

Bilingual Language Control in Visual Language Perception among Hungarian-English bilinguals

Volodymyr Revniuk

MA, Applied Linguistics

Supervisor: Szilvia Bátyi, PhD

University of Pannonia

Veszprem, Hungary

Table of Contents

Literature Review	3
1.1. Language perception.....	3
1.1.1. Introduction to language perception studies	3
1.2. Bilingual Language Control in perception.....	3
1.2.1. Bilingual Interactive Activation (BIA) model	3
1.2.2. Inhibitory Control (IC) model	4
1.3. Bilingual Language Control research methodology	6
1.3.1. The notion of switching cost.....	6
1.3.2. Findings of switching cost studies.....	6
1.3.3. Influence of language-specific stimuli	8
1.3.4. Potential influence of language dominance	9
1.4. Current study	10
1.4.1. Research questions	11
1.4.2. Hypotheses.....	11
Methodology	12
2.1. Design.....	12
2.2. Participants.....	12
2.3. Instruments	12
2.3.1. Lexical decision	12
2.3.2. Bilingual language profile	13
2.4. Procedure	13
2.5. Result analysis procedure	15
Results	17
3.1. BLP questionnaire analysis.....	17
3.2. Lexical decision accuracy analysis	19
3.3. Lexical decision reaction times analysis	23
3.4. Switching costs analysis	28
3.5. Pseudowords analysis	28
3.6. BLP questionnaire and lexical decision task performance correlation analysis	29
Discussion	33
4.1. Language control tendencies	33
4.2. Influence of linguistic background	34
Conclusions	36
References	37

Literature Review

1.1. Language perception

1.1.1. Introduction to language perception studies

Language perception studies investigate how people comprehend and understand language. In its basis, perception processes consist of receiving certain visual or audio signals, identifying them as language signals, identifying the language of the signal and interpreting those signals into some meaning (Warren, 2013).

Visual language perception deals with reading processes and spoken language perception deals with listening processes. Even though there are some basic similar features between the two, reading and listening are generally very different processes.

The field of visual language perception investigates numerous effects and processes that influence and constitute reading. Such findings are summarized in models of visual language perception, which attempt to describe the sequence of actions performed by human brain that make us understand the words that we see.

Interactive Activation model (McClelland & Rumelhart, 1981) indicates that connections among language units of various levels of complexity are not limited to activations of more complex units only but also includes the feedback to simpler units. These links can either co-activate some other language units (in line with neighborhood effect) or inhibit the activation of non-relevant units. This model can account for various phenomena of visual language perception, but this model would require some expansion to account for language perception of people who know more than one language.

In case of bilinguals, studies highlight that it is impossible to “switch off” one of the languages that bilingual knows. It means that all the time, both languages operate in bilingual’s mind (de Bot & Schreuder, 1993; Kroll & Stewart, 1994; Kroll & Sunderman, 2003; see Pavlenko, 2009 for a review). As a result, it is possible that the neighborhood effect would not result in activation of the connected words only in one language (if language scripts make it possible).

1.2. Bilingual Language Control in perception

1.2.1. Bilingual Interactive Activation (BIA) model

Obviously, we are able to understand words in the language they actually belong to, so the expansion for bilingual model is reasonable and more complex than for monolinguals.

The Bilingual Interactive Activation (BIA) model (Grainger and Dijkstra, 1992; Dijkstra and van Heuven, 1998; van Heuven et al., 1998) adapted the mechanism of Interactive Activation model of word recognition for bilinguals. The novel terminology includes the so-called “language nodes”. Such language node is the highest hierarchical unit of language storage, superior to relevant language symbols, phonemes, morphemes, etc.

BIA model implements the language network hypothesis, according to which the connections between word units and language nodes are bidirectional. It means that when perceiving a word activates the relevant word in mental lexicon, it also activates the language node that is connected to this word.

According to the BIA model, when a string of letters is presented, this visual input activates the words in both languages with similar letter organization and simultaneously inhibits all other words with different letter organization, irrespective of the language they belong to. Information from words sends activation to their respective language nodes that in turn, send inhibitory feedback to the words from other language node.

The activation of language nodes reflects the amount of activity in each lexicon, meaning that the more dominant language would have a stronger language node. More dominant usually (but not always) refers to bilingual’s native language, that, for example, has been used for longer period of time and is used similarly often to the second language. The activation of language nodes includes triggering activation of one language units and inhibition of others. Therefore, the more dominant language node would be able to apply stronger inhibition to the less dominant language. Balanced bilinguals that do not have the clearly defined dominant language, would have similarly strong activation and inhibition processes for L1 and L2.

The aforementioned combination of activation and inhibition processes between language nodes is the unique addition of the BIA model to IA model. They were summarized into the “language control mechanism”, which was studied even before BIA model was proposed. Language control mechanism is not limited only to perception processes, but is also highly relevant for language production, where it was first introduced.

1.2.2. Inhibitory Control (IC) model

Historically, one of the first proposals to include inhibitory processes in the mechanism of language control in production was made by Green (1986, 1998). According to the Inhibitory Control (IC) model, it is assumed that the problem of language control can be

resolved by applying extra inhibition to all units of a certain language. Before language nodes were proposed, Green (1986) adopted the “language tag” term, following the description by Albert and Obler (1978) – “a feature label associated with each individual item”.

As such, upon a deliberate intention to speak one language rather than the other, it would partially require the speaker to increase the activation of the units with L1 tags, and principally require to suppress the activation of the units with L2 tags. The suppression of L2 can be achieved either internally (within one language system, like for monolinguals, similarly to the framework of IA model) or externally (by L1 system activated that sends a command to suppress L2 system).

These mechanisms, despite having some elements named differently for IC and BIA model (e.g. language tags and language nodes), rely on the same combination of processes of language control. Yet, the idea of symmetrical strength of activation and inhibition processes was not proposed for IC model and its final predictions for language control differed from BIA model.

According to IC model, it is suggested that the concepts with relevant language units present in L1 and L2 should have a stronger connection with more dominant L1. In such case, it would be more difficult to use them in less dominant L2, as it would require more efforts to inhibit L1 representations being activated during their production. It means, that while L1 is the “stronger language”, it would require being inhibited much more than the “weaker language”. In such case, L1 would have to receive more inhibition during L2 production, compared to the opposite situation during L1 production

Once again, language dominance is not stable, and it can change due to different. Consequently, as the amount of inhibition is based on language dominance, then the amount of inhibition required for L1 or L2 can become similar for balanced bilinguals.

BIA and IC models, while originally being designed for different types of language use, both eventually were adapted for language production and language perception. According to IC model, language control would still require stronger inhibition of more dominant L1. However, BIA model account predicts that the activation of language nodes in perception is higher for L1, which would result in stronger inhibition of less dominant L2. Resolving the question of which model is more appropriate to account for language control in perception is one of the most important issues of recent language control studies.

1.3. Bilingual Language Control research methodology

1.3.1. The notion of switching cost

The data for language control studies came from various research, but eventually, this topic was studied via Lexical Decision tasks. Studies of context influence of language control in language production proposed a research method that is now dominates the studies of language control mechanism – language switching cost measurement (Allport, Styles and Hsieh, 1994; Rogers and Monsel, 1995). This research method examines if there is a change in reaction or production times of the stimuli in L1 or L2 in two conditions – when the language of the stimulus in target trial is the same as in previous trial (repetition trials) and different from the previous trial (switch trial). Such costs appear because in switch condition, the activation of one language has to overcome the inhibition that was applied to this language in previous trial. Switching costs can be measured for either production or recognition processes – it is only the language switching paradigm that is required.

The prediction for switching costs in language production for BIA and IC models are similar - the difference between reaction times in switch and repetition trials within one language (switching cost) is going to be higher for more dominant L1.

In language perception, the predictions of BIA and IC models are different. According to BIA model, inhibition of less dominant L2 should be higher, because of higher activation of L1, which should result in higher switching costs for L2. Opposite to this assumption, IC model predicts that the language with stronger activation, presumably more dominant L1, should also receive more inhibition, which would result in higher switching costs for the dominant language.

1.3.2. Findings of switching cost studies

Numerous studies of language control in production for unbalanced bilinguals have reported higher switching costs for more dominant L1, as was predicted by IC and BIA model (e.g., Meuter and Allport, 1999; Jackson et al., 2001; Philipp et al., 2007; Macizo et al., 2012; Peeters et al., 2014; Fink and Goldrick, 2015). At the very same time, other works also highlighted the presence of symmetrical switching costs for L1 and L2 for balanced bilinguals (Costa & Santesteban, 2004; Costa et al., 2006; Christoffels et al., 2007; Declerck et al., 2012; Fink and Goldrick, 2015; see van Assche et al., 2012 for a review). Language perception studies could not provide a clear answer for a long time. One of the earlier studies that was testing the validity of BIA model (van Heuven, Green,

Dijkstra, 1998) via testing the stimulus neighborhood effect for L1 and L2, found evidence of stronger inhibition being applied to L2 units. Yet, the studies that measured switching costs in language perception, repeatedly reported symmetrical switching costs for L1 and L2 (von Studnitz and Green, 1997, 2002; Thomas and Allport, 2000; Orfanidou and Summer, 2005; Macizo et al., 2012). It goes in line with both models and cannot clarify which one can account for language control in perception. Only one of the earlier perception studies found asymmetrical switching costs that were higher for L1 (Jackson et al., 2004), as was predicted by the IC model, but this work used a parity judgement task that was not used later in other language perception studies. Such contradictory observations called for revisions of the research methodology and the existing theoretical accounts of language control.

