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THE INTERACTION OF SEVERAL LANGUAGES IN THE COGNITIVE SYSTEM

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In this paper, we look into the interaction of several languages in a multilingual language system. Studies of three or more language-speakers are not common, with most research focused instead on various aspects of bilingualism. We believe, however, that research of processes happening when several (i.e. 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 planned to carry out a series of experiments where we manipulate the type of primes 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 the amount of interference would vary in different conditions. Our hypotheses were confirmed only in part for some stimuli but not for others. The implications of these results for the existing models and theories are discussed.

Keywords: Multilinguals, trilinguals, network model, parallel non-selective access, syntactic nodes, subliminal priming

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I. Introduction

The operation and interaction of several languages in the cognitive system – organization of lexicon, semantic memory, and syntactic structures – has been a subject of heated discussion in psychological literature for several decades. Most research in this area is dedicated to bilinguals, both early (fluent in both languages since childhood) and late (who acquired their second language at school or in adulthood).

However, there are very few studies dedicated to multilinguals, i.e., people fluent in three or more languages, one of which is usually their mother tongue acquired in early childhood and the other two were learned later in life (early trilinguals and multilinguals are extremely rare) to a high level of proficiency. Research of the organization and interaction of several language systems (rather than two) can provide some new information, unavailable in bilingual research.

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

It should be taken into account that people who speak more than two languages constitute a significant part of world's population (even though precise statistics are unavailable to us – perhaps 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 multilinguals provide a different approach to the problem of operation and interaction of language. In particular, they could potentially answer questions related to the interaction between L2, L3, etc. 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.

II. Multilingual language system

Most studies cited here are dedicated to bilingualism and we will logically assume that all findings are true for multilinguals as well.

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

This 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) (Gollan et al., 1997; Hoshino and Kroll, 2008; Thierry and Wu, 2007; Morford et al., 2011, Emmorey et al., 2008). Both languages are activated even when only one of them is currently used (Schwartz and 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 et al., 2011; Dussias and Sagarra, 2007; Van Hell and Dijkstra, 2002; Van Wijnendaele and Brysbaert, 2002; Grosjean, 1989; Linck,

Kroll, and Sunderman, 2009).

The most widely discussed and accepted theory of the organization of a bilingual's two languages states a single shared lexicon in which the activation of words is parallel and nonselective (see BIA and BIA+ (Dijkstra and Van Heuven, 1998; Dijkstra and 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 their similarity to the stimulus and their frequency. Subsequently one of the candidates gets chosen.

It was discovered relatively early that semantic representations are shared between the two languages (Schwanenflugel, 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 proposed by Potter et al. (1984) and the Revised Hierarchical Model (Kroll and Stewart, 1994). Modern research using priming also shows evidence of shared semantics. One of the methods used to obtain empirical support of this claim is semantic priming – an effect induced by semantically related stimuli. The semantic priming effect has been observed for L1 words on L2 words and vice versa (Duñabeitia, Perea, Carreiras, 2010; Duyck, 2005; Francis, Augustini, Sáenz, 2003; Grainger, Frenk-Mestre, 1998).

In comparison with the significant number of works dedicated to lexical access and semantic representations of bilinguals, there is less research concerning interaction of syntaxes (e.g., Bock, 1986; Bock, Griffin, 2000; Hartrsuiker et al., 2004; Schoonbaert et al., 2007). The object of interest in this case is shared or separate storage of the two syntaxes and their interaction.

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 et al. (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 in code-switching studies, demonstrating that bilinguals can switch from one language to the other within a sentence maintaining its syntactic integrity. The number of studies in this area is increasing (Dussias, Kroff, 2010).

We assume that it is possible to apply all these theories to a multilingual cognitive system by expanding them to three and more languages. (At this stage of analysis we consciously omit all the non-network mechanisms which are, of course, active in any language system). In this case we assume a multilevel network, functioning according to parallel access and non-selectivity principles. It has shared concept representations and categorical and combinatorial nodes for three (or more languages). The lemmas are stored in the same joint lexicon and are tagged for each of the three or more languages by a connection to one of the three language nodes. The 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. Precisely this type of connections and activation is behind semantic priming.

The interaction of syntaxes should be, in large part, similar: the activation of single lexical items regardless of their language spread to the corresponding categorical and combinatorial nodes (Hartsuiker et al., 2004). (This explains cross-language priming). Similar to BIA and BIA+ models, a specialized block provides the selection of a single lexical unit, while other competing units become inhibited (Dijkstra, Van Heuven, 1998).

It is worth noting that the efficiency of such a language system should increase with the increase of proficiency in L2 and L3.

