The Interaction of Several Languages in the Cognitive System

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Abstract. In this paper, we look into the interaction of several languages in a multilingual language system. Studies involving speakers of three or more language are not common, with most research focused instead on various aspects of bilingualism. We believe, however, that research of the processes involved when several (more than two) languages are used could provide the existing body of research with additional data about language interaction. In this study, we attempt to evaluate a multilevel network model shared between several languages which integrates lexical, semantic and syntactic information. To this end, we proposed an experimental paradigm in which trilingual participants translate phrases and sentences from their Language 2 to Language 3 (and vice versa) while they are primed subliminally with single words in Language 1. We carried out a series of experiments where we manipulated prime types as well as the type of phrases and sentences. We hypothesized that Language 1 primes will interfere with the translation between Languages 2 and 3, leading to longer translation times, and that the amount of interference would vary in different conditions. Our hypotheses were partially confirmed for some types of stimuli but not for others. The implications of these results for existing models and theories are discussed.

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Introduction

The operation and interaction of several languages in the cognitive system (organization of the lexicon, semantic memory and syntactic structures) has been a topic of much discussion in psychological literature for several decades. Most research in this area has involved people who speak two languages, both early bilinguals (fluent in both languages since childhood) and late bilinguals (who acquired their second language in school or during adulthood).

There are very few studies dedicated to multilinguals, defined as people fluent in three or more languages, one of which is usually their mother tongue acquired in early
childhood and the other two or more having been learned later in life to a high level of proficiency; early trilinguals and multilinguals are extremely rare. Research of the organization and interaction of several language systems (more than two) can provide some new information that is so far unavailable in bilingual research.

Bilinguals speak two languages, one of which (the native language) seems to be in a privileged position and serves as the basis of concept formation and development of syntactical structures. The other language is typically learned later using previously formed structures and mechanisms. Several decades of research show that the two languages of a bilingual are very closely interconnected (Grosjean, 1989; French & Jacquet, 2004; Kroll, Dussias, Bogulski, & Kroff, 2012; Kroll, Bogulski, & McClain, 2012, Francis, 1999; Kroll, Dussias, Bice, & Perotti, 2015).

It should be taken into account that people who speak more than two languages constitute a significant part of world’s population. Precise statistics are unavailable, in part because of the many possible ways to learn more than two languages. Considering this, studies of multilingual systems are very sparse (Proverbio, Roberta, & Alberto, 2007).

Studies of multilingual speakers provide a different approach to the issue of language operations and interactions. In particular, they could potentially answer questions related to the interaction between the second and the third languages (L2 and L3) in multilingual cognitive systems, levels of interaction, the role of the first language in the organization of the cognitive system, and mechanisms responsible for the choice of a certain language in a given task.

In this paper, after a brief overview of several theoretical models of bilingual language systems, we will formulate hypotheses concerning trilinguals and test them in a series of experiments with trilingual participants.

**Multilingual Language System**

The interaction of several languages in a bilingual language system is an established fact. Furthermore, this interaction occurs at different levels: the lexical level (Dijkstra & Van Heuven, 2002; Brysbaert, 1998; De Bruijn, Dijkstra, Chwilla, & Schriefers, 2001; Dijkstra, Timmermans, & Schriefers, 2000; Gollan & Kroll, 2003; Jared & Kroll, 2001; Jared & Szucs, 2002; Marian, Spivey, & Hirsch, 2003; Schwartz, Kroll, & Diaz, 2007; Von Studnitz & Green, 2002; Duyck, Assche, Drighe, & Hartsuiker, 2007), the semantic level, (Schwanenflugel & Rey, 1986; Grainger & French-Mestre, 1998; Potter, So, Eckardt, & Feldman, 1984) and the syntactic level (Bock, 1986; Hartsuiker, Pickering, & Veltkamp, 2004; Loebell & Bock, 2003; Bernolet, Hartsuiker, & Pickering, 2007). Language systems are flexible and permeable, and they interact in the course of reading, listening and speaking (Marian & Spivey, 2003; Van Heuven, Dijkstra, Grainger, & Schriefers, 2001; Kroll, Bobb, & Wodniecka, 2006; Schwartz & Kroll, 2006; Dijkstra, 2005; Strijkers, Costa, & Thierry, 2010; Misra, Guo, Bobb, & Kroll, 2012).

Interaction occurs between languages from the same or different language families (such as English and Japanese, or English and Chinese), as well as between languages that exist in different modalities (such as written and sign formats) (Gollan et al., 1997; Hoshino & Kroll, 2008; Thierry & Wu, 2007; Morford, Wilkinson, Villwock, Piñar & Kroll, 2011; Emmorey, Luk, Pyers & Bialystok, 2008). Both languages are activated even when only one is currently used (Schwartz & Kroll, 2006; Duyck et al., 2007; Dijkstra, 2005). Not only does the language learned first (L1) influence the language learned second (L2), but L2 can also make a significant impact on L1, even if the former was acquired relatively late in life (Sunderman & Kroll, 2006; Misra et al., 2012; Titone, Libben, Mercier, Whitford, & Pivneva 2011; Dussias & Sagarraga, 2007; Van Hell & Dijkstra, 2002; Van Wijndaele & Brysbaert, 2002; Grosjean, 1989; Linck, Kroll, & Sunderman, 2009).

Furthermore, both languages are activated simultaneously and nonselectively (Dijkstra & Van Heuven, 1998; Dijkstra & Van Heuven, 2002). That means that when a bilingual is presented with a sequence of letters or sounds, several lexical candidates get activated at the same time regardless of the language they belong to. Their activation is determined by similarity to the stimulus and lexical frequency. Subsequently, one of the candidates gets chosen.

It was discovered several decades ago that semantic representations are shared between the two languages in a bilingual system (Schwabedtflug & Rey, 1986; De Bot, 1992; Potter et al., 1984; Francis, 1999). This is assumed in lexical access models such as the Word Association Model, the Concept Mediation Model, both proposed by Potter et al. (1984), and the Revised Hierarchical Model (Kroll & Stewart, 1994). One of the methods used to obtain empirical support for this claim is semantic priming, which is an effect induced by semantically related stimuli. The semantic priming effect has been observed for L1 words on L2 words and vice versa, suggesting evidence for shared semantics (Duñabeitia, Perea, & Carreiras, 2010; Duyck, 2005; Francis, Augustini, & Sæenz, 2003; Grainger & Frenk-Mestre, 1998).