Reynolds et al. (2016) have conducted an important methodology review in their study. It was highlighted, that the major differences in language control patterns for production and recognition should come from the basic differences in their core mechanisms and some of these differences arise in lexicon. Several possible sources of symmetrical switching costs were proposed.

The first one was “language task schema activation/competition that affects response selection and initiation” (Reynolds et al., 2016). According to task schema account (von Studnitz and Green, 1997; Green, 1998; Thomas and Allport, 2000), language task schemas specify what language should be used and what configuration of the language should be used to perform a language task. It is proposed that perception processing is much less susceptible to interference from activated representations from non-target language, compared to speaking processing.

Other possible source of language control differences is early activation of language task schemas or language nodes, based on certain stimuli attributes. That is, it is possible that the perception of certain words could trigger early activation or inhibition of relevant or interfering language, as the language of such words can be recognized very fast.

Considering these observations, Mosca and de Bot (2017) have conducted a study to address the controversy in the studies focusing on language control in perception. In this study, in lexical decision experiment, English-Dutch language pair allowed the use of words with matched length and frequency of use that also were legal strings of letters in both languages. The use of such stimuli limited the number of language cues that could result in early inhibition of non-target language. In addition to that, researchers attempted

to account for a possible n-2 inhibition (Koch et al., 2010) that could interfere with the obtained results but was not accounted for in earlier language control works.

In lexical decision experiment, Mosca and de Bot observed asymmetrical, dominance-related (higher for L1) switching costs. These results went in line with the predictions of IC model. Similar results were observed only in one study (Jackson et al., 2004), but it is hard to state that these two works supported each other's claims. At the very same time, numerous works with presumably similar tasks and testing conditions as in the study by Mosca and de Bot, only reported the observation of symmetrical switching costs for L1 and L2 (von Studnitz and Green, 1997; Thomas and Allport, 2000; Orfanidou and Summer, 2005; Macizo et al., 2012).

1.3.3. Influence of language-specific stimuli

Mosca and de Bot highlighted two significant differences from other language control studies that could explain the novel results of their studies. First – the stimuli used in this study were controlled to be language non-specific. It was highlighted that items with language-specific orthography are recognized faster in both L1 and L2. It would mean that such words would activate the relevant language and inhibit the irrelevant language significantly faster compared to language non-specific words. In other studies of language control in perception, stimuli with unique language cues were used and those studies did not specify whether switching costs were modulated by orthography specificity (Thomas and Allport, 2000; Orfanidou and Summer, 2005).

One of the first most prominent studies that investigated the connection between language-specific visual stimuli and language control were a study by Grainger & Beauvillain (1987) and its later revision by Thomas & Allport (2000). It was initially proposed (Grainger & Beauvillain 1987) that orthographic cues play a significant role in language recognition and such cues, being unique for a language, can either equalize the recognition switching costs for L1 and L2, or have a confusing effect, if the orthographic features of words are shared between two languages. The revision by Thomas and Allport (2000), with more thorough and careful methodology organization, highlighted that switching costs and language control in general, cannot be attributed to the work of language system only. This goes in line with the proposal within the framework of IC model and the theory of task schemas implied in the model (von Studnitz and Green, 1997; Green, 1998). Task schema account predicts an important difference in recognition patterns for words with language-specific orthography – task schema competition does

not include the possibility of influence from orthography or, at least, such influence should be weak or less likely to happen. That is, contrary to former observations (Grainger & Beauvillain, 1987), in the study by Thomas and Allport (2000) no significant switching cost differences between L1 and L2 stimuli were found, as well as between stimuli with language specific and non-specific orthography.

The influence of orthographic specificity was also reviewed in a study by Orfanidou and Summer (2005), when authors used a language pair with partially different alphabets (English-Greek), which allowed the researchers to use the stimuli with unique and shared orthographic symbols. It was highlighted that the influence of language specific stimuli was significant only when all stimuli in a task block were only language specific or language non-specific. When such stimuli were mixed within one task block, orthographical features of the stimuli had no significant effect of switching costs.

1.3.4. Potential influence of language dominance

Yet, as it was mentioned, the features of language dominance for bilinguals can also play a crucial role in the work of language control mechanism. The whole debate on the relevant mechanism of language control is tightly connected to the notion of language dominance/language dominance. The predictions for language control in perception are opposite for IC and BIA models, but their difference is, once again, based on language dominance – whether language switching costs are dominance-related or dominance-reversed.

Language dominance is a complex structure with multiple levels. It does not only reside around the order of acquisition of languages or exposure to the languages, but rather includes multiple ways and modes of interaction with languages.

The notion of language dominance and its influence have been studied extensively over the past decades. There are numerous reports that language dominance interacts with all phenomena of language use and even non-linguistic cognitive processes. Studies of any form of language use cannot ignore the potential influence of language dominance and this factor should be carefully accounted for.

Previously, researchers assessed language dominance in their own way, without a standardized system or guidelines. Obviously, considering the significance of the potential influence of language dominance in Applied Linguistic studies, a deep and standardized notion and evaluation system of language dominance would be helpful in providing more reliable research findings.

Up to date, there is still no final consensus on what should be included in defining language dominance (Gollan et al., 2012; Kaushanskaya, Blumenfeld and Marian, 2020), but there are some shared ideas about the fundamentals. It was generally agreed that such fundamentals include: Age of language acquisition; Exposure to languages at the time of inquiry and through the lifetime; Estimate level of language proficiency.

One of the first multimodal systems of language dominance assessment was Language Experience and Proficiency Questionnaire (LEAP-Q) (Marian, Blumenfeld & Kaushanskaya, 2007). This system divided language dominance into a set of 8 factors: L1 Competence; L2 Learning; L2 Competence; L1 Maintenance; L2 Immersion; Media-Based Learning; Non-Native Status; Balance Immersion. In total, this questionnaire consists of 31 questions and allows a deep investigation of bilingual's language background.

It was later argued that LEAP-Q did not actually provide "gradient measure of language dominance", which developed into another system of assessment – Bilingual Dominance Scale (BDS) (Dunn & Tree, 2009). BDS is a set of 12 questions, with 3 paired questions for L1/L2 and 6 open-ended questions that provided a short list of relevant data on language learning and using history, current language use, environment and attitudes. Even though the results of this questionnaire did not provide a big load of information, it highly correlated with independent language proficiency tests and gave a reliable overview of bilingual's language dominance.

The accountability of LEAP-Q and BDS systems was argued in the development of another language dominance measurement system – Bilingual Language Profile (BLP) questionnaire (Birdsong, Gertken & Amengual, 2012). It was repeatedly highlighted that LEAP-Q was not exactly aimed at dominance assessment, as it rather investigates independent data for each of multilingual's languages, but rarely compared them to set a "composite dominance score" (Birdsong, Gertken & Amengual, 2012).

In relation to the mentioned issues, Birdsong et al. (2012) aimed at expanding that system by organizing more clear-cut separation of questions into 4 sets of factors for each of the studied languages: Language History; Language Use (current, not former); Language Proficiency and Language Attitudes. Even though the factors had different number of questions and potential scores, for the first time, these factor sets had their own weighting. BLP questionnaire provides the most detailed and careful evaluation system of language dominance that should consist of 4 main factors.

1.4. Current study

1.4.1. Research questions

The main aim of this study is to further investigate the mechanism of language control in perception within a new context of linguistically distant languages. The main research question of this study is:

- What language control model is more viable to account for the mechanism of language control?

The subquestions break down the main question into several smaller elements that have to be studied in the proposed order:

1. Is there a language switching cost during language control in perception for unbalanced bilinguals?
2. Is switching cost asymmetry dominance-related (in accordance with IC model) or dominance-reversed (in accordance with BIA model)?
3. What is the relation between language dominance and switching cost mechanism?

1.4.2. Hypotheses

(1) It is expected, that even in case of linguistically distant languages, which words could potentially initiate earlier and faster language recognition, switching costs should be present, as language control mechanism seems to rely on additional extra-linguistic control mechanisms (Green 1998; Thomas and Allport, 2000; Orfanidou and Summer, 2005).

(2) Considering that asymmetrical switching costs for language perception are expected, then in line with former studies (Jackson et al., 2004; Mosca & de Bot, 2017), they should be dominance-related, as predicted by IC model.

(3) Language dominance that has effect on various aspects of language use (e.g: Filippi et al., 2012), should definitely have influence on language switching cost. Except for overall language dominance, which should have positive correlations with switching costs (the higher the dominance in one of the language – the higher the switching cost), it is also expected that language History and Language Use would have significant influence on the reaction times and switching costs.

Consequently, from the hypothesized answers to the subquestions, the observations of this research would signify the Inhibitory Control model as the right model to account for language control in perception.