Thus, *all languages of a multilingual (trilingual) are integrated in single network containing lexical, semantic and syntactic information; conceptual and syntactic (combinatorial and categorical nodes) 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 this hypothesis we used subliminal priming paradigms. The idea behind this procedure is that the presentation of a stimulus on a subliminal level significantly influences the processing of the subsequent stimuli if they share some common properties with the prime. Cross-language syntactic and semantic priming-effects in a multilingual cognitive system are based on the integrated network principles described above. Moreover, the activation of a fragment of a syntactic or semantic network could be achieved with single word primes, i.e., 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 observing the role of L1 in the L2-L3 interaction. Russian native speakers rather proficient in at least two other languages – Spanish and English – were asked 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 Russian word primes that were semantically related to one of the words of the construction they had to translate or their direct translations. For example, the sentence *The people found the money,* which had to be translated into Spanish was preceded by a Russian prime *обнаружить (‘to discover’),* whose meaning was similar to that of the translation of the word *to find.* This prime is supposed to activate all the semantically related concepts as well as some syntactic nodes. Comparing the time of translation in the conditions with and without the prime allows us to explore the direction and the

degree of Russian prime influence (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.

One issue that has remained unmentioned so far in this paper and has not been yet reviewed here 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 et al., 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 line of research in linguistics (Paradis et al., 2009). To tentatively assess this matter, we included antonym primes to see if they would cause a similar effect to synonym primes.

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.

The studies we reviewed provide different priming results: priming can both facilitate and inhibit language processing depending on the task. For example in word recognition tasks, priming often causes facilitation (Schwanenfluger, Rey, 1986; Finkbeiner et al., 2004; Grainger, Frenck-Mestre, 1998; Duyck, Brysbaert, 2004). In production, however, the participants have to deal with several competing candidates which leads to interference (Kroll, Gollan, 2014; Kroll et al., 2012). This effect is explained with a combination of activation and inhibition processes occurring in the cognitive system. On one hand the more activated by the prime the nodes related to it are, the faster the extraction of the corresponding words; however, the more activated the network segment is, the more time required to inhibit all the extra activation and to make a choice from one of the competing candidates and to finally articulate it.

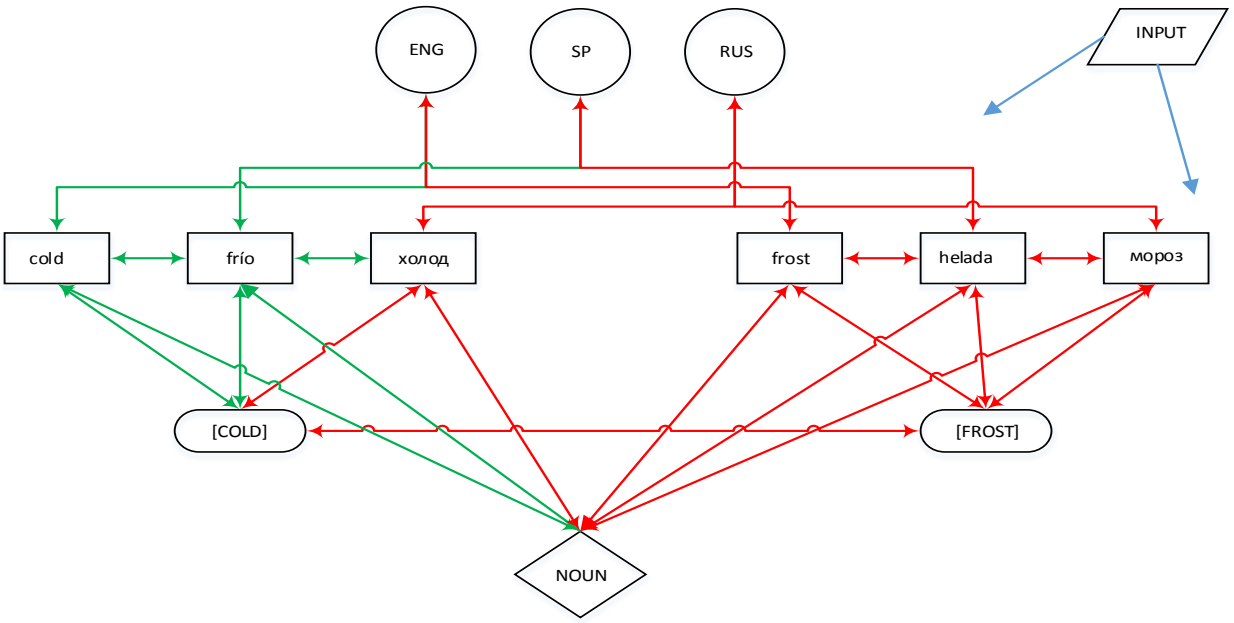


Fig. 1. Trilingual language network during L2-L3 translation with prime in L1.