The interaction of languages on a syntactic level is also a topic of interest (e.g., Bock, 1986; Bock & Griffin, 2000; Hartsuiker et al., 2004; Schoonbaert, Hartsuiker, & Pickering 2007).

A number of works using structural priming shows that bilingual participants are likely to repeat a previously presented syntactic structure while completing a task in a different language. In Loebell and Bock’s work (2003), this effect was observed for German and English dative constructions in German-English bilinguals. Hartsuiker and colleagues (2004) observed a similar effect for English and Spanish. In Desmet and Declerq’s paper (2006), it was shown that in Dutch speakers the primes influence ambiguity resolution in English sentences; the authors used ambiguous sentences with relative clauses (e.g., Someone shot the servant of the actress who was on the balcony). In this case the ‘who’ phrase attachment is not clear, whereas in Dutch the ambiguity can be resolved due to gender agreement.

The structural priming effect shows reliable evidence of shared syntactic structures. This idea is also supported by code-switching studies, demonstrating that bilinguals can switch from one language to the other within a sentence while maintaining its syntactic integrity. The number of studies in this area is increasing (Dussias & Kroll, 2010).
We assume that it is possible to apply all of these theories to a multilingual cognitive system by expanding them to three and more languages. In this case, we assume a multilevel network, functioning according to parallel access and non-selectivity principles. The multilevel network has shared concept representations and categorical and combinatorial nodes for three (or more) languages. We omit all the non-network mechanisms, which are, of course, active in any language system. Lemmas are stored in the same shared lexicon and are tagged for each of the three or more languages by a connection to one of the three language nodes. Activation spreads within a single level as well as between them. On the lexical (lemma) level, it spreads from the activated lemma to lemmas which are visually or acoustically similar regardless of their language. On the semantic level, activation from a concept node spreads to the nodes that have similar meaning or whose semantic features overlap; thus, activation of the words that share meaning occurs irrespective of the language.

Another important issue concerns the associative relationships in the network. That is, words can share meaning (or partial meaning) and thus be semantically related, they can co-occur in context and develop associative connections, or both (Charles, Reed, & Derrberry, 1994; Ferrand & New, 2003; Perea & Rosa, 2002; Fellbaum, 1995). Lexical antonyms often happen to be both semantically and associatively related. However, different pairs of antonyms are related to each other in different ways, which is a separate line of research in linguistics (Paradis et al., 2009).

The interaction of syntaxes should be, in large part, similar: the activation of single lexical items regardless of their language spreads to the corresponding categorical and combinatorial nodes (Hartsuiker et al., 2004). This explains cross-language priming.

Notably, that the efficiency of such a language system should increase with greater proficiency in L2 and L3.

According to the proposed model, all languages of a multilingual (trilingual) are integrated in a single network containing lexical, semantic and syntactic information; conceptual and syntactic (combinatorial and categorical) nodes are at least in part shared by the languages; words are stored in a common lexicon and their activation is parallel and non-selective.

For empirical verification of the implications of the proposed model, we used a subliminal priming paradigm. The idea behind this procedure is that the subliminal presentation of a stimulus significantly influences the processing of the subsequent stimuli if they share some common properties with the prime. Subliminal priming is achieved by a very brief presentation time (several dozens of milliseconds), low intensity and/or masking. The prime can be perceived and processed by the participant, but the participant has no conscious recollection of ever seeing the prime. We expect the primes to trigger highly automated and fast processes of language and word recognition. This method allows us to introduce an experimental manipulation that does not require the participant to consciously process the stimulus (Bar & Biederman, 1998; Draine & Greenwald, 1998). Furthermore, it allows us to create an ecologically valid situation of L1, L2 and L3 interaction. Cross-language syntactic and semantic priming effects in a multilingual cognitive system are, supposedly, based on the integrated network principles described above. Moreover, the proposed model suggests that the activation of a fragment of a syntactic or semantic network could potentially be achieved with single word primes. That is, a unit from one language can influence the units of other languages as long as they are somehow related on either a syntactic or semantic level. A single word can activate the corresponding nodes of the network on every level.

The idea of the experimental study we carried out involves putting the three languages of a trilingual in one task in a way that would allow us to observe the role of L1 in the L2–L3 interaction. Trilingual participants (in our case, Russian-Spanish-English trilinguals) were instructed to translate phrases and simple sentences from their L2 to L3 and vice versa as fast as they could. In the course of the task, they were presented subliminally with single word primes that were either semantically related to one of the words of the construction they had to translate, or were their direct translations. We supposed that the prime would activate all semantically related concepts as well as some syntactic nodes. Comparing the times of translation in the conditions with and without the prime allows us to explore the direction and the degree of the priming effect (or its network representation, to be precise) on the process of translation between the other two languages. This enables us to study the connections between the three languages in the trilingual cognitive system and to identify the levels (lexical, semantic and syntactic) and the extent of their interaction.

In our study, we used phrases and sentences as stimuli for reasons of ecological validity and because we wanted to see the language network in action within a context, namely to explore the influence of single words on various syntactic relationships.

Previous research provides different priming results: priming can both facilitate and inhibit language processing depending on the task. In word recognition tasks, priming often causes facilitation (Schwanenflugel & Rey, 1986; Finkbeiner, Forster, Nicol, & Nakamura, 2004; Grainger & Frenck-Mestre, 1998; Duyck & Brysbaert, 2004). In production tasks, however, participants have to deal with several competing candidates which leads to interference (Kroll & Gollan, 2014; Kroll, Bogulski, & McClain, 2012). This effect is attributed to a combination of activation and inhibition processes occurring in the cognitive system. On the one hand, the more activated by the prime the nodes related to it are, the faster the activation spreads to the corresponding words. On the other hand, the more activated the network segment is, the more time is required to inhibit all the extra activation and to make a choice from one of the competing candidates and to finally extract and articulate it. We speculate that the latter effect will supersede the former because, despite the quantity of the activated candidates, as long as the right concept is activated the activation will find the right target. However, the production phase of translation requires a rigorous selection of multiple recently activated options, which incurs a very high processing cost.

It is worth noting that semantically related lexical distractors are notorious for causing interference (e.g., Miller & Kroll, 2002; Bloem & La Heij, 2003). Miller and Kroll...
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(2002), contrary to what has been said, suggest that bilinguals can activate languages selectively, as the semantically related distractors in their study only caused interference when they were presented in the language of production. It is not clear that this would remain the case for trilinguals where the prime is presented in neither the input nor the production language; it may remain a selection candidate. One of the authors subsequently argued that selective access is a special case, as opposed to nonselective access which is typical in bilinguals (Kroll et al., 2006).

Thus, supposing that in a trilingual language system the languages are stored in an integrated network in which the activation is parallel and non-selective, priming should slow down L2–L3 translation. The primes activate too many competitors for selection, causing excessive competition and creating interference which takes more time to resolve. In this experimental situation, the primes should activate an excessive number of semantic and syntactic representations for L2–L3 translation, impairing the extraction of lexical, semantic and syntactic information. This situation imposes a large amount of inhibition, and therefore slows down the translation. These hypothetical processes in the integrated network of Russian-English-Spanish trilinguals is illustrated in Figure 1.

![Figure 1. Trilingual language network during L2 (Spanish)-L3 (English) translation with prime in L1 (Russian). Bidirectional arrows indicate the spreading of activation within a trilingual language network with the L1 prime preceding the L2-L3 translation: the activation of interconnected lexical (L1–L3), semantic and syntactic nodes. Green arrows indicate relevant word selection. Red arrows indicate excessive activation; that is, the activation of nodes irrelevant for task completion.](image)

This effect is the consequence of the proposed network organization. L1 primes will activate some unnecessary and excessive lexical, semantic and syntactic nodes. This will cause interference due to the activation of too many candidates at the same time or due to suppression of irrelevant units (there is no way to tease the processes of selection and inhibition apart using this paradigm). This is the consequence of the close connection between the three languages and the parallel non-selective activation principle. Furthermore, some research suggests that L1 has a lower activation threshold than L2, L3, and so on (Gollan, Montoya, Cera & Sandoval, 2008; Murray & Forster, 2004), and therefore its activation is harder to suppress.

2. The strongest effect will be achieved with the presentation of synonym and antonym primes (compared to direct translation primes).

This is also a consequence of the network organization wherein the presence of common semantic and syntactic nodes provides simultaneous activation of words in each language. A certain contribution to the priming effect in this case is due to interference on the lexical level (connections between translation equivalents) and semantic level (activation of various semantic nodes due to possible different meanings, connotations, etc.). The activation is expected to be significantly more pronounced with L1 synonym and antonym primes (primes that would be a synonym/antonym of the direct translation). In this situation, the activation spreads to more lexical and semantic nodes than would occur with direct translation, thus leading to more interference. This means that to make a translation with a synonym prime, more suppression is required in comparison with direct translation.

### Experiment 1

In the first experiment, we tested three hypotheses:

1. L1 primes will interfere with translation in both directions (from L2 (Spanish) into L3 (English) and from L3 into L2).

2. The results of this experiment were partially published in Ezrina and Spiridonov (2014).
It is worth mentioning that the interaction of languages at the semantic level will be confirmed only if all primes inhibit the translation.

3. A prime targeted at the head of the phrase will cause stronger interference than a prime targeted at the dependent unit.

Since a complete set and a possible hierarchy of syntactic units in the language system are not defined, we will limit the explanation of the influence of syntactic properties of the prime to the impact associated with the head and the dependent of the phrase. The phrase has a certain hierarchy; that is, the syntactic properties of the head apply to the whole phrase whereas the syntactic properties of the dependent are only applicable to the dependent itself. In network model terms, this means that the syntactic nodes connected to the head of the phrase are more strongly activated than the nodes connected to the dependent unit.

Admittedly, the time interval between the prime onset and target processing will vary, and therefore the first word in a phrase should be primed more strongly than subsequent words. Furthermore, it is unclear when the priming effect should subside. Unfortunately, this paradigm does not account for this possible confound.

The presentation of a Russian prime (in this case, a single word prime without any context) activates all of its syntactic properties (i.e., the nodes related both to its grammatical class and syntactic constructions in which the word can possibly appear). The prime is followed by the presentation of an L2 or L3 phrase in which the head is already defined, causing a number of nodes associated with the head to be activated. Syntactic nodes associated with the dependent unit are significantly less activated. During translation into another language, further (third) activation of the head and lesser activation of the dependent occurs. Thus, a strong interference between the three sets of matched and mismatched activated syntactic nodes is created. However, with the head of the phrase priming, the prime properties interfere with the strongly activated properties of the heads of L2 and L3 phrases, as opposed to the case of dependent priming wherein the interference occurs between less activated dependents. Therefore, in the latter situation the interference is weaker. This means that the syntactic head priming will lead to greater translation times than those for the dependent priming.

Table 1. Experiment Design and Examples of the Stimuli (Phrases and Primes) for Each Design Cell

<table>
<thead>
<tr>
<th>Noun phrase</th>
<th>Verb phrase</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Example</strong></td>
<td><strong>Example</strong></td>
</tr>
<tr>
<td><strong>Head target (21)</strong></td>
<td><strong>Head target (28)</strong></td>
</tr>
<tr>
<td>Una mujer desconocida</td>
<td>Oir una canción</td>
</tr>
<tr>
<td>Un niño maravilloso</td>
<td>Engañar a la gente</td>
</tr>
<tr>
<td>La mañana siguiente</td>
<td>Empezar la partida</td>
</tr>
<tr>
<td><strong>Dependent target (24)</strong></td>
<td><strong>Dependent target (27)</strong></td>
</tr>
<tr>
<td>Un fiel marido</td>
<td>Prestar ayuda</td>
</tr>
<tr>
<td>Una aventura loca</td>
<td>Pagar el precio</td>
</tr>
<tr>
<td>Una puerta abierta</td>
<td>Admitir el fracaso</td>
</tr>
<tr>
<td><strong>Baseline</strong></td>
<td><strong>Baseline</strong></td>
</tr>
<tr>
<td>Una ventana rota</td>
<td>Esperar las noticias</td>
</tr>
<tr>
<td><strong>Head target (15)</strong></td>
<td><strong>Head target (31)</strong></td>
</tr>
<tr>
<td>A red chair</td>
<td>To eat the bread</td>
</tr>
<tr>
<td>A fulfilled dream</td>
<td>To kill with a knife</td>
</tr>
<tr>
<td>A useful gain</td>
<td>To find love</td>
</tr>
<tr>
<td><strong>Dependent target (24)</strong></td>
<td><strong>Dependent target (10)</strong></td>
</tr>
<tr>
<td>A brave man</td>
<td>To waste the time</td>
</tr>
<tr>
<td>A tired worker</td>
<td>To build a house</td>
</tr>
<tr>
<td>An old building</td>
<td>To lose the war</td>
</tr>
<tr>
<td><strong>Baseline</strong></td>
<td><strong>Baseline</strong></td>
</tr>
<tr>
<td>A cold wind</td>
<td>To grow in the forest</td>
</tr>
</tbody>
</table>

**Note:** Number of phrases and primes of a given type is shown in parentheses.
Method

Participants. Twelve trilinguals proficient in Russian, Spanish and English participated in this experiment (8 female, 4 male; age $M = 17.58; SD = 3.54$). Russian was their native language and it was required that their level of proficiency in Spanish and English be no lower than B2 according to the Common European Framework of Reference (CEFR). The participants were high school and university students as well as university graduates. Their proficiency levels in both languages were confirmed by international certificates (FCE for English and DELE B2 for Spanish or higher level certificates), results of the Unified State Exam taken for both languages (Russian graduation exam required to enter a university, corresponding to the B2 level), or a university degree in both languages. The participants received no compensation for taking part in the experiment. They were informed that participation was voluntary and had no negative consequences, and they were also debriefed after the experiment. All participants gave their informed consent.

Stimuli. The participants were required to translate simple phrases from Spanish into English and vice versa (see Table 1 for examples). The following types of phrases were used: noun phrase formed with a noun and an adjective (the noun being the syntactic head of the phrase) and verb phrase formed with a verb and a noun (the syntactic head of the phrase is the verb). We used both plural and singular forms of nouns and adjectives, but only verb infinitives.

Only words appearing in the text of level B2 international examination papers were used. Sample B2 international examination papers were used as sources of the stimuli because words which appear in such papers are considered to be familiar. The chosen words were subsequently searched in the corpora to obtain examples of use. These examples were simplified to accommodate the experimental criteria (the verbs were put in the infinite form, noun phrases were reduced to one noun and one adjective, and verb phrases were reduced to one verb and one noun). Other criteria such as word length were not controlled for, considering the variability among the three languages. In total, there were 224 phrases, 112 for each language. The number of stimuli was unbalanced across design cells given the limited number of words that met the aforementioned criteria. Therefore, data for individual stimuli were not analyzed.

For each of the words in a phrase, there was a corresponding Russian single word prime of one of the following types: a direct translation, a direct translation synonym (understood broadly as a word with similar meaning, but not having the same meaning) and an antonym (see Table 1).

The targets of the prime could be either the head or the dependent. The Russian primes could be nouns, verbs and adjectives used to prime four types of targets: noun (in the head or dependent position), adjectives or verbs. Primes were presented in their dictionary forms: singular nouns, singular number and masculine gender for adjectives, and infinitive verbs. Synonyms and antonyms were selected using synonym dictionaries (Apresian, 2003; Abramov, 1999). The length of the prime varied from 3 to 11 letters. All had translation equivalents in other languages. Stimuli contained no cognates to avoid any cognate facilitation effect.

Procedure. The participants had to translate each phrase individually as fast as they could in both directions (L2–L3 and L3–L2). The phrases appeared on a CRT screen (Samsung, 17-inch diagonal, 85 Hz frequency, 960 × 600 pixel resolution). The participants were sat 50 cm away from the screen; the height of the font of the stimuli was 1.5 cm, the length of the longest word reached 12 cm. All phrases were preceded by a 12 ms long subliminal prime and a mask (black screen) of the same onset time. A blank slide was used as the baseline. To ensure that participants were paying attention to the screen, each trial was preceded by a fixation cross which appeared in the center of the screen and was fixated with both eyes. A trial structure is illustrated in Figure 2.

Each participant saw each phrase only once. Each phrase was assigned a fixed prime that never varied in the experiment — all participants were presented with the same set of phrases with the same primes. The stimuli were randomized for every participant. The phrases were organized in four blocks, two for each language; the blocks were presented in the following sequence: Spanish–English–Spanish–English. Participants were notified about the change of language every time. Furthermore, the test trials were preceded by a practice session of 10 phrases.

Before giving a response, participants had to press the space bar that then switched on the audio recording of the answer. The recording stopped when the participants pressed the space bar again.

The experiment was designed in E-Prime 2.0, which was used to create the presentation of stimuli and to time and record the translations. Response time data were collected using Sony Sound Forge 9.0 software.

Self-report. In a post-experimental interview, the participants were asked which slides they saw and in what sequence (instruction, fixation cross, stimulus) and whether they noticed anything unusual (e.g., screen blinking).

Design. Within-subject factors were Translation Direction (from Spanish to English, or from English to Spanish), Prime Type (translation, synonym, antonym or baseline/blank), Type of Phrase (noun phrase or verb...
phrase) and Type of Target (syntactic head [noun or verb], syntactic dependent [adjective or noun] or baseline [for noun phrases or verb phrases]). Consequently, the experiment had an incomplete factorial design; noun phrases with a blank prime were used as the baseline for all other noun phrases with primes, and verb phrases with a blank prime were used as the baseline for all other verb phrases with primes. Since the baseline phrases were preceded by a blank prime, and therefore had no target, a separate baseline for each condition (noun-syntactic head, noun-syntactic dependent, verb and adjective targets) was not provided. Thus, we compared the translation time of the noun phrase with a blank prime with the translation times of the noun phrases where the head nouns or the adjectives were the targets of priming. Similarly, we compared the translation time of a verb phrase with a blank prime with translation times of the verb phrases where the verbs or the dependent nouns were the targets of priming.

The dependent variable was the response time, which was measured from the onset of the stimulus presentation to the onset of speech.

**Results**

All participants were able to perform the task.

Responses were excluded if they contained errors or differed from the mean response time (RT) calculated once over all participants by more than three standard deviations (about 8% of data points were removed in this manner). The average error rate was not analyzed. Mean RT for each participant was calculated over each condition and used for analysis by ANOVA.

Since we were not interested in the interaction between Prime Type and Phrase or Type of Target, the experiment had an incomplete factorial design, and it was impossible to run the four-way or three-way ANOVA. Therefore, we calculated three separate two-way ANOVAs: one with Translation Direction and Prime Type as factors, and two with Translation Direction and Type of Target as factors.

**Analysis of priming effect by prime type.** We ran a $2 \times 4$ repeated-measures ANOVA with Translation Direction (Spanish–English, English–Spanish), and Prime (translation, synonym, antonym, no prime/baseline) as within-subject factors. The ANOVA revealed a significant influence of Prime Type on translation time in both directions $F(3.66) = 3.316$, $p = .025$, $\eta^2 = .131$ (see Figure 3). The factor interaction was not significant $F(3.66) = .030$, $p = .993$, $\eta^2 = .001$. Mauchly’s sphericity test was not significant $W = .840$, $p = .607$.

Since the main effect was significant and the interaction of factors was not, we carried out post hoc comparisons of Prime Type (with Bonferroni correction for multiple testing) for the data averaged across Translation Directions. The post hoc analysis revealed a trend that Russian synonym primes slow down translation times comparing to the baseline ($p = .06$)

**Effect of Russian primes on Spanish and English noun phrases and verb phrases.** We analyzed the possible influence of Russian primes on translation time between L2 and L3 separately for two types of phrases (noun phrases and verb phrases). We ran two two-way ANOVAs with repeated measures: a) with Translation Direction (Spanish-English, English-Spanish) and Prime Target (verb, dependent noun, baseline verb phrase with a blank prime, i.e. no target) and b) with Translation Direction (Spanish-English, English-Spanish) and Prime Target (head noun, adjective and baseline noun phrase with a blank prime) as within-subject factors. The first ANOVA revealed significant interference caused by the Russian prime on translation time in verb phrases (verb + noun) in both directions, as shown in Figure 4 ($F(2, 44) = 4.557$, $p = .016$, $\eta^2 = .172$) but not in noun phrases ($F(2, 44) = 1.210$, $p = .287$, $\eta^2 = .052$). The interaction of the factors was not significant ($F(2, 44) = .071$, $p = .663$, $\eta^2 = .012$). The second ANOVA did not reveal a significant interference ($F(2, 44) = 1.541$, $p = .226$, $\eta^2 = .065$).

Since the main effect of Prime Target was significant and the interaction of factors was not, we carried out post hoc analysis (with Bonferroni correction for multiple testing) for both translation directions. It revealed significantly longer translation times in the case of verb target compared to the baseline ($p = .025$).

**Self-report.** All participants reported having seen only the slides with the instruction, a fixation cross and a task phrase. They did not notice anything unusual during the experiment; they only mentioned the blinking of the screen after being specifically asked about it. They did not pay attention to it, thinking of it as a “program defect”. This suggests that the priming was indeed subliminal and that the participants were not conscious of seeing the primes.

**Discussion**

The results show a trend that Russian synonym primes increase translation times between L2 and L3. This appears to be evidence of interference, which almost reaches significance with synonym primes. Also, it is worth pointing out the similarity of the priming effect pattern in both translation directions. However these results cannot provide substantial evidence supporting Hypotheses 1 and 2.
According to the proposed model, the source of the interference is the excessive activation caused by priming: Russian lexical nodes, activated by the Russian prime, interfere with Spanish and English lexical nodes, which complicates the selection process. The same thing happens when excessive syntactic and semantic nodes are activated. The greatest interference in both translation directions occurs in the case of synonym primes (i.e., primes similar but not fully identical in meaning to one of the words in the target phrase). These primes activate both relevant and excessive fragments of the language network. The processing of “excessive” activation requires more time.

Hypothesis 3 was partially supported by the results: the priming of the syntactic head of one phrase type (the verb in the verb phrase) appears to interfere with the translation process. The priming of the dependent noun and noun and adjective in noun phrases did not cause any significant effect.

This priming effect of Russian verb primes may be due either to interference of activated similar syntactic structures or to mismatching syntactic properties of Russian, Spanish and English words. But the properties of our method do not provide specification for which matching/mismatching categorical and combinatorial features of Russian, Spanish and English cause the observed effect. For example, in the preparation of the experiment, Russian verbs were selected according to their meaning and semantic relatedness to Spanish and English verbs and not based on the similarity of their syntactic properties (which would have been impossible to match across the three languages). One of the significant differences is case grammar in Russian and its absence in English and Spanish. The need to deal with the activation of syntactic nodes that are irrelevant in a given situation would also lead to an increase in translation time.

The syntactic effects of Russian priming are also supported by the following result. The translation of noun phrases from English into Spanish in the baseline condition appeared to be significantly slower than the translation from Spanish into English of the same type of phrases. A possible explanation of this effect comes from the different word order in noun phrases in English and Spanish. Spanish phrases of this type often begin with a noun (for example los ojos (noun) verdes (adjective), “green eyes”; un viento (noun) frio (adjective), “cold wind”) whereas in English the word order is the opposite: the adjective comes before the noun. The need to reverse the word order complicates the translation. However, this effect is monodirectional: a similar translation time difference was not observed in the Spanish-to-English translation direction in the baseline condition.

It appears that the results obtained in this experiment provide evidence of semantic and some syntactic connections between Russian, Spanish and English words involved in translation processes. The semantic connections between the three languages are evidenced by greater L2–L3 and L3–L2 translation times which are observed with direct translation and synonym primes. Moreover, since the activation caused by Russian primes slows down the translation between two non-native languages, the parallel and non-selective activation of the different languages which predetermines the observed inhibition can be supported.

The observed results are consistent, in general, with the network model and with the parallel non-selective language activation approach. A possible difference between bilingual and trilingual language systems is that a trilingual would have to select between a greater number of various activated semantic, syntactic and lexical nodes and to inhibit more language information; therefore, interference between the language nodes will be more pronounced due to the need to balance more languages.

A significant limitation of the first experiment appears to be the use of phrases which substantially restrict the set of syntactic connections involved in the translation process. Experiment 2 aimed to overcome this drawback by using full sentence stimuli.

**Experiment 2**

In Experiment 2 we tested the following hypotheses to see how categorical and combinatorial nodes of a trilingual (in this case, a Russian–Spanish–English trilingual) work.

1. Russian primes will slow down the translation of all types of sentences in both translation directions. This hypothesis is motivated by the network organization, in which Russian primes will activate related syntactic nodes. The need to select between several activated items as well as the need to suppress excessive activation will lead to an increase in the time needed to translate in both directions.

2. Russian primes targeted at the subject or the verb will cause more inhibition than primes targeted at the object of the sentence. This hypothesis is based on a theoretical assumption regarding the definite syntactic hierarchy in the sentence: the subject and the verb are syntactic heads governing other words in the sentence. Syntactic nodes corresponding to the heads should be activated more in comparison to those corresponding to the dependents. In other words, with subjects and verbs, Russian words interfere with strongly activated syntactic
heads of the sentence, and with objects they interfere with the more weakly activated properties of the dependent. Therefore, primes targeted at the subject and the verb should lead to longer translation times.

It is noteworthy that a significant priming effect in this case will evidence the connections between the syntactic structures of the three languages used in the experiment (i.e., common categorical and/or combinatorial nodes).

**Method**

**Participants.** Twenty-nine Russian native speakers (20 female, 9 male; $M_{age} = 19.35; SD = 38.67$) volunteered to take part in this experiment. Eleven participants also took part in Experiment 1, and they had not reported seeing the primes after Experiment 1. Their levels of proficiency in Spanish and English were no lower than B2 according to CEFR. The participants had to present international cer-

---

**Table 2.** Experiment Design and Examples of the Stimuli (Phrases and Primes) for Each Design Cell

<table>
<thead>
<tr>
<th>Example</th>
<th>Prime</th>
<th>Example</th>
<th>Prime</th>
<th>Example</th>
<th>Prime</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Active voice (15)</strong></td>
<td></td>
<td><strong>Passive voice (15)</strong></td>
<td></td>
<td><strong>Question (15)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Spanish</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subject target (3)</td>
<td></td>
<td>Subject target (3)</td>
<td></td>
<td>Subject target (3)</td>
<td></td>
</tr>
<tr>
<td>El fuego quemó la casa</td>
<td>Пламя</td>
<td>El trabajo fue hecho por mi marido</td>
<td>Труд</td>
<td>¿Compró el amigo las entradas?</td>
<td>Прямою</td>
</tr>
<tr>
<td>Verb target (3)</td>
<td></td>
<td>Verb target (3)</td>
<td></td>
<td>Verb target (3)</td>
<td></td>
</tr>
<tr>
<td>El pueblo encontró el dinero</td>
<td>Обнаружить</td>
<td>El coche fue comprado por mi abuelo</td>
<td>Приобретать</td>
<td>¿Tomó muchas cosas el ladrón?</td>
<td>Забрать</td>
</tr>
<tr>
<td>Object target (3)</td>
<td></td>
<td>Object target (3)</td>
<td></td>
<td>Object target (3)</td>
<td></td>
</tr>
<tr>
<td>El chico dice la verdad</td>
<td>Истина</td>
<td>Mis padres están sorprendidos por mi fracaso</td>
<td>Неудача</td>
<td>¿Siente alegría tu abuelo?</td>
<td>Счастье</td>
</tr>
<tr>
<td><strong>Baseline</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>El alumno pregunta al maestro</td>
<td>Blank screen (6)</td>
<td>La llave fue perdida por mi</td>
<td>Blank screen (6)</td>
<td>¿Llegó tarde el invierno?</td>
<td>Blank screen (5)</td>
</tr>
<tr>
<td><strong>English</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subject target (3)</td>
<td></td>
<td>Subject target (3)</td>
<td></td>
<td>Subject target (3)</td>
<td></td>
</tr>
<tr>
<td>The fear stopped the beast</td>
<td>Боязнь</td>
<td>The power is gained by the workers</td>
<td>Мощь</td>
<td>Does the death scare you?</td>
<td>Гибель</td>
</tr>
<tr>
<td>Verb target (3)</td>
<td></td>
<td>Verb target (3)</td>
<td></td>
<td>Verb target (3)</td>
<td></td>
</tr>
<tr>
<td>The band finished song</td>
<td>Завершить</td>
<td>This town is loved by all</td>
<td>Нравиться</td>
<td>Did the dog dig a hole?</td>
<td>Копать</td>
</tr>
<tr>
<td>Object target (3)</td>
<td></td>
<td>Object target (3)</td>
<td></td>
<td>Object target (3)</td>
<td></td>
</tr>
<tr>
<td>The car crossed the border</td>
<td>Край</td>
<td>The children are scared by the darkness</td>
<td>Мрак</td>
<td>Did the teacher leave the room?</td>
<td>Помещение</td>
</tr>
<tr>
<td><strong>Baseline</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The stone hit the wall</td>
<td>Blank screen (6)</td>
<td>The king was murdered by a servant</td>
<td>Blank screen (6)</td>
<td>Do the shops sell your book?</td>
<td>Blank screen (5)</td>
</tr>
</tbody>
</table>

**Note:** Number of phrases and primes of a given type is shown in parentheses.
Stimuli. The stimuli for Experiment 2 were simple Spanish and English sentences each containing a subject, a verb and an object (see Table 2). As in Experiment 1, the sentences consisted of words and grammar appearing in international examinations for the B2 proficiency level. The subjects and verbs exist both in singular and plural forms; only the simple verbal tenses were used. Three types of sentence structure appeared as stimuli: active voice, passive voice and yes/no questions. This would allow comparing the functioning of syntactic nodes primed with Russian single words.

The grammaticality of the sentences was verified using text corpora Corpus de Español [http://www.corpusdeespanol.org/], Real Academia Española – Corpus de Referencia del Español Actual [http://corpus.rae.es/creanet.html] and the British National Corpus [http://www.natcorp.ox.ac.uk/]. Additionally, native speakers of Spanish and English evaluated the grammaticality of the sentences.

The sentences were organized in four blocks, two for each language. The blocks were presented in the following sequence: Spanish–English–Spanish–English. Participants were notified about the change of language every time. Furthermore, the test trials were preceded by a practice run of 10 phrases. The sentences were randomized within each block. There was a total of 90 sentences; 45 for each language, 15 sentences of each type (active voice, passive voice, yes/no question) in each language.

In Experiment 1, the strongest tendency was obtained when the phrases were primed with a synonym (see Table 1 for examples). As in that experiment, the synonyms in Experiment 2 did not fully share meanings with the targets as well as the combinatorial and stylistic features.

Russian primes were presented in their dictionary forms: the singular of nouns and the infinitive of verbs. Synonyms and words with similar meaning were selected using synonym dictionaries (Apresian, 2003; Abramov, 1999). The targets were the subject, the verb and the object. All sentences could be translated to a sentence of similar structure. All words had translation equivalents in all three languages. Importantly, the stimuli did not contain any cognates to avoid an eventual cognate facilitation effect.

Stimuli were distributed in such a way that every combination of conditions was presented to each participant an equal number of times, and each participant saw all the stimuli. An empty slide was used as the prime in the baseline condition.

Procedure. The general procedure of this experiment replicated the procedure of Experiment 1. Participants were instructed to translate simple sentences from Spanish into English and vice versa. The sentences were presented one by one on a computer screen (CRT, Samsung, 17-inch diagonal, 85 Hz frequency, 960 × 600 pixels resolution). The participants were seated 50 cm away from the screen. The height of the font of the stimuli was 1.5 cm, and the length of the longest word reached 12 cm. Each sentence was preceded by a prime lasting 12 ms and a mask consisting of 12 hashes (#), one character longer than the longest Russian prime. The mask was changed to avoid the blinking effect that was reported by some participants during the previous experiment. The mask onset time was also 12 ms. The prime and mask were preceded by a fixation cross appearing in the center of the screen. The trial structure of this experiment is illustrated in Figure 5.

Before giving their responses, the participants had to press the space bar that switched on the audio recording of the answer. The recording stopped when the participants pressed the space bar again.

The experiment was designed using E-Prime 2.0 software, which carried out the presentation of stimuli and recorded the responses and types of sentences and primes.

Participants were allowed to translate the sentences as they saw fit: any change of structure was accepted on the condition that it did not affect the meaning of the sentence. There were no additional instructions. If a sentence presented in the passive voice was translated into an active voice sentence, then the sentence was analyzed as active and vice versa: if the original sentence was in the active voice but the translation was passive, then it was analyzed as passive. Furthermore, in Spanish, questions with and without inversion are grammatical, and therefore both versions were accepted. For example, the question ¿El amigo compró las entradas? “Did the friend buy the tickets?” pronounced with question-like intonation was considered correct as was the question with inversion ¿Compró el amigo las entradas? There is also a colloquial form of a question with direct word order adding the conjunction si (“if”): ¿Si el amigo compró las entradas? This form was also accounted for as a question.

The translation onset time was checked using Sony Sound Forge 9.0.

Self-report. In a post experimental interview, participants were asked which slides they saw, in what sequence (instruction, fixation cross, stimulus) and whether they noticed the blinking of the screen.

Design. Within-subjects factors were Translation Direction (from Spanish to English or from English to Spanish), Target Type (subject, verb, object or baseline/no target) and Type of Sentence (active, passive, question). The experiment had a $2 \times 3 \times 4$ full factorial design.

The dependent variable was the time between the onset of the sentence presentation and the beginning of translation.

Results

Responses containing errors and responses that differed from the mean response time (calculated once over all participants) by more than three standard deviations were excluded; in all, about 9.5% of data points were removed. The mean RT for each participant was calculated over each condition and used for an ANOVA. See results in Table 3.

All participants were able to perform the task; the average error rate was not analyzed.
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We ran a 4 × 3 × 2 repeated-measures ANOVA with Syntactic Target (subject, verb, object, no prime/baseline), Type of Sentence (active, passive, question) and Translation Direction (Spanish-to-English or English-to-Spanish) as within-subject factors. Mauchly’s sphericity test was significant for all three factors: Syntactic Target (W = .542, p = .03), Type of Sentence (W = .862, p = .017) and Translation Direction (W = .434, p = .001). Consequently, epsilon correction by Jung-Feldt was used.

A three-way ANOVA revealed a significant main effect for Syntactic Target: F(3,168) = 3.391, p = .019, η2 = .057. The main effect for Type of Sentence was not significant: F(2, 112) = 2.629, p = .077, η2 = .045. The interaction of factors was significant: Syntactic Target × Type of Sentence: F(6,336) = 4.423, p < .001, η2 = .073; Syntactic Target × Translation Direction: F(3,168) = 4.117, p = .012, η2 = .069; Type of Sentence × Translation Direction: F(2,112) = 8.669, p < .001, η2 = .134; Syntactic Target × Type of Sentence × Translation Direction: F(6,336) = 3.876, p = .001, η2 = .065.

Since the interaction of factors was significant, we decided to carry out separate analyses for the types of sentences and for each translation direction. We ran a 2 × 4 repeated-measures ANOVA with Translation Direction (Spanish-to-English, English-to-Spanish) and Syntactic Target in the active voice sentences (subject, verb, object, no prime/baseline) as within-subject factors. We ran the same analysis procedure for the passive voice sentences and questions. Only a two-way ANOVA with Syntactic Target in the active voice sentences revealed a significant priming effect of Russian words on translation time in both directions: F(3, 168) = 6.960, p < .001, η2 = .111. The interaction of factors was also significant: F(3,168) = 8.330, p < .001, η2 = .129. See results in Table 3.

To assess the differences between conditions, we calculated a one-way repeated measures ANOVA with Target Type as a factor separately for each translation direction for the active voice sentences (the levels in both translation directions were: baseline, subject, verb, object). For the Spanish-to-English translation direction, Mauchly’s sphericity test was not significant: W = .664, p = .063. ANOVA showed a significant priming effect on translation time: F(3, 84) = 9.667, p < .001, η2 = .257. Post hoc analysis with Bonferroni correction for multiple testing demonstrated that the Spanish-to-English translation time for active voice sentences with the Russian prime targeted at the verb was significantly longer than baseline (p = .012), and also significantly longer than when the Russian prime targeted the subject (p = .039) or object (p < .001).

For the English-to-Spanish translation direction, Mauchly’s sphericity test was not significant: W = .754, p = .184. ANOVA showed a significant priming effect on translation time F(3, 84) = 3.772, p = .014, η2 = .119. Post hoc analysis with Bonferroni correction for multiple testing demonstrated that the translation time for active voice sentences from English into Spanish with the Russian prime targeted at the subject was significantly longer than baseline (p = .05) and also significantly longer than when the Russian prime targeted the verb (p = .045).

All other comparisons were not statistically significant.

In the other types of sentences, the two-way ANOVA with repeated measures showed no significant priming effect: results for the passive voice were F(3, 168) = 1.706,

---

Table 3. Mean Translation Times of Three Sentence Types Primed with Russian Words with Various Syntactic Targets (ms)

<table>
<thead>
<tr>
<th>Sentence type</th>
<th>Target type</th>
<th>Spanish – English</th>
<th>English – Spanish</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td><strong>Active</strong></td>
<td>Subject</td>
<td>7561</td>
<td>3811</td>
</tr>
<tr>
<td></td>
<td>Verb</td>
<td>10828</td>
<td>6201</td>
</tr>
<tr>
<td></td>
<td>Object</td>
<td>5858</td>
<td>2732</td>
</tr>
<tr>
<td></td>
<td>Baseline</td>
<td>6930</td>
<td>3272</td>
</tr>
<tr>
<td><strong>Passive</strong></td>
<td>Subject</td>
<td>7975</td>
<td>3662</td>
</tr>
<tr>
<td></td>
<td>Verb</td>
<td>8799</td>
<td>3342</td>
</tr>
<tr>
<td></td>
<td>Object</td>
<td>11379</td>
<td>5942</td>
</tr>
<tr>
<td></td>
<td>Baseline</td>
<td>8212</td>
<td>3641</td>
</tr>
<tr>
<td><strong>Question</strong></td>
<td>Subject</td>
<td>8831</td>
<td>5560</td>
</tr>
<tr>
<td></td>
<td>Verb</td>
<td>10151</td>
<td>5165</td>
</tr>
<tr>
<td></td>
<td>Object</td>
<td>7534</td>
<td>3477</td>
</tr>
<tr>
<td></td>
<td>Baseline</td>
<td>7385</td>
<td>3011</td>
</tr>
</tbody>
</table>
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(that is, they require significantly more resources than inhibition of primes, making the priming effect insignificant). Such mechanisms could be, for example, the transformation rules that intervene after the activation of certain network segments and use sets of activated lexical units to formulate sentences. In any case, it would appear that the network model in question does not completely illustrate sentence production and should be expanded by a number of procedures that would provide for that, as well as for translation.

It is worth noting a very important procedural issue of the experiment. We did not control the relative difficulty of the primes and the targets (although all stimuli used were taken from sample exam papers for the B2 level) and, more importantly, we did not vary the combinations of phrases/sentences and primes (each phrase/sentence had a “fixed” prime). Therefore, without additional control experiments, it is not possible to exclude the possibility that the effect was caused by a difference in items and not by the absence or presence of a prime.

In conclusion, we suggest that studies involving trilingual participants allow us to approach existing research questions from another point of view and to see some unique features of the multilingual language system even given its unquestioned similarity to that of bilinguals. Therefore, it is important to continue testing the network models developed for bilinguals on trilingual participants in order to assess their possible limitations.

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Взаимодействие нескольких языков в когнитивной системе человека

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Аннотация. В этой работе рассматривается взаимодействие нескольких языков в когнитивной системе мультилингва. Большая часть исследований посвящена различным аспектам билингвизма, а исследования трилингвов и полиглотов проводятся достаточно редко. Тем не менее нам кажется, что изучение когнитивных процессов, задействованных при использовании трех и более языков, может дать дополнительные сведения об их взаимодействии. В этой работе делается попытка оценить единую для нескольких языков многоуровневую сетевую модель, включающую лексический, семантический и синтаксический компоненты. С этой целью мы предложили экспериментальную парадигму, в которой испытуемые переводят словосочетания или предложения с одного неродного языка на другой в обоих направлениях, в ходе чего им предъявляются подпороговые праймы на родном языке. Мы провели серию экспериментов, в которой варьировались типы праймов и типы словосочетаний и предложений. Мы предположили, что праймы на родном языке создадут интерференцию и приведут к увеличению времени перевода между неродными языками. Также время перевода будет варьироваться в зависимости от условий. Наши гипотезы подтвердились частично, только на некоторых типах стимулов. В работе обсуждаются связи полученных результатов с существующими моделями и теориями.

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Ключевые слова: билингвы, трилингвы, билингвизм, трилингвизм, сетевая модель, неизбирательный доступ, синтаксические узлы, семантические узлы, сублиминальный прайминг, подпороговый прайминг, перевод, русский язык, испанский язык, английский язык

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Studying bilingualism and the role of inhibition in language processing.

1. Introduction

2. Theoretical Framework

3. Methodology

4. Results

5. Discussion

6. Conclusion

References