Methodology

2.1. Design

This study is a single-factor within-participants design. Thirty-two participants performed a lexical decision task and were administered a Bilingual Language Profile questionnaire (Birdsong et al. 2012).

2.2. Participants

32 bilingual participants took part in this research. All participants were native speakers of Hungarian who have acquired English after the age of 7. The average age of participants was 24.32 (SD=6.68). 28 participants were between the ages of 18-27 years old and 4 participants were over 27 years old. Further information on participants' linguistic background will be reported in the Results section, as a part of BLP questionnaire results.

2.3. Instruments

2.3.1. Lexical decision

Lexical decision experiment was used in this research in which participants are usually asked to decide whether the presented string of letters is a word or a pseudoword. The stimuli consisted of 28 real words and 28 pseudowords. Real words included 14 English and 14 Hungarian words - all of them were nouns denoting real concrete objects. No word had its translation included in the list and not a single word was a cognate. All words were matched for word frequency ($t=0.88$, $p>0.05$). Information about English word frequencies ($M=7.85$, $SD=2.84$) was derived from British National Corpus (BNC) online source (<https://www.english-corpora.org/bnc/>) and data on Hungarian word frequencies ($M=6.87$, $SD=3.03$) was derived from the Hungarian corpus developed by Language Technology Research Group (<http://corpus.nytud.hu/cgi-bin/mnszgyak>). English ($M=5.57$, $SD=0.52$) and Hungarian ($M=5$, $SD=0.55$) words were matched for orthographic length ($t=2.83$, $p>0.05$). Pseudowords were created by changing the sub-syllabic elements of the real words, selected for this study. Pseudowords had the same orthographic length as their real-word counterparts. Language specific symbols (such as á, ű, gy) were not used for words or pseudowords.

All items were presented in the center of a 15-inch computer screen set to $1,366 \times 768$ pixel resolution and they were seen from a distance of approximately 40- 80 cm. Words

and pseudowords were presented in white uppercase letters against a black background. The software PsyToolkit was used (Stoet, 2010, 2017) for data collection.

2.3.2. Bilingual language profile

The BLP questionnaire was administered by email, after finishing the lexical decision task. The BLP questionnaire was compiled in English language and consisted of 48 questions in total, inquiring on some relevant personal information and linguistic background. Only participants' emails contained information about their identity, but they were only used to provide the BLP questionnaire and were not used for data analysis. Participants' personal information and BLP data is not revealed in this research to protect the anonymity of the participants.

2.4. Procedure

Participants were tested individually, in a quiet room; they received oral instructions from the principal investigator and written instructions on the computer screen. The whole session consisted of a practice session and main session of lexical decision tasks. All participants were instructed to report as quickly and correctly as possible.

In the lexical decision task, the reaction times were measured as the time span between the display of the stimulus on the screen and pressing of one of the response buttons. As it can be seen on the Figure 1, a trial consisted of: (1) a blank screen for 250 ms; (2) a fixation cross for 250 ms; (3) a blank screen for 250 ms; (4) a target stimulus for 2000 ms.

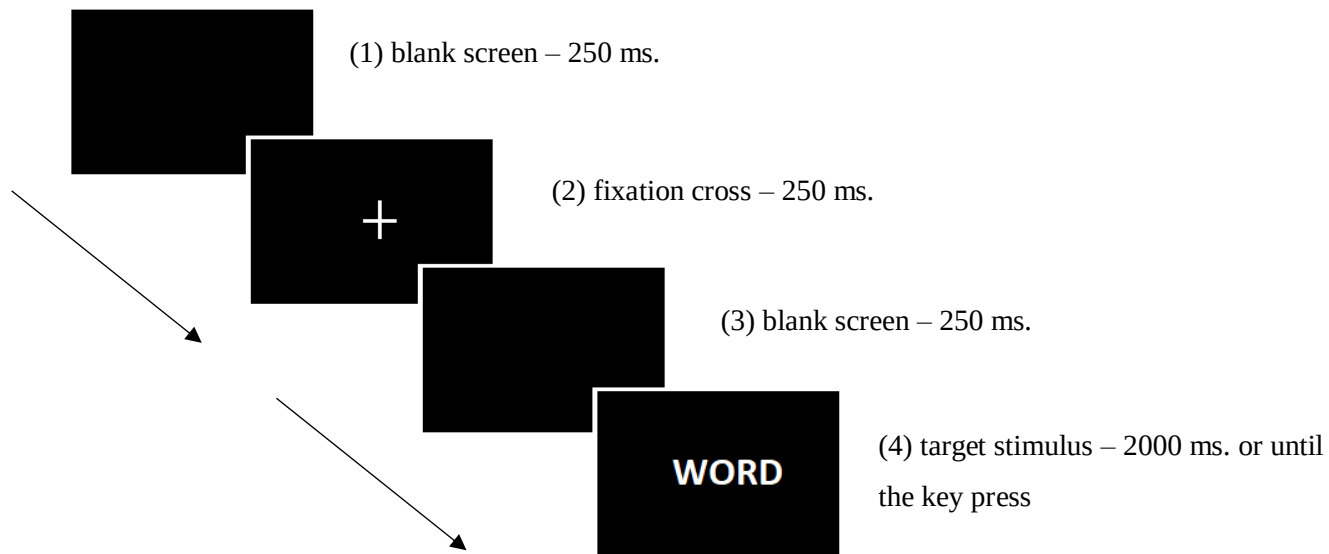


Figure 1. Example of lexical decision task trial

Participants were instructed to decide whether the presented strings of letters were real or non-sense words by pressing one of two buttons on the left or right sides of the keyboard. The task consisted of 336 trials in total. 1/3 of the trials (112) were non-sense words and the remaining trials were real English (112) and real Hungarian (112) words. Participants were instructed that the language to which words belonged was irrelevant for the task.

Only one item was displayed at the time. To exclude effects of backwards inhibition (influence of trial order on the reaction times) on switch trials, all trials were organized in 4-item-chunks (84 chunks in total for 336 trials) (for a review on backward inhibition, see Koch et al., 2010). Every chunk consisted of 3 *repetition trials* at the beginning and 1 *switch trial* at the end. The whole test consisted of 252 repetition trials and 84 switch trials.

There were 2 types of chunks in the test: *full-word chunks* that included only real words and *partial-word chunks* that included both words and pseudowords.

In full-word chunks, the first 3 trials belonged to the same language, while the last one was a switch to another language (e.g. L1 word - L1 word - L1 word – L2 word = LOVAG – SZOBOR – LABDA - CARROT).

In partial-word chunks, different types of trials (words and pseudowords) and both languages (L1 and L2) were included. Because of this, there were 2 groups of partial-word chunks:

- With first 3 trials being real words from the same language and the last one being a pseudoword of any language (e.g. L1 word - L1 word - L1 word - L1 pseudoword = LOVAG – SZOBOR – LABDA - KALUG);
- With first 3 trials being pseudowords from the same language and the last one being a real word from any language (e.g. L1 pseudoword - L1 pseudoword - L1 pseudoword – L2 word = KALUG – SZOTOL – PILLVE - RAZOR).

Each word was seen only once in each chunk position. For 28 full-word chunks, there were 2 possible item combinations (14 chunks for each) and for 56 partial-word chunks, there were 8 possible item combinations (7 chunks for each).

If two items (e.g., pencil-onion-X-X) had occurred together in a chunk, this item combination was not repeated. Additionally, their derived pseudowords (e.g., menvil-uniein-X-X) were never presented together within a chunk. Real words and pseudowords derived from them (e.g., pencil-X-X-menvil) never occurred in the same chunk. Moreover, a given item was never seen within the next 5 trials and the same type of chunk never occurred more than twice in a row.

Four lists of the task were created for testing. In order to perform the appropriate comparison of the switch cost, only the last two elements of a chunk were analyzed, leading to the same number of repetition and switch trials under analysis (84 repetition and 84 switch trials per task list).

Each participant was administered with one list only. The language of instructions for the task was English. Before the main experiment, participants did a practice session of 24 trials and these practice items were not included in the data analysis.

2.5. Result analysis procedure

In order to investigate the influence of language balance on the reaction times and switching costs for trials in specific conditions, the system of language balance measurement is required. The BLP questionnaire that was used in this research allows assigning numerical values to 4 sets of bilinguals' linguistic background: Language History, Language Use, Language Proficiency and Language Attitudes. The total values for one language background are calculated as a sum of 4 sets of language background. BLP framework also allows giving a numerical value to estimate language dominance, as

a measure of difference between L1 and L2 linguistic backgrounds. Therefore, better language balance is associated with lower score of language balance, and stronger language imbalance would be associated with higher language balance score. Every set of bilingual linguistic background was individually weighted, so that, for example, the influence of Language Use cannot outweigh the influence of Language Performance. The data for the reaction times analysis was organized as follows. Each participant has finished one trial block of 336 trial, but research design presupposed that only 50% of these trials (168) could be analyzed. The data on each trial included the *reaction time*, *answer status* (correct/incorrect) and *trial characteristics*. Trial characteristics were combinations of 4 trial variables that could take 2 values each:

- Language of the stimulus – L1 or L2 (language of the original word for pseudoword stimuli);
- Type of the stimulus – Word vs Pseudoword;
- Trial type – Repetition vs Switch (relates only to the language of the previous trial, so that the sequence like: L1 word – L1 pseudoword would be considered “Repetition”);
- Response Priming – Response Repetition vs Response Change (relates to the repetition of the correct response required, so that the sequence like: L1 word – L2 word, would be considered “Response Repetition”).

Each trial had a condition that was a combination of different values of 4 variables (e.g.: L1-Word-Repetition- Response Repetition trial).

To report on accuracy rates and correlations, average response accuracy in different conditions were calculated and used for analysis (e.g.: average accuracy for L1 trials). When the comparison of accuracy rates is conducted for two groups of stimuli that are different values of one variable, for example L1 stimuli vs L2 stimuli, it means that any other variable can take any value, and it is only the language of a trial that is considered in comparison.

The comparison of the reaction times has been conducted in the same manner as the comparison of accuracy rates, but only trials with correct answers were included in the analysis.

Results

3.1.BLP questionnaire analysis

This section presents the participants' language background in the L1 and L2 as measured by the BLP. Table 1 shows that on average, participants'

- L1 language history was significantly higher than L2 language history ($t(30) = 23.73$, $p < 0.001$);
- L1 use was significantly higher than L2 use ($t(30) = 5.88$, $p < 0.001$);
- L1 proficiency was significantly higher than L2 proficiency ($t(30) = 5.07$, $p < 0.001$);
- L1 language attitude was significantly higher than L2 language attitude ($t(30) = 2.71$, $p < 0.01$);
- L1 total background was significantly higher than L2 total background ($t(30) = 9.85$, $p < 0.001$).

Table 1. Participants' linguistic background data

	L1 (Hungarian)		L2 (English)		Significance
Language History	M=45.58	SD=5.37	M=13.53	SD=6.53	$p < 0.001$
Language Use	M=34.42	SD=6.85	M=19.90	SD=6.97	$p < 0.001$
Language Proficiency	M=52.06	SD=4.83	M=44.81	SD=7.55	$p < 0.001$
Language Attitude	M=46.86	SD=12.29	M=38.22	SD=11.31	$p < 0.01$
Total Language Background	M=178.93	SD=20.18	M=116.47	SD=22.94	$p < 0.001$

Table 1 shows the distribution of the answers on all factors and it is apparent that L1 language proficiency and attitude is more homogeneous than L2 showing a great variation in attitudes towards the L2.

Figure 2. Distribution of linguistic background values in L1 and L2

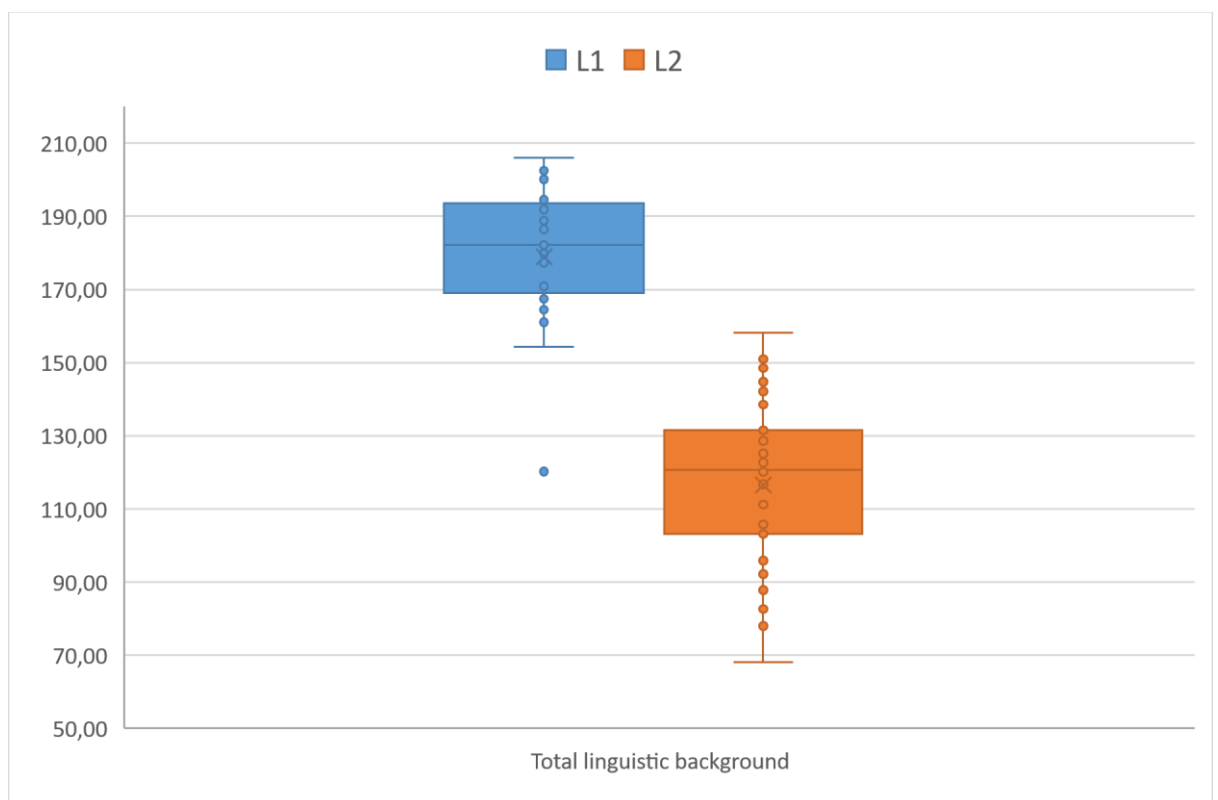
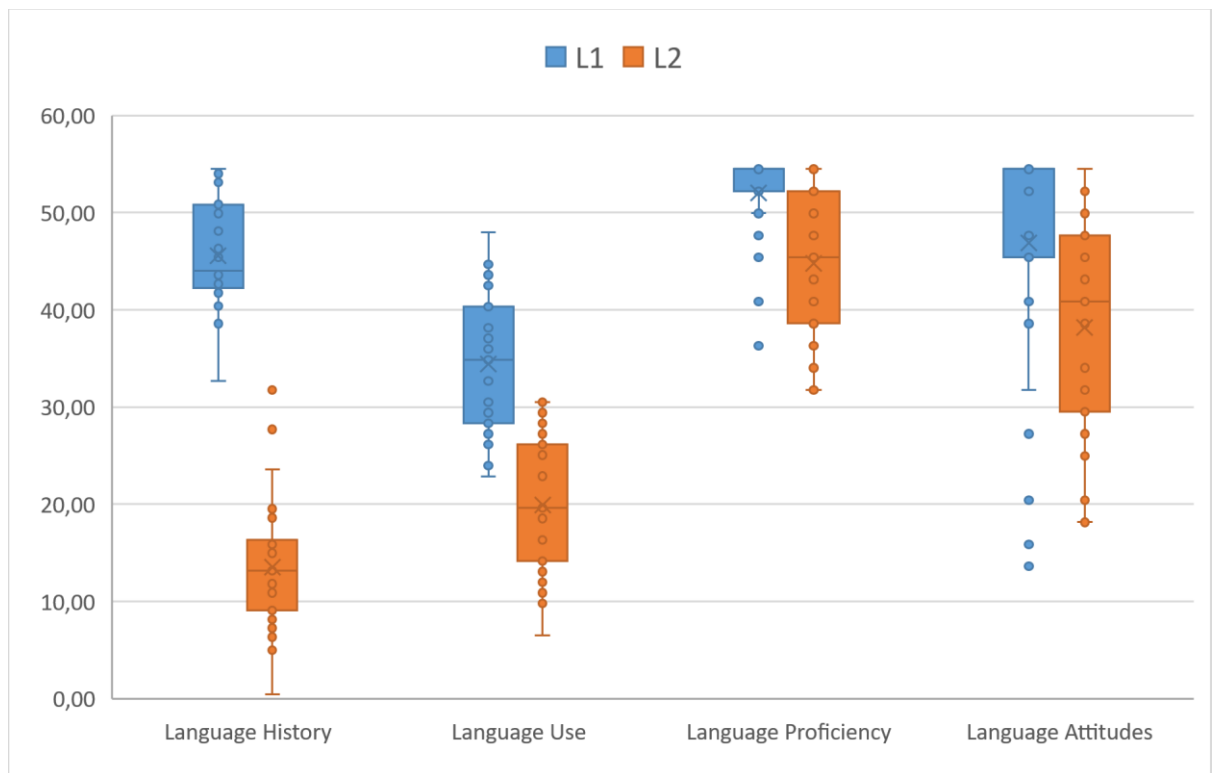


Figure 3. Distribution of total linguistic background values in L1 and L2

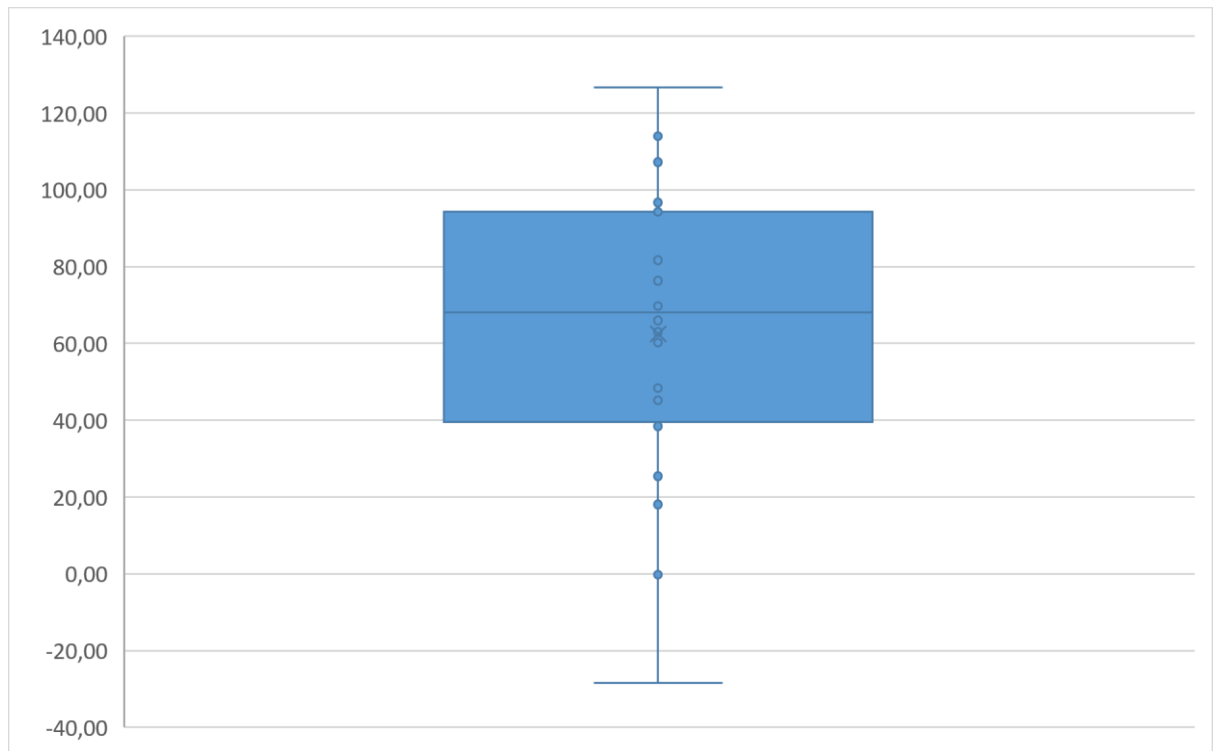


Figure 4. Distribution of language dominance values among participants

On average, participants' language dominance was equivalent to 62.45 according to the BLP formula ($M=62.46$, $SD=35.30$), which meant that the participants are L1 dominant bilinguals. In total, there were 6 participants that could be considered relatively balanced bilinguals.

3.2.Lexical decision accuracy analysis

This section presents the accuracy of participant's performance in lexical decision task. Table 2 shows that on average, participants' mean accuracy was 93.95%, furthermore:

- Responses to L1 stimuli were significantly more accurate than to L2 stimuli ($t(30) = 3.35$, $p<0.01$);
- Responses to words were significantly more accurate than to pseudowords, ($t(30) = 3.41$, $p<0.01$);
- Responses to repetition trials were significantly more accurate than to switch trials, ($t(30) = 3.91$, $p<0.001$);
- Responses to trials in response repetition condition were significantly more accurate than to trials in response change condition, ($t(30) = 5.32$, $p<0.001$).

Compared conditions	M	SD	Significance
L1	95.66%	4.11	p<0.01
L2	92.24%	5.31	
Words	95.22%	3.71	p<0.01
Pseudowords	91.42%	6.45	
Repetition	94.73%	3.63	p<0.001
Switch	92.40%	4.94	
Response repetition	97%	2.75	p<0.001
Response change	87.85%	9.47	

Table 2. Participants' accuracy rates of responses to trials in the given conditions

Table 2 shows the distribution of the accuracy on all factors and it is apparent that accuracy of reactions to words and stimuli in response repetition conditions is more homogeneous than reactions to pseudowords and stimuli in response change conditions. The accuracy of responses is more homogeneous to L1 than to L2 stimulus. Considering that in this study we are interested in the features of the perception of real words only, trials that were pseudowords were excluded from further analysis. Table 3 shows that on average, in such conditions, participants':

- Responses to L1 words were significantly more accurate than to L2 words, ($t(30) = 5.70$, $p < 0.001$);
- Responses to words in repetition condition were significantly more accurate than to words in switch condition, ($t(30) = 2.33$, $p < 0.05$);
- Responses to words in response repetition condition were significantly more accurate than to words in response change condition, ($t(30) = 3.90$, $p < 0.001$).

Words only comparison			
Compared conditions	M	SD	Significance
L1	98.73%	2.07	p<0.001
L2	91.69%	6.85	
Repetition	95.71%	3.75	p<0.05
Switch	94.39%	4.41	
Response repetition	96.89%	3.20	p<0.001
Response change	90.21%	9.63	

Table 3. Participants' accuracy rates of responses to word trials in the given conditions

Table 3 shows the distribution of the accuracy on all factors and it can be seen that accuracy of reactions to L1 words and words in response repetition conditions is more homogeneous than reactions to L2 words and words in response change conditions.

It was decided to additionally analyze how could the effect of trial type (repetition vs switch) and response priming (response change vs response repetition) vary for words in language separately. Table 4 shows that on average, in such conditions, participants':

- Responses to words in repetition condition were not significantly more accurate than to words in switch condition for both L1 ($p>0.05$) and L2 ($p>0.05$) words. Such observation was unexpected, since it was mentioned that responses to L1 and L2 words together, in repetition condition were significantly more accurate than to words in switch condition ($t(30) = 2.33$, $p<0.05$).
- Responses to L1 words in response repetition condition were significantly more accurate than to words in response change condition, ($t(30) = 3.16$, $p<0.01$);
- Responses to L2 words in response repetition condition were significantly more accurate than to L2 words in response change condition, ($t(30) = 3.68$, $p<0.001$).

Words only, within language comparison
--

Compared conditions	M	SD	Significance
L1 repetition	98.9%	2.04	p>0.05
L1 switch	98.46%	3.11	
L2 repetition	92.52%	6.84	p>0.05
L2 switch	90.32%	8.65	
L1 response repetition	99.92%	0.43	p<0.001
L1 response change	95.16%	8.33	
L2 response repetition	93.84%	6.43	p<0.001
L2 response change	85.25%	1.38	

Table 4. Comparison of participants' accuracy rates of responses to word trials of different languages in the given conditions

Table 4 shows the distribution of the accuracy on all factors and it is apparent that:

Accuracy of reactions to L2 words in language repetition condition is more homogeneous than to L2 words in language switch condition;

Accuracy of reactions to L1 words in response repetition condition is more homogeneous than to L1 words in response change condition;

Accuracy of reactions to L2 words in response change condition is lower, but more homogeneous than to L2 words in response repetition condition.

Finally, the main focus of this research is on the interference that words from one language have on the reaction to words from another language. That would require to limit the analyzed trials only to the words in response repetition condition (i.e. words followed by words). Table 5 shows that on average, in such conditions, participants':

- Responses to L1 words in response repetition, language repetition condition (L1 followed by L1) were significantly more accurate than in language switch condition (L2 followed by L1), ($t(30) = 4.79$, $p < 0.001$);

- Responses to L2 words in response repetition, language repetition condition were significantly more accurate than in Language Switch condition, ($t(30) = 5$, $p < 0.001$);

It means, that accuracy is influenced by language switching in both directions (switching from L1 to L2 or L2 to L1).

Words primed by words, within language comparison			
Compared conditions	M	SD	Significance
L1 repetition	99.88%	0.64	p<0.001
L1 switch	94.8%	5.78	
L2 repetition	95.22%	0	p<0.001
L2 switch	91.94%	8.99	

Table 5. Comparison of participants' accuracy rates of responses to word trials of different languages primed by words, in the given conditions

Table 5 shows the distribution of the accuracy on all factors and it is apparent that accuracy of reactions to L1 and L2 words in response repetition, language repetition condition is more homogeneous than to L1 and L2 words in response repetition, language change condition.

3.3. Lexical decision reaction times analysis

This section presents the reaction times (RTs) in different conditions of the lexical decision task. Table 6 shows that on average, participants':

- Responses to L1 stimuli were significantly faster than to L2 stimuli ($t(30) = 5.93$, $p < 0.001$)
- Responses to words were significantly faster than to pseudowords ($t(30) = 11.81$, $p < 0.001$)
- Responses to repetition trials were significantly faster than to switch trials ($t(30) = 6.41$, $p < 0.001$)

- Responses to trials in response repetition condition were significantly faster than to trials in response change condition ($t(30) = 11.64, p < 0.001$)

All stimuli comparison			
Compared conditions	M (ms)	SD	Significance
L1	591.81	68.12	p<0.001
L2	626.59	75.72	
Words	570.65	61.38	p<0.001
Pseudowords	688.91	96.17	
Repetition	599.84	71.57	p<0.001
Switch	627.64	68.9	
Response repetition	579.19	68.75	p<0.001
Response change	677.21	78.75	

Table 6. Participants' reaction times to trials in the given conditions

Table 6 shows the distribution of the reaction times on all factors and it is apparent that reaction times to words are more homogeneous than to pseudowords.

Similarly to accuracy analysis, trials that were pseudowords, were excluded from further analysis. Table 7 shows that on average, in such conditions, participants':

- Responses to L1 words were significantly faster than to L2 words ($t(30) = 7.42, p < 0.001$);
- Responses to words in repetition condition were significantly faster than to words in switch condition ($t(30) = 8.51, p < 0.001$);
- Responses to words in response repetition condition were significantly faster than to words in response change condition ($t(30) = 7.80, p < 0.001$)

Words only comparison			
Compared conditions	M (ms)	SD	Significance
L1	547.94	60.82	p<0.001
L2	595.42	68.05	
Repetition	555.17	63.49	p<0.001
Switch	596.77	61.25	
Response repetition	552.19	63.85	p<0.001
Response change	632.55	70.32	

Table 7. Participants' reaction times to word trials in the given conditions

Table 7 shows the distribution of the reaction times on all factors and it is apparent that reaction times to Words across both languages and various conditions are generally homogeneous.

Further investigation focused on the effect of trial type and response priming for words from each language separately. Table 8 shows that on average, in such conditions, participants':

- Responses to words in repetition condition were significantly faster than to words in switch condition for both L1 ($t(30) = 6.11$, $p < 0.001$) and L2 ($t(30) = 4.99$, $p < 0.001$) words.
- Responses to words in response repetition condition were significantly faster than to words in response change condition for both L1 ($t(30) = 8.01$, $p < 0.001$) and L2 ($t(30) = 5.61$, $p < 0.001$) words.

Words only, within language comparison			
Compared conditions	M	SD	Significance
L1 repetition	531.72	59.65	p<0.001
L1 switch	575.34	70.41	

L2 repetition	580.46	76.18	p<0.001
L2 switch	620.58	61.16	
L1 response repetition	527.76	61.93	p<0.001
L1 response change	613.18	77.53	
L2 response repetition	578.67	74.39	p<0.001
L2 response change	655.25	71.76	

Table 8. Comparison of participants' reaction times to word trials of different languages in the given conditions

Table 8 shows the distribution of the reaction times on all factors and it is apparent that: Reaction times to L2 words in language Switch condition are more homogeneous than to L2 words in language repetition condition;

Reaction times L1 words in response repetition condition are more homogeneous than to L1 words in response change condition.

Once again, the main focus of this research is on the interference that words from one language have on the reaction to words from another language. Table 9 shows that on average, in such conditions, participants':

- Responses to L1 words in response repetition, language repetition condition were significantly faster than in language switch condition ($t(30) = 4.68$, $p < 0.001$)
- Responses to L2 words in response repetition, language repetition condition did not differ significantly in reaction times compared to language switch condition ($p > 0.05$)

It means, that the difference between repetition and switch trials was significant only for L1 words but not for L2 words.

Words primed by Words, within language comparison

Compared conditions	M	SD	Significance
L1 repetition	512.95	59.15	p<0.001
L1 switch	557.4	79.87	
L2 repetition	588.23	62.3	p>0.05
L2 switch	573.71	83.62	

Table 9. Comparison of participants' reaction times to word trials of different languages primed by words, in the given conditions

Table 09 shows the distribution of the reaction times on all factors and it is apparent that reaction times to L1 and L2 words in response repetition, language repetition condition are more homogeneous than to L1 and L2 words in response repetition, language change condition;

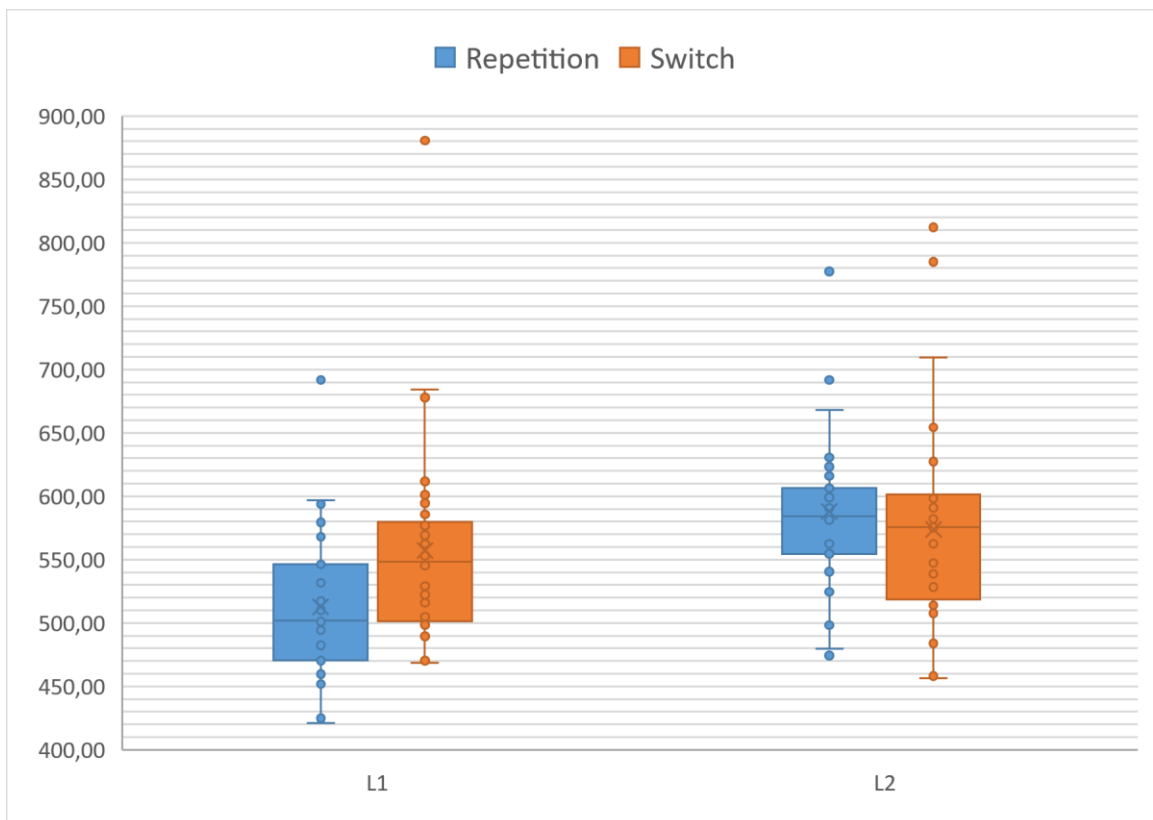


Figure 5. Distribution of participants' reaction times to words primed by words in repetition and switch conditions in L1 and L2

3.4.Switching costs analysis

Previous observations indicate that the switching costs were significant only for one language, but it is still unclear whether these switching costs were significantly different for L1 and L2. In order to assure that, we have also calculated the switching costs as the difference between reaction times in repetition and switch conditions.

On average, participants' switching cost for L2 words in response repetition condition was significantly higher than for L1 words in response repetition condition ($t(30) = 5.18$, $p < 0.001$)

It means that in this research, dominance-related switching cost was observed.

3.5.Pseudowords analysis

The additional analysis of the reaction times to pseudowords have revealed that language had no effect on reaction times in any conditions, meaning that it did not matter which language the pseudowords were derived from – reaction to them was similarly fast for L1 and L2.

The total set of the target reaction time data of lexical decision experiment is summarized in Table 10

	Response Repetition		Response Change	
	L1	L2	L1	L2
Words				
Language repetition	512.95	588.23	613.35	614.64
Language switch	557.4	573.71	613.71	693.79
Switching cost	44.45***	-14.52	0.36	79.15***
Pseudowords				
Language repetition	660.75	659.35	716.79	719.34
Language switch	N/A	N/A	729.14	729.11
Switching cost	N/A	N/A	12.35	9.77

Table 10. The mean reaction times and switching costs to the trials in various complex conditions (e.g.: L1, word, language switch, response repetition trial condition)

(Note: $p < 0.001^{***}$, $p < 0.01^{**}$, $p < 0.05^*$, $p < 0.05$)

3.6.BLP questionnaire and lexical decision task performance correlation analysis

The analysis of correlations of BLP questionnaire data with lexical decision task data (Reaction times and Switching costs included) revealed that:

- L2 language history – RT to L1 words in response repetition, language repetition condition: negative, medium correlation, $r(29) = -.37$, $p < 0.05$, meaning that participants with richer L2 language history responded significantly faster to L1 words primed by L1 words.
- L2 language history – RT to L2 words in response repetition, language repetition condition: negative, medium correlation, $r(29) = -.40$, $p < 0.05$, meaning that participants with richer L2 language history responded significantly faster to L2 words primed L2 words.
- L2 language history – RT to L2 words in response repetition, language switch condition: negative, medium correlation, $r(29) = -.46$, $p < 0.01$, meaning that participants with richer L2 language history responded significantly faster to L2 words primed L1 words.

Trial condition RTs and SCs	Language History		Language Use	
	L1	L2	L1	L2
L1 Repetition	-0.3	<u>-0.37*</u>	0.01	-0.04
L1 Switch	-0.11	-0.2	0.05	-0.05
L2 Repetition	0.05	<u>-0.4*</u>	0.23	-0.22
L2 Switch	-0.05	<u>-0.46**</u>	0.26	-0.26
L1 Switching cost	0.17	0.11	0.07	-0.02
L2 Switching cost	-0.16	-0.29	0.16	-0.16

Table 11. Correlations of reaction times and switching costs with language history and language use values

(Note: $p < 0.001^{***}$, $p < 0.01^{**}$, $p < 0.05^*$, $p < 0.05$)

No significant correlations were observed between Lexical decision task performance and Language Use (Table 11), Language Proficiency and Language Attitudes, neither for L1 nor for L2 (Table 12):

Trial condition RTs and SCs	Language Proficiency		Language Attitudes	
	L1	L2	L1	L2
L1 Repetition	-0.15	-0.12	0.04	0.09
L1 Switch	-0.07	-0.21	-0.03	0.01
L2 Repetition	0.18	-0.28	0.33	-0.13
L2 Switch	0.07	-0.31	0.21	-0.18
L1 Switching cost	0.06	-0.18	-0.09	-0.09
L2 Switching cost	-0.11	-0.17	-0.06	-0.15

Table 12. Correlations of reaction times (RT) and switching costs (SC) with language proficiency and language attitudes values

(Note: $p < 0.001^{***}$, $p < 0.01^{**}$, $p < 0.05^*$, $p < 0.05$)

Several correlations of Lexical decision task performance with total linguistic background values for each language and language dominance values were observed:

- L2 Total Background - RT to L2 words in response repetition, language switch condition: negative, medium correlation, $r(29) = -.40$, $p < 0.05$, meaning that participants with richer L2 Background responded significantly faster to L2 Words primed L1 words
- Language dominance - RT to L2 words in response repetition, language repetition condition: negative, medium correlation, $r(29) = .41$, $p < 0.05$, meaning that participants with less language dominance responded significantly slower to L2 Words primed L2 words
- Language dominance – L2 words in response repetition, language switch condition: negative, medium correlation, $r(29) = .38$, $p < 0.05$, meaning that

participants with less language dominance responded significantly slower to L2 words primed L1 words

Trial condition RTs and SCs	Total language Background		Language Dominance
	L1	L2	
L1 Repetition	-0.09	-0.11	0.02
L1 Switch	-0.05	-0.13	0.06
L2 Repetition	0.33	-0.34	<u>0.41*</u>
L2 Switch	0.22	<u>-0.4*</u>	<u>0.38*</u>
L1 Switching cost	0.03	-0.08	0.07
L2 Switching cost	-0.05	-0.26	0.14

Table 13. Correlations of reaction times and switching costs with total linguistic background and language dominance values

(Note: $p < 0.001^{***}$, $p < 0.01^{**}$, $p < 0.05^*$, $p < 0.05$)

In addition to current observations, it was decided to analyze the potential correlations (Table 14) between the lexical decision task performance and differences in components of linguistic backgrounds between languages (e.g.: How higher differences in L1 and L2 language use would correlate with the reaction times). Significant correlations included:

- Language history difference – L2 words in response repetition, language repetition condition: positive, medium correlation, $r(29) = .38$, $p < 0.05$, meaning that participants with higher difference in language history responded significantly slower to L2 words primed L2 words
- Language History difference – L2 words in response repetition, language switch condition: positive, medium correlation, $r(29) = .36$, $p < 0.05$, meaning that participants with higher difference in language history responded significantly slower to L2 words primed L1 words
- Language Proficiency difference – L2 words in response repetition, language repetition condition: positive, medium correlation, $r(29) = .38$, $p < 0.05$, meaning

that participants with higher difference in language proficiency responded significantly slower to L2 words primed L2 words

Trial condition RTs and SCs	Language history difference	Language use difference	Language proficiency difference	Language attitudes difference
L1 Repetition	0.11	0.03	0.02	-0.03
L1 Switch	0.09	0.05	0.16	-0.03
L2 Repetition	<u>0.38*</u>	0.23	<u>0.38*</u>	0.31
L2 Switch	<u>0.36*</u>	0.26	0.33	0.26
L1 Switching cost	0.02	0.05	0.21	-0.01
L2 Switching cost	0.14	0.16	0.09	0.05

Table 14. Correlations of reaction times and switching costs with differences in linguistic background values

(Note: $p < 0.001^{***}$, $p < 0.01^{**}$, $p < 0.05^*$, $p < 0.05$)

Discussion

The aim of this study was to investigate bilingual language control mechanism in visual recognition. More precisely, the goal was to find out which language control model, Bilingual Interactive Activation or Inhibitory Control, is more viable to account for the mechanism of language control. In order to clearly and logically discuss the obtained results of the study, the predictions of the IC and the BIA models will be briefly overviewed first and then findings will be connected to them.

4.1. Language control tendencies

According to the IC model, language control processes replicate the patterns of general behavior control, including those that are not related to language at all. Within the framework of the Inhibitory Control Model, the theory of task schema (Norman and Shallice, 1986) is adopted. It was proposed that task schemas, which were developed for using each language, compete for activation when only one language is intended to be used. To use a certain language effectively, bilinguals have to activate one language task schema and inhibit the task schema of another language. In the mind of unbalanced bilinguals' the dominant language is more active than the non-dominant language. In such case, using L1 means activating the L1 and slightly inhibiting the weaker L2. In case of L2 use, the stronger L1 would require much more inhibitory efforts. Therefore, the L1 inhibition would be stronger compared to L2 inhibition, i.e. asymmetric inhibition.

Even though the Bilingual Interactive Activation model also includes the inhibitory mechanism, its basis is different. Within the BIA framework, the inhibition of one language is symmetrical to the activation of another language – when a language is activated to a certain degree, another language is equally strongly inhibited. It can be concluded that the BIA model predicts stronger inhibition of L2, as a result of stronger activation of the more dominant L1, opposite to predictions of the IC model.

First, since the predictions of both models heavily rely on the presence of the dominant language, they predict the same language control tendencies for balanced bilinguals – symmetrical inhibition applied to L1 and L2. Therefore, before confirming the validity of one of language control models, it is required to check the presence of asymmetrical switching costs for L1 and L2.

Presence of symmetrical switching costs would not allow us to definitely answer the main question of this study. Yet, considering the fact that this study involved, to the most

part, unbalanced, L1 dominant bilinguals, it was hypothesized that asymmetrical switching costs would be observed. According to the obtained results, the RT difference between repetition and switch trials was significant only for L1 words, but not for L2 – i.e. the significant switching cost was present only for L1. The comparison of switching costs revealed that they differed significantly, which means that asymmetrical switching costs were observed. The first hypothesis was confirmed.

As it was mentioned before, the IC and BIA models predict different direction of switching cost asymmetries. This switching cost should be higher for L1 words, compared to L2 words, if the IC model is the viable account of language control. In case of BIA model, higher switching cost is predicted for L2 words.

Considering the theories and findings of the earlier studies (Von Studnitz and Green, 1997; Green, 1998; Orfanidou & Summer, 2005; Mosca & de Bot, 2017), it was hypothesized that dominance-related switching costs would be observed, as predicted by the IC model. The observed asymmetrical switching costs were higher for participants' more dominant language. The hypothesis was confirmed and clear evidence of relevance of IC model for language control in bilingual visual language perception were observed.

4.2. Influence of linguistic background

In addition to investigating the relevance of language control models, this study was also aimed at investigating the influence of individual linguistic background variables and language dominance on language control.

Mostly unbalanced, L1 dominant bilinguals participated in this study. While many other research articles tried to gather relatively homogeneous groups of bilinguals, it was so only in relation to participants' L2 proficiencies. We evaluated linguistic backgrounds more broadly. L2 background was not seen as a dichotomous variable (i.e. comparing the performances of more and less proficient bilinguals), but rather as a continuous variable which allows for correlation analysis – whether and how changes in linguistic backgrounds resulted in changes in lexical decision task performance.

It was hypothesized that language dominance, daily language use and language learning and using history should have influence on language control mechanism – i.e. the mentioned components of linguistic background should have a certain significant correlation with LDT task performance. The hypothesis was partially confirmed.

Language history had negative correlations with the reaction times to L2 words in both repetition and switch conditions, but no correlations with L2 switching costs were

observed. It means that the reactions to L2 words were faster among people who studied and used L2 for longer, which is obvious. Yet, the inhibition of L2 seemed to be relatively similar for those who had “poorer” and “richer” L2 history.

Language dominance also had correlations with the reaction times to L2 words in both repetition and switch conditions, but that was negative correlation. It means that the reactions to L2 words were faster among people who had less defined language dominance – more balanced bilinguals.

At the very same time, no correlations were observed with language attitudes and language use, which partially contradicts out hypothesis, as language use was expected to correlate with LDT performance. The absence of any significant correlations meant that performance of participants that used L2 more and less often was quite similar, as well as performance of participants with better and worse attitudes to L2.

An interesting case has been observed with language proficiency. Neither L1, nor L2 language proficiencies had any significant correlations with LDT performance, but we have found significant, positive correlation between language proficiency difference and RTs to L2 words in language repetition condition. Language proficiency difference showed how strong was the difference between L1 proficiency and L2 proficiency. Our finding means that participants who had less difference in their language proficiencies tended to perform faster in LDT (in case of L2 word stimuli). This case can be explained through an example from the obtained results:

	L1 proficiency	L2 proficiency	Proficiency difference	RTs to L2 words
Participant 1	45.4	43.13	2.27	546.23
Participant 2	54.48	43.13	11.35	606.57

As it can be seen, people with the same level of L2 proficiency had different reaction times to L2 words, because one of the participants reported lower L1 proficiency and consequently had lower proficiency difference, which led to faster performance. Even though this is the perfect example of such tendency and other cases were not so straightforward, the statistical analysis concluded that there was a significant tendency in case of proficiency difference, but no such tendency in case of L2 or L1 proficiencies.

Conclusions

We have obtained clear evidence of stronger inhibition being applied to bilinguals' more dominant language in accordance with the Inhibitory Control model of language control.

Language control mechanism has been studied for over 20 years at this point, but to the most part, research could not provide clear and reliable evidence in favor of only one model. The more definite recent findings (Mosca and de Bot, 2017), in addition to the results obtained in this research, tip the scales in favor of the IC model, but further evidence are required to reliably solidify its relevance.

Extra analyses of the applied research methodologies would positively contribute to the testing of language control mechanism. Even though the influence of various methodological features has already been studied earlier (e.g.: Costa and Santesteban, 2004; Costa et al., 2006; Orfanidou and Summer, 2005; Reynold et al., 2016; Thomas and Allport, 2000), extra evidence of the obtained findings coming from different research contexts are required to solidify the understanding of the interfering factors.

The novelty of the current study is connected with the revised approach to evaluation of participants' language dominance and linguistic backgrounds that was not seen as a dichotomous, but rather as a continuous variable. Such approach was adopted for the first time in language control studies. We argue that this tendency has to be continued, as it has potential to explaining the earlier contradicting observations in language control research. Considering the fact that so far, the influence of other methodological features was mostly proven to be insignificant, linguistic background may be the main source of inconsistencies within the results of earlier language control studies.

The influence of language learning and using history, together with the influence of language proficiency differences that we have observed has never been addressed in earlier language control studies, which further signifies the relevance of new approaches to linguistic background evaluation. Current research proposes a framework for measuring the influence of linguistic backgrounds on language switching costs.

References

- Albert, M. L., & Obler, L. K. (1978). *The bilingual brain: Neuropsychological and neurolinguistic aspects of bilingualism*, Academic Press.
- Allport, D. A., Styles, E. A., & Hsieh, S. (1994). Shifting intentional set: Exploring the dynamic control of tasks. In C. Umiltà & M. Moscovitch (Ed.), *Attention and performance 15: Conscious and nonconscious information processing* (pp. 421–452). The MIT Press.
- Assche, E. V., Duyck, W., & Hartsuiker, R. J. (2012). Bilingual Word Recognition in a Sentence Context. *Frontiers in Psychology*, 3. <https://doi.org/10.3389/fpsyg.2012.00174>
- Christoffels, I. K., Firk, C., & Schiller, N. O. (2007). Bilingual language control: An event-related brain potential study. *Brain Research*, 1147, 192–208. <https://doi.org/10.1016/j.brainres.2007.01.137>
- Costa, A., & Santesteban, M. (2004). Lexical access in bilingual speech production: Evidence from language switching in highly proficient bilinguals and L2 learners. *Journal of Memory and Language*, 50(4), 491–511. <https://doi.org/10.1016/j.jml.2004.02.002>
- Costa, A., Santesteban, M., & Ivanova, I. (2006). How do highly proficient bilinguals control their lexicalization process? Inhibitory and language-specific selection mechanisms are both functional. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 32(5), 1057–1074. <https://doi.org/10.1037/0278-7393.32.5.1057>
- de Bot, K., & Schreuder, R. (1993). Word production and the bilingual lexicon. In R. Schreuder & B. Weltens (Ed.), *The bilingual lexicon* (pp. 191–214). John Benjamins Publishing Company. <https://doi.org/10.1075/sibil.6.10bot>
- Declerck, M., Koch, I., & Philipp, A. M. (2012). Digits vs. pictures: The influence of stimulus type on language switching. *Bilingualism: Language and Cognition*, 15(4), 896–904. <https://doi.org/10.1017/S1366728912000193>
- Dijkstra, T., & van Heuven, W. J. B. (1998). The BIA model and bilingual word recognition. In J. Grainger & A. M. Jacobs (Eds.), *Localist connectionist approaches to human cognition* (pp. 189–225). Lawrence Erlbaum Associates Publishers.
- Dunn, A. L., & Fox Tree, J. E. (2009). A quick, gradient Bilingual Dominance Scale*. *Bilingualism: Language and Cognition*, 12(03), 273. <https://doi.org/10.1017/S1366728909990113>

- Filippi, R., Leech, R., Thomas, M. S. C., Green, D. W., & Dick, F. (2012). A bilingual advantage in controlling language interference during sentence comprehension. *Bilingualism: Language and Cognition*, 15(4), 858–872. <https://doi.org/10.1017/S1366728911000708>
- Fink, A., & Goldrick, M. (2015). Pervasive benefits of preparation in language switching. *Psychonomic Bulletin & Review*, 22(3), 808–814. <https://doi.org/10.3758/s13423-014-0739-6>
- Gollan, T. H., Weissberger, G. H., Runnqvist, E., Montoya, R. I., & Cera, C. M. (2012). Self-ratings of spoken language dominance: A Multilingual Naming Test (MINT) and preliminary norms for young and aging Spanish–English bilinguals. *Bilingualism: Language and Cognition*, 15(3), 594–615. <https://doi.org/10.1017/S1366728911000332>
- Grainger, J., & Beauvillain, C. (1987). Language blocking and lexical access in bilinguals. *The Quarterly Journal of Experimental Psychology Section A*, 39(2), 295–319. <https://doi.org/10.1080/14640748708401788>
- Grainger, J., & Dijkstra, T. (1992). On the representation and use of language information in bilinguals. In R. J. Harris (Ed.), *Cognitive processing in bilinguals* (pp. 207–220). North-Holland. [https://doi.org/10.1016/S0166-4115\(08\)61496-X](https://doi.org/10.1016/S0166-4115(08)61496-X)
- Grainger, J., Midgley, K., & Holcomb, P. J. (2010). Chapter 14. Re-thinking the bilingual interactive-activation model from a developmental perspective (BIA-d). B. M. Kail & M. Hickmann (Eds.), *Language Acquisition and Language Disorders* (pp. 267–283). John Benjamins Publishing Company. <https://doi.org/10.1075/lald.52.18gra>
- Green, D. (1986). Control, activation, and resource: A framework and a model for the control of speech in bilinguals. *Brain and Language*, 27(2), 210–223. [https://doi.org/10.1016/0093-934X\(86\)90016-7](https://doi.org/10.1016/0093-934X(86)90016-7)
- Green, D. W. (1998). Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and Cognition*, 1(2), 67–81. <https://doi.org/10.1017/S1366728998000133>
- Jackson, G. M., Swainson, R., Cunningham, R., & Jackson, S. R. (2001). ERP correlates of executive control during repeated language switching. *Bilingualism: Language and Cognition*, 4(2), 169–178. <https://doi.org/10.1017/S1366728901000268>
- Jackson, G. M., Swainson, R., Mullin, A., Cunningham, R., & Jackson, S. R. (2004). ERP Correlates of a Receptive Language-Switching Task. *The Quarterly Journal of Experimental Psychology Section A*, 57(2), 223–240. <https://doi.org/10.1080/02724980343000198>

- Kaushanskaya, M., Blumenfeld, H. K., & Marian, V. (2020). The Language Experience and Proficiency Questionnaire (LEAP-Q): Ten years later. *Bilingualism: Language and Cognition*, 23(5), 945–950. <https://doi.org/10.1017/S1366728919000038>
- Koch, I., Gade, M., Schuch, S., & Philipp, A. M. (2010). The role of inhibition in task switching: A review. *Psychonomic Bulletin & Review*, 17(1), 1–14. <https://doi.org/10.3758/PBR.17.1.1>
- Kroll, J. F., & Stewart, E. (1994). Category Interference in Translation and Picture Naming: Evidence for Asymmetric Connections Between Bilingual Memory Representations. *Journal of Memory and Language*, 33(2), 149–174. <https://doi.org/10.1006/jmla.1994.1008>
- Kroll, J. F., & Sunderman, G. (2003). Cognitive Processes in Second Language Learners and Bilinguals: The Development of Lexical and Conceptual Representations. B. C. J. Doughty & M. H. Long (Ed.), *The Handbook of Second Language Acquisition* (pp. 104–129). Blackwell Publishing Ltd. <https://doi.org/10.1002/9780470756492.ch5>
- Macizo, P., Bajo, T., & Paolieri, D. (2012). