Russian speakers in Winawer et al. (2007). In other words, if one speaks two languages that divide the blue color spectrum into two, it may cause the two color categories to be more resistant to attrition. Moreover, it was previously claimed that if CCE can be eliminated by the verbal interference as easily as in Russian blues study (Winawer et al., 2007), the Whorfian hypothesis must be false (Regier et al., 2010). To conclude, the case of Lithuanian blues suggests that the CCE may be stronger than it was previously reported to be.

Crucially to the H3 hypothesis, our results indicated that the "activated" on-line language affects bilinguals' color perception. According to Lupyan (2020) the on-line effect of language appears when color perception is being affected in the moment of matching colors. In detail, when the verbal interference in color matching task was in Lithuanian, LN participants were faster to match the colors that were between two categories, namely one *žydra* "light blue" and the other *mėlyna* "dark blue", while when the verbal interference was in Norwegian, they were of similar speed for both comparisons, in other words, it did not matter if colors were within the same category or between the two categories, similar to Norwegian speakers. Since Norwegian language does not have the light/dark blue color boundary, once Norwegian was activated in the bilingual mind of LN participants, the boundary advantage in their L1-Lithuanian did not influence color matching anymore.

If Lithuanians in Norway showed CCE when matching colors in Lithuanian and no CCE in Norwegian due to categorical perception, it could have meant that color appearance was altered only during the moments of color label access (Winawer and Wittholf, 2012). Interestingly, Forder & Lupyan (2019) found that verbal interference of hearing color labels before the color matching trial exaggerated the CCE. When participants heard a color word (e.g., "blue") right before the matching trials their accuracy increased: typical blues were distinguished from less typical blues better. However, in our design, the interference was concerned with remembering digit combinations and not color labels, therefore the dual task was expected to interfere with assigning BCTs to the color patches. Thus, our results confirm that the BCTs of the language that is actively used in the task can influence color matching decision and therefore momentarily affect color perception. Our results revealed that providing linguistic hints in the color matching task can activate color language for a participant and that the verbal hints do not have to be related to color labels. In other words, if language like Lithuanian, which has two BCTs for blue, is "activated" by verbal interference, it is enough for the CCE to be observed[26]. In contrast, if Norwegian that has a single BCT to describe all blue shades is "activated" for a bilingual speaker, it is enough to remove the CCE observed in L1-Lithuanian.

The results of LN in the verbal interference condition in both of their languages rejected the last null hypothesis and accepted the second option of our H3 (see Section 4). In detail, we accepted the third scenario in Cook's model (2016) for relationship between L1 and L2 color concepts in the bilingual mind. Following this scenario, Lithuanian-Norwegian bilinguals would be switching their L1-Lithuanian and L2-Norwegian color concepts in their minds depending on which language they are using in the moment. In situations, like, for example, participating in a color matching experiment both in Lithuanian and in Norwegian, they would adapt their color concepts to the language "activated" by the verbal hints in order to rehearse numbers and to match colors. As the CCE was not observed when the task was performed in L2-Norwegian, this result indicated that in this task bilinguals strictly used their L2 that has only one BCT for blue. Nonetheless, when the task was in Lithuanian, the CCE was observed indicating that L1-Lithuanian was used to complete the task.

6.5.2.4 Color distance

In the previous sections of discussion, we have largely focused on the color category aspect of our results, while the color distance was discussed less. In all our statistical models, distance was shown to be a highly significant effect. *Post hoc* analysis of the models revealed that all the participants despite speaking languages with different linguistic categories for blue were faster when the colors were far from each other than when they were near. It is likely that the effect of distance has to do with color lightness and language is less relevant as compared to the CCEs. On the other hand, the language involvement in the effect of color distance is plausible. Our findings revealed that the effect of color distance was the strongest for Lithuanians in Lithuania (LL) and the weakest for Norwegians

[26] Participants were rehearsing digit combinations rather than color labels.

(NN), while bilinguals (LN) were in the middle. It can be speculated that this effect is off-line language effect caused by the long-term experience with the light/dark separation in language which alters the distances between the color patches in the perception of blue color continuum. In this scenario, Lithuanians who use their L1 most of the time perceive the light/dark separation the most, therefore the near colors are perceived as very similar and take longer time to discriminate, while far colors are perceived even more far from each other and therefore take less time to discriminate. Assuming that Lithuanian-Norwegian bilinguals use both languages somewhat equally, their perceptual space of blue is less warped (Lupyan et al, 2020). Whereas Norwegians (NN) do not have the two basic labels for blue color and therefore the effect of distance is the weakest for them. Importantly, Norwegians (NN) still had the distance effect, because distant colors are still more visually distinct, hence easier to discriminate.

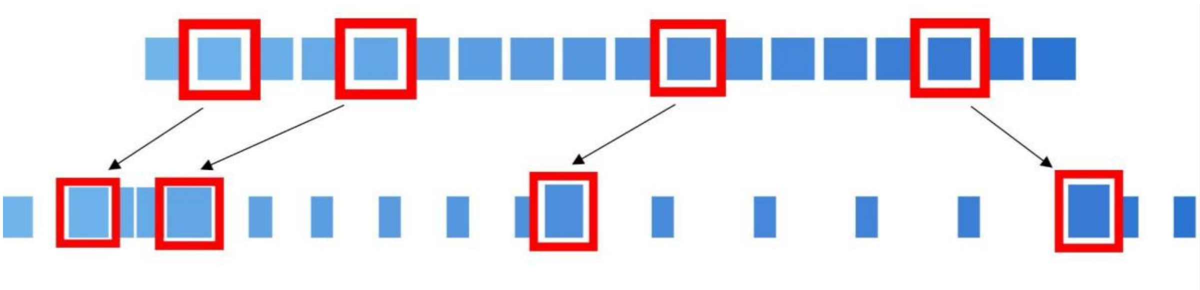

Figure 6.8: Color distance distortion due to usage of the two BCTs for blue color continuum. Near colors are perceived closer, while far colors are perceived more distant than they are in the equidistant color continuum.

According to Forder and Lupyan (2019), in case of categorical perception, discriminability around the boundary and for colors located about midway between two color prototypes increases while discriminability near the category prototype slightly decreases. However, in our study's design, colors were grouped into far and near comparisons depending on how many steps apart they are from one another: near colors were two steps apart, while far colors were four steps apart (Figure 6.8). An improved design in the future studies could include measuring for distance of stimuli's placement in terms of both the boundary and the prototypes of light/dark blues.

6.5.3 Unanticipated Obstacles due to COVID'19

When we had our first meeting with the supervisors in 2019, we could not have anticipated that the pandemic was coming and how it would change the present study. Even though the lab in the University of Oslo was open throughout the testing process, it was challenging to find participants who would be willing to take a risk to leave home and come to the experiment. Therefore, the testing process in Oslo was longer than expected. Another obstacle, of course, was the data collection at the visiting institution in Lithuania. Most of the educational institutions in Lithuania were closed for the whole year of 2021, which meant that they could not host an experiment to which people that are not affiliated with the university would be allowed to enter the premises. Finally, in July of 2021, we found an institution that allowed us to test Lithuanian participants. The mentioned obstacles were solved but resulted in extension of the deadline of this MPhil thesis.

6.5.4 Limitations

6.5.4.1 Language background questionnaire

The Language and Social Background Questionnaire (LSBQ; Anderson, Mak, Keyvani Chahi, & Bialystok, 2018) that was chosen and adapted for the current study included sections where participants were asked to self-rate their language proficiency and exposure to all the languages they knew. A possible limitation of a self-rated language proficiency is that some participants might rate their knowledge incorrectly. Perhaps, the use of a standardized language proficiency test would have derived more detailed and accurate results. However, since the focus of the study was the experimental data, self-rated proficiency and exposure were acceptable. Further, since the Language Proficiency questionnaire was developed for bilinguals, the questions where subjects had to weigh their use of the two languages were not applicable for multilingual speakers. A good solution to this would be to develop a questionnaire that would weigh all the languages a subject knows or to simply select participants who only know the languages of interest and ask them to report their use of those languages. To find participants who do not know more than two languages and to evaluate each participant individually, however, would be time consuming, therefore requires a larger scope study.

6.5.4.2 Three seconds time out

We used 3 second time outs for all our trials which resulted in a significant data loss in the interference blocks. The time to choose the correct digit in the interference blocks should have been longer or unlimited to overcome this issue.

6.5.4.3 Color stimuli

The stimuli used in the experiments were quite alike because we only considered colors that are in between the *žydra* and *mėlyna* prototypes. In terms of the relativist approach, the prototypes are not necessarily the ending points of the category but rather the "best" examples of the color category (Briscoe, 2012). We were concerned with our stimuli being not diverse enough, thus we included two additional shades to each extreme of the blue color continuum to address this issue.

6.5.4.4 Participant samples

The sample sizes in the current study were acceptable and the statistical models converged with many factors included in the analysis, but they could have been better balanced, so that all three groups would have a similar number of participants and their mean ages would match better for revealing more subtle effects in the data. To retest the current findings, more homogeneous groups would be beneficial.

6.5.5 Contribution to language science and further research

The current study aimed to contribute to color categorization research in bilingual Lithuanian-Norwegian speakers. This was accomplished by extending and adapting color categorization methodology by Winawer et al. (2007) study on Russian blues, to the Lithuanian blues. Winawer et al. (2007) revealed color matching differences in speakers that have different linguistic categories to describe blue color spectrum. However, the mentioned study had its limitations: Russian speakers of the study were from the U.S., which likely meant that they were actively using English too. We extended the study by separating Lithuanians who live in Lithuania and Lithuanians who live in Norway to have more controlled samples of the participants. The phenomenon of Lithuanians emigrating to Norway created a perfect experimental condition, since Lithuanian and Norwegian use different linguistic categories to describe blue color continuum. Also, the verbal interference for LN speakers was performed in both of their languages which was not executed in the previous studies. In addition, to the best of our knowledge, this study is one of the first to explore L2 effects on non-verbal perceptual processes such as color matching with and without verbal interference in one of the two Baltic languages. Our improved experimental design provides a new insight into the relationship between languages in the mind, specifically that color categorization adapts to the language which is used in the moment. It was beyond the scope of this study to address the question of how each language in multilingual mind would affect color perception. Since Lithuanians from Norway in this study were speaking more than two languages, it would be interesting to further assess whether other languages a speaker knows affect their color categorization.

7 Conclusion

The current thesis contributed to the debate on whether language and living in a foreign country can affect the perception of color categories within the blue color continuum. The color category effects (CCEs) were found through the behavioral tasks of matching colors with and without verbal interference in either Norwegian or Lithuanian. We found that differences of linguistic categories between Norwegian and Lithuanian speakers translate into differences in color matching tasks. Namely, Lithuanians showed a CCE, while Norwegians did not. The current results advocate that language influences color perception. Moreover, the ongoing experience with Norwegian in Lithuanian speakers living in Norway was reported to lead to a less balanced color boundary choice in the identification task. However, their matching of the blue stimuli was close to the Lithuanians living in Lithuania when the task was without interference and with the verbal interference in Lithuanian. These results suggest that the light/dark blue color boundary is not fading way in Lithuanian-Norwegian bilinguals even though they live in L2-Norwegian environment. We have also shown that verbal interference only partially removed the cross-linguistic effects or CCEs in the color matching tasks for Lithuanians who live in Lithuania. Moreover, the CCE were completely removed for Lithuanians who live in Norway when the verbal interference task was performed in their mother tongue – Lithuanian. On the contrary, when Lithuanians in Norway were examined with the verbal interference in Norwegian, the CCE was no longer observed. In conclusion, we advocate that the activated language influences our perception of the world. To better understand how color terminology in different languages works in multilingualism, future studies may develop a study design to test multilinguals in each of their languages.

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Appendices

Appendix 1: Information letter and consent form for the participants

Color Categorization and Bilingualism: The case of Lithuanian and Norwegian
This is an inquiry about participation in a research project where the main purpose is to examine color perception across Norwegian and Lithuanian speakers. In this document, we will give you information about the purpose of the project and what your participation will involve.

Purpose of the project
The goal of studying color perception in linguistics is to understand more of humans' take on the visual stimuli of colors in connection to the words for colors. In the current project, we examine color perception in Norwegians and Lithuanians. You will be asked to fill out an online survey about your experience with languages and perform a behavioral experiment on the MPhil student's, Akvile's Sinkeviciute's computer. The experiment will involve three simple tasks where you will have to make quick, but accurate decisions on colors.

Who is responsible for the research project?
NTNU: Norwegian University of Science and Technology is the institution responsible for the project.

Why are you being asked to participate?
You have been invited to participate in this project because you are between 18 and 40 years old, you are either a native Norwegian speaker or a native Lithuanian speaker who lives in Lithuania or Norway. Your participation requires you to have normal vision, normal color vision and normal hearing. Also, in order to participate in this project, you should not previously have had any brain or head injuries. Furthermore, we are looking for participants who have no neurological impairments, such as epilepsy. The study is a part of an MPhil thesis carried out by the student Akvile Sinkeviciute. Professors Mila Vulchanova, NTNU, Julien Mayor, UiO and Postdoctoral Fellow Natalia Kartushina, UiO, supervise the study.

What does participation involve for you?
Your participation will involve an online 10-minute survey and a behavioural experiment on a computer, consisting of three tasks where you will have to discriminate colors (by pressing buttons on the keyboard) and to remember numbers. The program will code your answer (accurate vs. wrong) and your response time. The experiment of three smaller tasks will take around or less than 15 minutes.
The survey consists of three parts. In the first part of the survey, you will be asked questions about yourself, such as your age, gender, handedness, whether you have hearing problems, and so on. The other two parts of the survey will be about your experience with languages, for example, the amount of languages you speak and how proficient you are in each of them. Your answers will be collected electronically through Nettskjema online survey. The collected data then will be stored in an encrypted USB.

Participation in the project is voluntary. If you choose to participate, you can withdraw your consent without giving a reason. Note that if you want to withdraw, this must be done before the 28th of February 2021. On the 1st of March 2021, I will make all the data anonymous by destroying all sources that contain your personal data. Therefore, it will no longer be possible to tell which data belongs to who, which is the reason for why the deadline for withdrawing from the study is 28th of February 2021. There will be no negative consequences should you wish to withdraw from the study.

Your personal privacy – how we will store and use your personal data
We will only use your personal data only for the purpose(s) specified in this information letter. We will process your personal data confidentially and in accordance with data protection legislation (the General Data Protection Regulation and Personal Data Act).

- Your data will only be available to me, Akvile Sinkeviciute, and my project's supervisors: Mila Vulchanova (NTNU), Julien Mayor (UiO), and Natalia Kartushina (UiO).
- If at any point of time me or another researcher will want to use your data I will replace your name and contact details with a code. The list of names, contact details and respective codes that will be stored separately from the rest of the collected data. I will store the data on an encrypted file on a USB drive, which will be anonymized at the end of the project. Only gender and age might appear in the data that will not be connected to your name in any way.
- If this project gets published in an academic journal, your personal data will not be recognizable. Only gender and age might appear in the publication that will not be connected to your name in any way.

What will happen to your personal data at the end of the research project?
The data collection is scheduled to end on 28th of February in 2021. The data of Your name and contact details will be anonymized, if at any point of time after the end of project, me or another researcher will want to use only your data, it will be anonymous and it will not be possible to identify your data.

Your rights
So long as you can be identified in the collected data, you have the right to:

- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?
We will process your personal data based on your consent. Based on an agreement with NTNU: Norwegian University of Science and Technology, NSD – The Norwegian Centre for Research Data AS has assessed that the processing of personal data in this project is in accordance with data protection legislation.

Where can I find out more?
If you have questions about the project or want to exercise your rights, contact:

- NTNU: Norwegian University of Science and Technology via: o Akvile Sinkeviciute akviles@ntnu.no, +4741399196
  - o Mila Vulchanova, mila.vulchanova@ntnu.no, +47 73596791
- UiO: University of Oslo via:
  - o Julien Mayor julien.mayor@psykologi.uio.no, +47 22845149
  - o Natalia Kartushina, natalia.kartushina@psykologi.uio.no, +47 22845021
- Our Data Protection Officer: Thomas Helgesen, thomas.helgesen@ntnu.no, +47 93079038
- NSD – The Norwegian Centre for Research Data AS, by email: (personverntjenester@nsd.no) or by telephone: +47 55 58 21 17.

Yours sincerely,

Mila Vulchanova Akvile Sinkeviciute
Project Leader Student
(Researcher/supervisor)

Consent form

I have received and understood information about the project Color Categorization and Bilingualism: The case of Lithuanian and Norwegian and have been given the opportunity to ask questions. I give consent:

❑ to participate in an online survey in which I will be asked for my personal data (email address, age and gender).
❑ to participate in a behavioral experiment on a computer.
❑ for my de-identified data (information about my age and gender) to be published in a scientific paper as part of the group analysis in a way that I can not be recognised.

I give consent for my personal data to be processed until 31st of July, 2021.

(Signed by participant, date)

Appendix 2: Language and Social Background Questionnaire

Sex: Male Female
Handedness: Left Right

How long have you lived in Norway?
1 year
2 years
3 years
4 years
5 years
6 years
7 years
8 years
9 years
10 and more years

Have you ever lived in another country (that is not Lithuania and not Norway)?
If yes, where and for how long?
1.
2.
3.

Language Background
List all the languages you can speak and understand including Lithuanian, in order of fluency:

1.
2.
3.
4.
5.

Where did you learn these languages?
o Home
o School
o Community
o Other

At what age did you start learning it/acquiring it? (If from birth, write "0")

Relative to a highly proficient speaker's performance, rate your proficiency level on a scale of 0-10 for the following activities conducted in Lithuanian and your other language(s).

16.1 Lithuanian
0 = No Proficiency 10= High Proficiency

Speaking 0 1 2 3 4 5 6 7 8 9 10
Understanding 0 1 2 3 4 5 6 7 8 9 10
Reading 0 1 2 3 4 5 6 7 8 9 10
Writing 0 1 2 3 4 5 6 7 8 9 10

16.2 Of the time you spend engaged in each of the following activities, how much of that time is carried out in Lithuanian?

None / Little / Some / Most / All

Speaking
Listening
Reading
Writing (writing frequency)

Second/Third/Fourth/Fifth Language:

0 = No Proficiency 10= High Proficiency

Speaking 0 1 2 3 4 5 6 7 8 9 10
Understanding 0 1 2 3 4 5 6 7 8 9 10
Reading 0 1 2 3 4 5 6 7 8 9 10
Writing 0 1 2 3 4 5 6 7 8 9 10

17.2 Of the time you spend engaged in each of the following activities, how much of that time is carried out in (Second/Third/Fourth/Fifth) language?

None / Little / Some / Most / All

Speaking
Listening
Reading
Writing (writing frequency)

Community Language Use Behavior

18. Please indicate which language(s) you most frequently heard or used in the following life stages, both inside and outside home.

18.1 Infancy

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

18.2 Preschool age

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

18.3 Primary School age

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language

Only the other language

18.4 High school age

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

19. Please indicate which language(s) you generally use when speaking to the following people.

19.1 Parents

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

19.2 Siblings

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

19.3 Grandparents

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

19.4 Other Relatives

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

19.5 Partner

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

19.6 Roommates

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

19.7 Neighbours

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

19.8 Friends

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

20. Please indicate which language(s) you generally use in the following situations.

20.1 Home

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

20.2 School

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

20.3 Work

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

20.4 Social activities (e.g. hanging out with friends, movies)

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language

Mostly the other language
Only the other language

20.5 Religious activities

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

20.6 Extracurricular activities (e.g. hobbies, sports, volunteering, gaming)

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

20.7 Shopping/ Restaurants/Other commercial services

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

20.8 Health care services/ Government/ Public offices/ Banks

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

21. Please indicate which language(s) you generally use for the following activities.

21.1 Reading

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

21.2 Emailing

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

21.3 Texting

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

21.4 Social media (e.g. Facebook, Twitter etc.)

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

21.5 Writing shopping lists, notes, etc.

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

21.6 Watching TV/ listening to radio

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

21.7 Watching movies

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

21.8 Browsing on the Internet

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

21.9 Praying

All Lithuanian
Mostly Lithuanian
Half Lithuanian half other language
Mostly the other language
Only the other language

22. Some people switch between the languages they know within a single conversation (i.e. while speaking in one language they may use sentences or words from the other language). This is known as "language-switching". Please indicate how often you engage in language-switching. If you do not know any language(s) other than Lithuanian, fill in all the questions with 0, as appropriate.

With parents and family / With friends / On social media

Never
Rarely
Sometimes
Often
Always

Appendix 3: The measures of Norwegian proficiency in LN participants. Participants 16, 24, 34, and 35 were excluded from the study.

ID		Speaking Frequency	Listening Frequency	Reading Frequency	Years lived in Norway	Age of Acquisition						**Exposure to Norwegian**
	Mean of:	2.83	2.74	2.66	7.49	9.57						-16.83
	standard deviation	0.71	0.89	0.76	2.59	2.84						4.05
	cut-off value											**-20.88**
1		3	3	3	3	17.2	-4.31	-3.74	-3.93	-3.32	-3.19	-18.49
2		3	3	2	1	9.2	-4.31	-2.42	-2.66	-3.51	-3.59	-16.48
3		3	3	3	9	11.6	-4.31	-3.08	-3.93	-3.14	-3.59	-18.05
4		3	3	3	8	10	-2.51	-2.42	-7.75	-2.59	-3.19	-18.45
5		3	3	3	6	7.6	-2.51	-2.42	-2.66	-2.59	-3.19	-13.36
6		4	4	4	6	5.2	-3.41	-2.42	-2.66	-2.59	-2.79	-13.86
7		2	3	3	1	7.2	-3.41	-2.42	-2.66	-2.59	-3.59	-14.65
8		3	3	2	10	11.6	-5.21	-3.08	-4.57	-3.14	-3.59	-19.58
9		3	3	3	8	12.8	-3.41	-1.75	-2.02	-2.77	-3.59	-13.54
10		3	3	3	10	9.2	-2.51	-2.42	-2.66	-2.59	-3.59	-13.75
11		3	3	3	10	10.4	-4.31	-2.42	-2.66	-2.77	-3.19	-15.34
12		3	3	3	10	11.2	-3.41	-3.08	-3.29	-2.95	-3.19	-15.92
13		3	2	2	7	6.4	-3.41	-2.42	-3.29	-2.77	-3.19	-15.08
14		3	3	3	8	10.8	-3.41	-1.75	-2.02	-2.77	-3.19	-13.14
15		3	3	3	8	4.8	-2.51	-2.42	-2.66	-2.59	-3.19	-13.36
16		2	3	2	6	10.8	-7.02	-5.72	-5.84	-3.69	-3.99	-26.26
17		3	3	3	10	13.2	-4.31	-3.08	-3.29	-2.95	-3.19	-16.83
18		2	2	2	10	8.4	-5.21	-3.74	-3.93	-2.77	-3.59	-19.24
19		2	3	2	10	8.8	-5.21	-3.74	-3.29	-2.95	-3.59	-18.79
20		3	3	3	10	10.8	-3.41	-2.42	-3.29	-2.77	-3.19	-15.08
21		3	3	3	10	8.8	-3.41	-2.42	-2.66	-2.77	-3.19	-14.44
22		3	3	3	5	9.2	-3.41	-3.08	-2.66	-2.59	-3.59	-15.32
23		3	3	3	7	9.2	-4.31	-3.74	-2.66	-2.77	-3.19	-16.67
24		4	4	4	5	10.8	-2.51	-1.75	-2.02	-2.77	-2.79	-11.84
25		3	2	2	9	10.8	-4.31	-3.74	-4.57	-3.14	-3.19	-18.95
26		0	0	1	4	10.4	-8.82	-6.39	-6.48	-4.25	-4.38	-30.31
27		3	3	3	10	11.6	-3.41	-2.42	-2.66	-2.40	-3.19	-14.07
28		3	3	3	8	11.6	-2.51	-2.42	-2.66	-2.59	-3.19	-13.36
29		3	3	3	8	8.8	-4.31	-2.42	-2.66	-2.59	-3.19	-15.16
30		3	3	3	4	7.6	-2.51	-2.42	-2.66	-2.59	-3.19	-13.36
31		2	0	1	8	10.4	-4.31	-3.74	-3.93	-2.77	-3.99	-18.74
32		4	4	4	9	2	-3.41	-3.08	-3.29	-2.77	-2.79	-15.34
33		3	3	2	10	3	-2.51	-3.08	-3.29	-2.59	-3.19	-14.65
34		3	1	1	8	3	-6.11	-5.72	-5.20	-3.32	-3.99	-24.35
35		2	2	2	6	2	-6.11	-5.06	-5.20	-3.32	-3.59	-23.29

Appendix 4: The measures of Norwegian proficiency in LN participants. Participants 16, 24, 34, and 35 were excluded from the study.

ID		Speaking	Understanding	Reading	Writing	Writing Frequency						**Norwegian proficiency**
	Mean of:	73	80	77	74	2.54						0.00
	standard deviation	15.7	17.1	20.5	20.9	0.89						4.34
	cut-off value											**-4.34**
1		70	70	70	50	3	-0.22	-0.57	-0.35	-1.14	0.52	-1.76
2		70	90	90	40	2	-0.22	0.60	0.63	-1.61	-0.61	-1.22
3		70	80	70	60	2	-0.22	0.02	-0.35	-0.66	-0.61	-1.82
4		90	90	10	90	3	1.06	0.60	-3.27	0.78	0.52	-0.32
5		90	90	90	90	3	1.06	0.60	0.63	0.78	0.52	3.58
6		80	90	90	90	4	0.42	0.60	0.63	0.78	1.64	4.07
7		80	90	90	90	2	0.42	0.60	0.63	0.78	-0.61	1.82
8		60	80	60	60	2	-0.85	0.02	-0.84	-0.66	-0.61	-2.94
9		80	100	100	80	2	0.42	1.19	1.11	0.30	-0.61	2.41
10		90	90	90	90	2	1.06	0.60	0.63	0.78	-0.61	2.45
11		70	90	90	80	3	-0.22	0.60	0.63	0.30	0.52	1.83
12		80	80	80	70	3	0.42	0.02	0.14	-0.18	0.52	0.91
13		80	90	80	80	3	0.42	0.60	0.14	0.30	0.52	1.98
14		80	100	100	80	3	0.42	1.19	1.11	0.30	0.52	3.54
15		90	90	90	90	3	1.06	0.60	0.63	0.78	0.52	3.58
16		40	40	40	30	1	-2.13	-2.33	-1.81	-2.09	-1.74	-10.10
17		70	80	80	70	3	-0.22	0.02	0.14	-0.18	0.52	0.28
18		60	70	70	80	2	-0.85	-0.57	-0.35	0.30	-0.61	-2.08
19		60	70	80	70	2	-0.85	-0.57	0.14	-0.18	-0.61	-2.08
20		80	90	80	80	3	0.42	0.60	0.14	0.30	0.52	1.98
21		80	90	90	80	3	0.42	0.60	0.63	0.30	0.52	2.46
22		80	80	90	90	2	0.42	0.02	0.63	0.78	-0.61	1.23
23		70	70	90	80	3	-0.22	-0.57	0.63	0.30	0.52	0.66
24		90	100	100	80	4	1.06	1.19	1.11	0.30	1.64	5.30
25		70	70	60	60	3	-0.22	-0.57	-0.84	-0.66	0.52	-1.76
26		20	30	30	0	0	-3.40	-2.91	-2.30	-3.53	-2.87	-15.01
27		80	90	90	100	3	0.42	0.60	0.63	1.26	0.52	3.42
28		90	90	90	90	3	1.06	0.60	0.63	0.78	0.52	3.58
29		70	90	90	90	3	-0.22	0.60	0.63	0.78	0.52	2.31
30		90	90	90	90	3	1.06	0.60	0.63	0.78	0.52	3.58
31		70	70	70	80	1	-0.22	-0.57	-0.35	0.30	-1.74	-2.58
32		80	80	80	80	4	0.42	0.02	0.14	0.30	1.64	2.52
33		90	80	80	90	3	1.06	0.02	0.14	0.78	0.52	2.51
34		50	40	50	50	1	-1.49	-2.33	-1.32	-1.14	-1.74	-8.02
35		50	50	50	50	2	-1.49	-1.74	-1.32	-1.14	-0.61	-6.30

Appendix 5: Explanations of the excel spreadsheet that we used to derive the measure the Norwegian proficiency of Lithuanians in Norway.

ID		Speaking	Understanding	Reading	Writing	Writing Frequency						Norwegian proficiency
	Mean of:	73	80	77	74	2.54						0.00
	standard deviation	15.7	17.1	20.5	20.9	0.89						4.34
	cut-off value											**-4.34**
1		70	70	70	50	3	-0.22	-0.57	-0.35	-1.14	0.52	-1.76

The excel spreadsheet counted the proficiency score for each participant in the following way: 1) mean of Speaking proficiency of all participants (for example, 73, for Speaking) was taken away from the self-reported proficiency score, in the example above, the participant reported their proficiency in speaking Norwegian to be 70 (in a scare from 0 to 100), and 2) the result was divided by the standard deviation of the Speaking (15.7) to get the number in the red box. The formula is provided below:

(70-73)/15.7)=-0.22

1		70	70	70	50	3	-0.22	-0.57	-0.35	-1.14	0.52	**-1.76**

The last step in counting the proficiency score was to add the values in the colored boxes above:

-0.22 + (-0.57) + (-0.35) + (-1.14) + 0.52 = 1.76

That is how we derived the overall proficiency score which is -1.76 for the participant in this example. To derive the cut off value, we took away one standard deviation from the mean of all the participants overall proficiencies in Norwegian.

	Norwegian proficiency
Mean of:	0.00
standard deviation	4.34
cut-off value	**-4.34**

0.00-4.35=-4.34

Identical methods were applied to measure the exposure to Norwegian (Appendix 3). The procedures of calculating the proficiency and exposure scores were adapted from the excel spreadsheet offered by the authors of the Language and Social Background Questionnaire (LSBQ; Anderson, Mak, Keyvani Chahi, & Bialystok, 2018).

Appendix 6: The languages of LN participants and the ages of acquiring (AoA) them

	AoA Norwegian	AoA English	AoA Russian	AoA German	AoA Polish	AoA Swedish	AoA Danish	AoA Spanish	AoA French	AoA Korean	AoA Hungarian	AoA Icelandic
LN01	26	15	12	10								
LN02	23	7	11				17					19
LN03	13	9		16						19		
LN04	29	10	7									
LN05	21	8										
LN06	29	10	0			18						
LN07	23	7						22				
LN08	26	9	0	11								
LN09	28	18	12	12								
LN10	16	18	12									
LN11	27	15	12	8								
LN12	23	10	11									
LN13	43	11	7									
LN14	18	8	0		0							
LN15	32	10	0	14								
LN16	25	12	14					29				
LN17	19	9	0				22					
LN18	33	10	6			39						
LN19	27	10										
LN20	27	7	6									
LN21	29	17	15	11								
LN22	22	8										
LN23	19	10	12									
LN24	5	6										
LN25	12	7										
LN26	22	11		8								
LN27	23	7	13						13			
LN28	29	23	6								24	
LN29	22	9	5									
LN30	10	6										
LN31	27	10			28							
MEAN AoA	23.5	10.5	7.7	11.3	14	29	20	26	13	19	24	19

Appendix 7: The languages of LL participants and the ages of acquiring (AoA) them

	AoA English	AoA Russian	AoA German	AoA Polish
LL02	11	15		
LL03	7	12		
LL04	9	12		
LL05	8			
LL06	12			
LL07	8			
LL08	10	8		
LL09	11	13		
LL10	14	11		
LL11	18	0	11	0
LL13	7	5		5
LL14	11	0		
LL15	11	6		
LL16	9			
LL17	8	12		
LL18	5			
LL19	12	20		
LL20	10		8	
LL22	8			
LL23	12			
LL24	9			
LL25	11	12		
LL26	10		12	
LL27	10			
LL28	13	12		
LL29	8	11		
LL30	8	12		
LL31	14	12		
LL32	8			
LL33	8			
LL34		3		
LL35	13	11		
LL36	11	7		
LL37	8	6		20
LL38	10	12		
LL39	20	8	11	
LL40	10	15		
LL41	11	11		
MEAN AoA	10.4	9.8	10.5	8.3

Appendix 8: The languages of NN participants and the ages of acquiring (AoA) them

	AoA English	AoA French	AoA German	AoA Swedish	AoA Danish	AoA Spanish	AoA Macedonian	AoA Dutch	AoA Arabic
NN01	6								
NN02	9								
NN03	8					14			
NN04	3	14							
NN05	7		28						
NN06	5			7	7				
NN07	6					14			
NN08	11			3	20				
NN09	4		13						
NN10	3								
NN11	7	13							
NN12	7			8	15				
NN13	7		15						
NN14									
NN15	6								
NN16	9			10	10				
NN17	7	9							
NN18	7								
NN19									
NN20	8		13						
NN21	5	13							
NN22	6								
NN23	9								
NN24	6	12							
NN25	0								
NN26	7			6	12				
NN27	5								
NN28	9						0		
NN29	6					20			
NN30	6	12							
NN31	6	12							
NN32	6								
NN33	7		16						19
NN34	6		13	10				21	
NN35	6	16	14				17		
MEAN AoA	6.4	12.6	16	7.3	13	16	8.5	21	19