Bidirectional arrows indicate the spreading of activation within a trilingual language network with L1 prime preceding the L2-L3 translation – the activation of interconnected lexical (L1 – L3), semantic (Sem) and syntactic (Syn) nodes. Green arrows indicate relevant word selection. Red arrows indicate excessive activation, i.e. the activation of nodes irrelevant for task completion.

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, the priming should slow down the L2 – L3 translation. The primes activate too many competitors for selection, creating interference which takes more time to resolve.

Experiment 1

In the first experiment we tested three hypotheses:

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

This effect is the consequence of network organization. Russian 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, etc. (Gollan et al., 2008; Murray and Forster, 2004), therefore its activation is harder to suppress.

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

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

It is worth mentioning that the interaction of languages on 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.

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 impact associated with the head and the dependent of the phrase. The phrase has a certain hierarchy, i.e., 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, it means that

the syntactic nodes connected to the head of the phrase are more strongly activated than the nodes connected to the dependent.

The presentation of Russian prime (in this case – a single word prime outside any context) activates all its syntactic properties, i.e., the nodes related both to its grammatical class and syntactic constructions in which this word can possibly appear. The prime is followed with a presentation of an L2 or L3 phrase, in which the head is already defined (a number of nodes associated with the head are activated). Syntactic nodes associated with the dependent are significantly less activated. During translation into another language, further (third) activation of the head and lesser activation of 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 heads of L2 and L3 phrases as opposed to the case of dependent priming where the interference occurs between less activated dependents. Therefore in the latter case, the interference is weaker. This means that the syntactic head priming will lead to greater translation times than the dependent priming.

Participants

12 trilinguals proficient in Russian, Spanish and English participated in this experiment (8 female; 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 CEFR (Common European Framework of Reference). To participate in the experiment the participants needed to provide international certificates (FCE for English and DELE intermedio for Spanish or higher level certificates), results of the Unified State Exam (Russian graduation exam required to enter a university, corresponding to the B2 level) taken for both languages, or a university degree in both languages.

Stimuli

The participants were required to translate simple phrases (eg. *Bellas flores – "beautiful flowers", An old friend*) from Spanish or English into English or Spanish and vice versa. 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 (in this case the syntactic head of the phrase is the verb). We used both plural and singular form of nouns and adjectives, but only verb infinitives. Only the words appearing in the text of level B2 international examination papers were used. There was a total amount of 288 phrases, 144 for each language.

The phrases were randomized within 8 blocks, 4 for each language; the blocks were presented in order to iterate the languages (1st block in Spanish – 1st block in English - 2nd block in Spanish, etc.).

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

The targets of the prime could be either the head or the dependent, i.e., 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 form: singular number for nouns, singular number and masculine gender for adjectives, and infinitive for verbs. For example, in the phrase *Aguantar el frío "To endure the cold"* the dependent noun was primed by either of these words: *холод "cold", мороз "frost", жара "heat".* Synonyms and antonyms were selected using synonym dictionaries (Апресян, 2003; Абрамов, 1999). All lexis had translation equivalents in other languages. Stimuli contained no cognates to avoid an eventual cognate facilitation effect.

Procedure

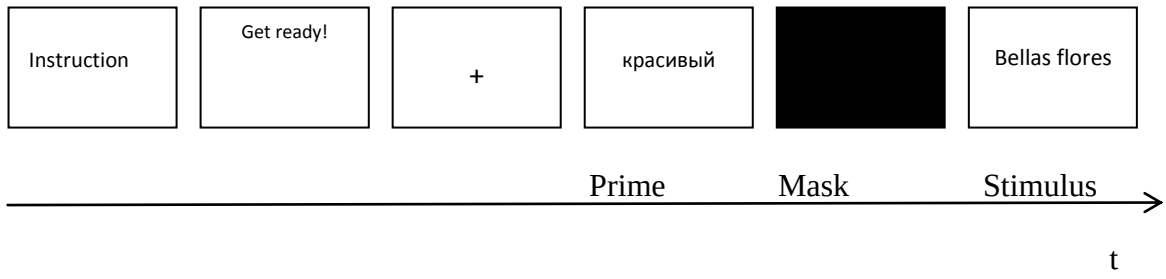
The participants had to translate each phrase individually as fast as they could in both directions (L2-L3 and L3-L2). The phrases appeared on a CRT screen (Samsung, diagonal – 17 inches, frequency – 85 Hz, definition – 960x600 pixels). All phrases were preceded by a 12 ms long subliminal prime and a mask (black screen) of the same onset time. A blank slide was used as the baseline. To ensure the 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.

The experiment was designed in E-Prime 2.0 which was used to create the presentation of stimuli and to time and record the translation.

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

Fig. 2. Experiment 1 trial structure



Durations: prime – 12 ms, mask – 12 ms, fixation cross – 750 ms. Duration of other slides was determined by the participants.

Within-subjects factors were translation direction (from Spanish to English and from English to Spanish), prime type (translation, synonym, antonym or baseline) and type of target (noun-syntactic head, noun-syntactic dependent, verb, which is always the syntactic head, and adjective which is always the syntactic dependent). Consequently, the experiment had a 2 x 4 x 4 design.

The dependent variable was the time between the presentation of a phrase and the beginning of the translation.

Results

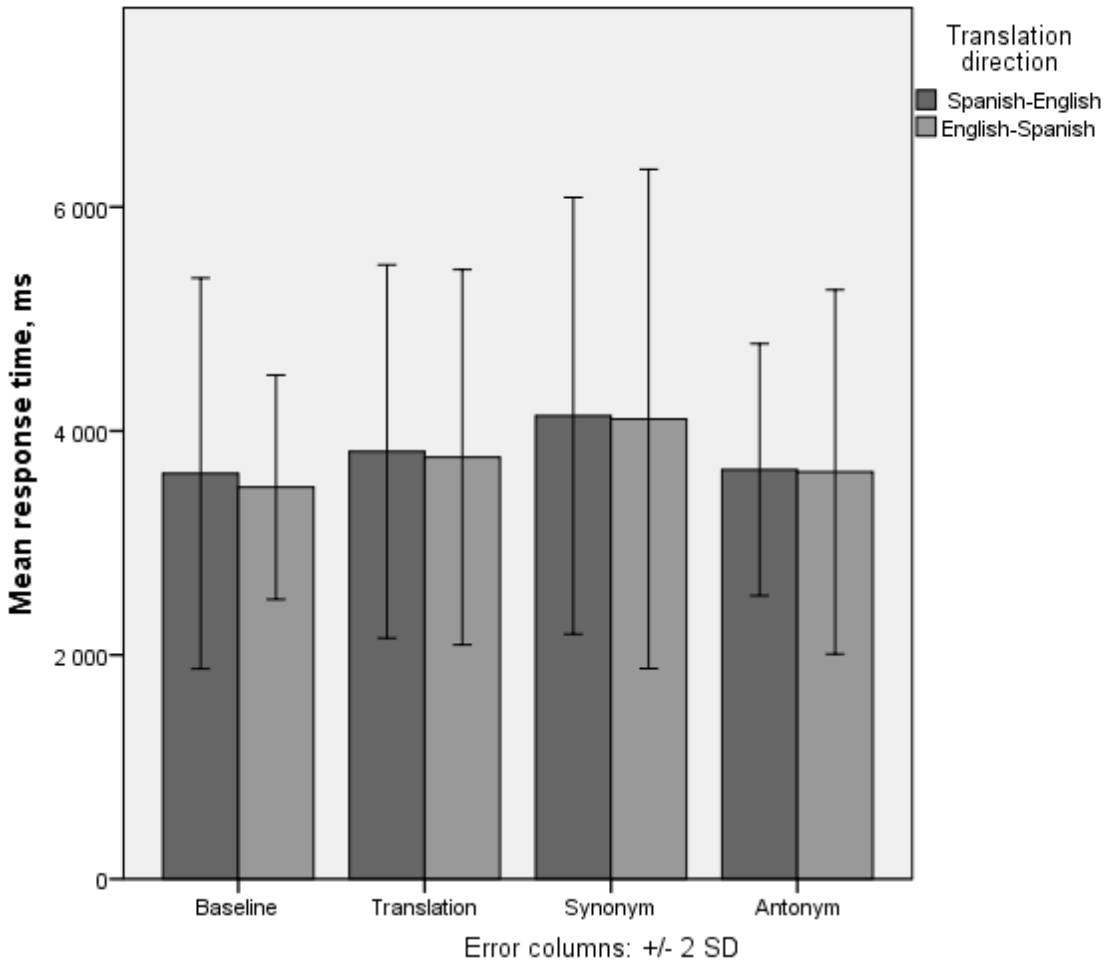
Responses containing errors and response that differed from the mean response time by more than two standard deviations were excluded.

1) A two-way ANOVA with repeated measures (with prime type and translation direction

factors) revealed a significant influence of prime type on the translation time in both directions F (3.66) = 3.316, p = .025, η_p^2 = .131 (see Fig. 3). The factor interaction was not significant (F<1).

A Kolmogorov – Smirnov test showed that the results were distributed normally, therefore we used a paired samples t-test which showed that translation time from Spanish to English was significantly longer with a Russian synonym prime (t= - 2.238, p = .047). With translations from Spanish to English there was a tendency of inhibition with the same type of prime (t= - 1.821, p = .096). Other differences between the experimental conditions were not significant.

Figure 3. Correlation of prime type and translation time

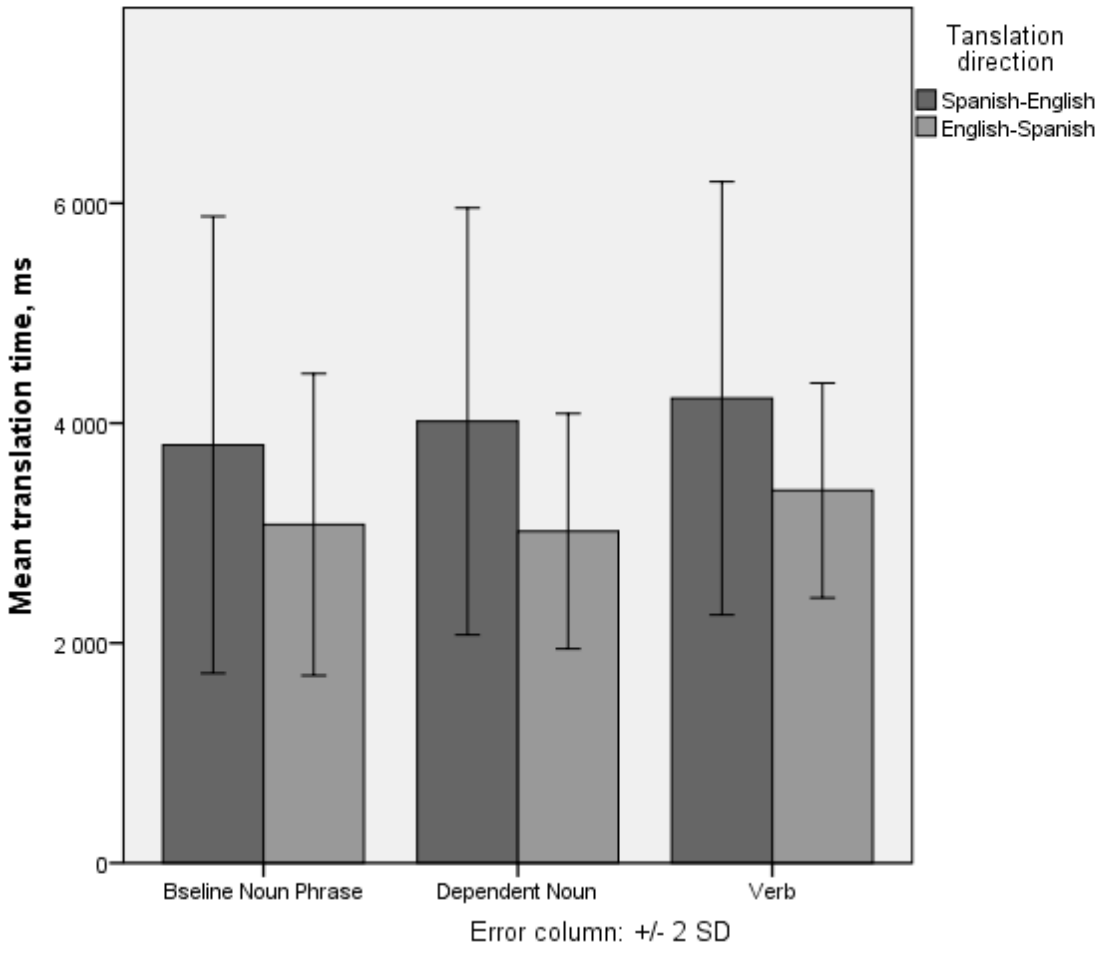


2) A two-way ANOVA with repeated measures (with syntactic target and translation direction targets) revealed a significant interference caused by Russian prime on translation time in verb + noun types of phrases F (2, 44) = 4.557, p = .016, η_p^2= .172 (see Fig. 4). The interaction of

the factors was not significant ($F < 1$).

A Kolmogorov – Smirnov test showed that the results were distributed normally therefore we used paired samples t-test which showed that the translation of verb + noun phrases is significantly inhibited by verb primes in Spanish – English translation direction (t= - 2.850, p = .016); there is a tendency for inhibition in Spanish – English translation direction (t= - 2.145, p = .055). Other differences including those between the baseline and between other target types were not significant.

Figure 4. Priming effect in noun phrases



Priming of noun phrases in both translation directions as well as interaction of factors was not significant (in both cases $F < 1.1$).

Comparison of translation times in the baseline condition (without prime) showed that noun

phrases are translated from English into Spanish significantly slower than verb phrases ($t = -4.056$, $p = .002$).

3) **Self-report**. All participants reported having seen only the slides with instruction, 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 i.e. the participants were not conscious of seeing the primes.

Discussion

The results show that Russian direct translation and synonym primes slow down the translation between L2 and L3. This appears to be evidence of interference, which reaches significance with synonym primes. Also, it is worth pointing out the similarity of the priming effect pattern in both translation directions. Thus, Hypotheses 1 and 2 are confirmed. However, our tentative attempt to obtain priming effect from associative and semantic connections between antonyms was unsuccessful.

Consistent with our assumption the source of the interference is the excessive activation caused by priming: Russian lexical nodes, activated by 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.

The verification of Hypothesis 3 showed similar results in Russian priming: increase of translation time was observed with Russian verb primes in verb phrases in both translation directions. Thus, Hypothesis 3 was confirmed only for the syntactic head of one phrase type. Priming of dependent noun and noun and adjective in noun phrases does 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. 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 three languages). One of the significant differences, for example, is the 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 in this case would also lead to an increase in translation time.

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. It is also worth mentioning that the translation of noun phrases from English into Spanish in the baseline (no prime) 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) frío "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 mono-directional: similar translation time difference in Spanish – English translation direction in the baseline condition was not observed.

It appears that the results obtained in this experiment evidence 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 prime is slowing 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 confirmed.

The observed results are consistent, in general, with the network model and with the parallel non-selective language activation approach. The possible difference between bilingual and trilingual language systems is that a trilingual would have to select between a greater amount of various (semantic, syntactic, lexical) activated nodes and 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 significantly restrict the set of syntactic connections involved in the translation process. Experiment 2 (aimed at overcoming this drawback) was designed using full sentence stimuli.

Experiment 2

In Experiment 2 we tested the following hypotheses to see how categorical and combinatorial nodes of a 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 the 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 time needed to translate for 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).

Participants

Twenty-nine (20 female; M = 19.35; Sd = 38.67) Russian native speakers volunteered to take part in this experiment. Their level of proficiency in Spanish and English was no lower than B2 according to CEFR. The participants had to present international certificates of language proficiency (FCE or higher for English and DELE intermedio or higher for Spanish) or a university degree diploma with a specialization in both languages. This experiment took place six months after Experiment 1.

Stimuli

The stimuli for this experiment were simple sentences containing subject, verb and object (e.g., *The birds drink the water*), in Spanish and English. Like in Experiment 1, the sentences consisted of lexis and grammar appearing in international examinations for the B2 proficiency level. The subject and the verb could appear both in singular and in plural form; 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.corpusdelespanol.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, Spanish and English native speakers 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. The participants were notified about the change of language every time. Furthermore, the test trials were preceded by a trial run of 10 phrases. The sentences were randomized within each block. There was a total of 90 sentences; 45 for each language.

The previous experiment showed that the most effect on translation time was caused by synonym primes, therefore only this prime type was used in this experiment. For example, the sentence *El pueblo encontró el dinero "The people found the money"* was preceded by the word *обнаружить "to discover".* Like in the previous experiment the synonyms did not fully share the meaning with the targets as well as the combinatorial and stylistic features.

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

The stimuli were distributed in a way that every combination of conditions was presented to each subject an equal amount of times. An empty slide was used as the baseline condition.

Procedure

The 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, diagonal – 17 inches, frequency – 85 Hz, definition – 960x600 pixels). Each sentence was preceded by 12 ms long prime and a mask consisting of 11 hashes (#) (one sign longer than the longest Russian prime). The mask was changed to avoid the blinking effect that was reported by some participants of 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 on Fig. 5.

Before giving the answer the participants had to press the space bar that switched on the 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, fixated and recorded the response and types of sentence and prime.

The participants could 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 passive voice was translated with an active voice sentence then the sentence was analyzed as active and vice versa: if the original sentence was in active voice but the translation was in passive then it was analyzed as passive. Furthermore, in Spanish, questions with and without inversion are grammatical, 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"* e.g. *¿Si el amigo compró las entradas?* This form was also accounted for as question.

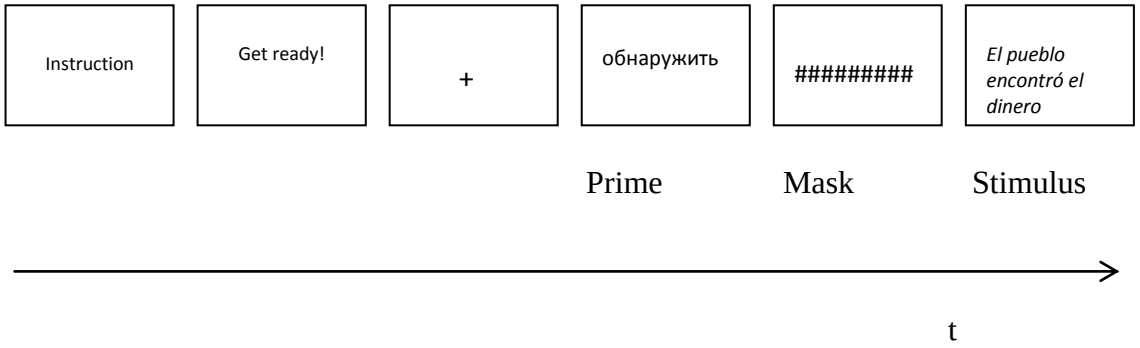
The translation onset time was monitored using Sony Sound Forge 9.0.

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

Within-subjects factors were translation direction (from Spanish to English and from English to Spanish), target type (subject, verb or object) and type of sentence (active, passive, question). The experiment had a 2 x 3 x 3 design.

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

Fig. 5. Experiment 2 trial structure



Durations: prime – 12 ms, mask – 12 ms, fixation cross – 750 ms. Duration of other slides was determined by the participants.

Results

Responses containing errors and responses that differed from the mean response time by more than two standard deviations were excluded.

Table 1. Mean translation time of active voice sentences in both directions with three syntactic targets (subject, verb and object).

Target type	*Translation direction*	Mean	SD
Baseline	*Sp – Eng*	6930	3271.7
	Eng – Sp	7287	3142.2
Subject	*Sp – Eng*	7561	3811.2
	Eng – Sp	10190	5190.6
Verb	*Sp – Eng*	10828	6201.3
	Eng – Sp	7635	2896.1
Object	*Sp – Eng*	5858	2732.4
	Eng – Sp	7920	3770.1

1) A two-way ANOVA with repeated measures (factors: syntactic target in the active voice sentences and translation direction) revealed a significant priming-effect of Russian words on translation time in both directions F (3. 168) = 6.960. $p < .001$. $\eta_p^2 = .111$. The interaction of factors was also significant F (3.168) = 8.330. $p < .001$. $\eta_p^2 = .129$. See results on Table 1.

A Kolmogorov – Smirnov test revealed that the results were distributed normally. Therefore, we used paired sample t-test for further data analysis. It revealed that the translation time of active voice sentences with a Russian prime for verb target in English-Spanish translation direction were significantly longer than those in the baseline condition (t= - 3.501. p = .002). In English – Spanish translation direction, however, a similar effect was observed in the subject target condition (t= - 2.626. p = .014). Other comparisons did not reveal any significant results.

In other types of sentences (passive voice and yes/no question) the two-way ANOVA with repeated measures showed no significant priming-effect ($F < 1.96$ in both cases). However, it showed interactions of translation direction and target type factors in both types of sentences F (2.657. 148.786) = 3.196. p = .03. $\eta_p^2 = .054$ (Mauchly sphericity test was significant therefore Huynh-Feldt correction was used) and F (3.168) = 3.789. p = .012. $\eta_p^2 = .063$, for passive voice and question respectively.

2) Paired sample t-test showed that in Spanish – English translation direction in active voice sentences, the translation times were significantly longer when Russian words prime the subject or the verb than when they prime the object (t = -2.386. p = .024 and t = -4.454. p < .001, respectively). In the yes/no questions, the primes targeted at the verb slow down the translation significantly comparing to the primes targeted at the object (t = -2.445. p = .021). In passive sentences the primes targeted at the object slow down the translation more than the primes targeted at the subject or verb (t = -2.581. p = .015 and t = -2.011. p = .05, respectively).

The translation time of the active voice sentences in Spanish-English translation direction is longer with the subject targeted primes t = -2.364. p = .025).

All other comparisons were not statistically significant. The results are shown in Table 2.

Table 2. Mean translation time of three sentence types primed with Russian words with various syntactic targets

		Spanish – English		English – Spanish	
		Mean	SD	Mean	SD
Active	Subject	7561	3811.2	10190	5190.6
	Verb	10828	6201.3	7635	2896.1
	Object	5858	2732.4	7920	3770.1
Passive	Subject	7975	3662.1	10470	5790.1
	Verb	8799	3342.3	8836	4639.6
	Object	11379	5941.8	9180	4461.2
Question	Subject	8831	5559.8	8868	4088.3
	Verb	10151	5164.9	9002	3986.7
	Object	7534	3477.4	9497	5304.8

Discussion

In this experiment we could observe longer translation times only with active voice sentences. Furthermore, this effect appears to be selective, being significant only in two cases: Russian primes targeted at the verb significantly interfere with the translation into English and primes targeted at the subject interfere with translation into Spanish. Translation time of passive voice sentences and questions correlates with the interaction of translation direction and syntactic target type factors. However, no significant increase of translation time due to Russian primes could be observed. Thus, Hypothesis 1 was not shown to be true in general, but it was demonstrated for active voice sentences.

Hypothesis 2 was also proved only in part and only on the same type of stimuli. The Russian primes targeted at the subject or the verb with Spanish – English translation direction and targeted at the subject with English – Spanish translation direction interfere significantly only with the

translation of active voice sentences in comparison with primes targeted at the object.

The structure of the results shows evidence that the predictions based on the network model in question are true only with active voice sentences, for which the negative priming effect of Russian primes was observed. Passive voice sentences and questions did not seem to "behave" in accordance with those predictions and appear to be somehow "protected" against the inhibition caused by primes. Therefore, we obtained evidence of the presence of shared syntactic network of the three languages using only active voice sentence stimuli. This result seems plausible assuming the relative structural similarity of active voice in Russian, English and Spanish as opposed to passive voice and questions. Interference caused by Russian primes leads to longer syntactic information processing in this case.

General discussion

The series of two experiments described in this paper allowed us to test the potential of the network model expanded to accommodate the three languages of a trilingual. Following Hartsuiker et al. (2004), we considered a model where semantic and syntactic (categorical and combinatorial) nodes are shared by all languages, their lexical storage is integrated and the activation of lexical nodes of several languages is parallel and nonselective, applying it to analyze the processes of translation between L2 and L3 in trilinguals.

The results of the first experiment using phrases as stimuli revealed evidence of how semantic and syntactic components of the model work: Russian direct translation and synonym primes significantly increase the translation times between L2 and L3. Additionally, we saw the interference of Russian verb primes on the translation of verb + noun phrases in both translation directions.

According to our assumption, the source of this effect is the excessive activation increased by subliminal priming: Russian words activate lexical, semantic and syntactic nodes in a trilingual language system that are excessive for Spanish – English or English – Spanish translation. All the

extra nodes create “noise” and interfere with the relevant items, possibly also having to be suppressed and requiring more time resources. Therefore, we observed a negative priming effect.

The results of the second experiment using sentence stimuli provide only limited evidence for the syntactic part of the model in question: its predictions are to some extent proved only for active voice sentences, where in some cases of priming we observed interference. This effect can also be explained with interference and inhibition of excessive activation caused by Russian words. Thus, evidence of syntactic nodes shared between Russian, Spanish and English involved in translation was obtained only in one type of sentence.

To what extent is the language network shared? Evidence from trilinguals

Once expanded, the existing network models of parallel nonselective access to all types (lexical, semantic and syntactic) of nodes (Hartsuiker et al., 2004) could be used to analyze trilingual and multilingual language systems.

The research carried out on trilingual participants allowed us to see the interaction between the three languages assuming a reasonably high level of proficiency. A significant increase in the translation time in the condition of subliminal priming with Russian words semantically related to words in translation task (Experiment 1) demonstrates that the languages are closely connected at a lexical and semantic level. Furthermore, the activation of semantic connections is more salient with synonym primes.

The syntactic connections between the three languages are evidenced by longer translation times of active sentences primed with Russian words in both directions (Experiment 2). However. this effect appears to be selective and cannot be observed with passive voice sentences and questions.

Thus, the shared parallel and nonselective activation network model expanded to three languages works similarly to the bilingual network, demonstrating lexical, semantic and syntactic connections. However, the interference and inhibition processes in this case are more pronounced.

The results, however, cast doubts on the sufficiency of the network model in question for the

explanation of translation processes of passive voice sentences and questions with Russian primes. These sentences, unlike the active voice sentences, seemed unaffected by priming, appearing somehow resistant to it. One of the possible explanations for this would be mechanisms of sentence generation that override the priming effect or "protect" from other influence the units that are supposed to be used (e.g. 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.

In conclusion we should note that trilingual studies allow us to analyze the subject of research from another point of view and to see some unique features of the multilingual language system even given its unquestioned similarity to that of the bilinguals.

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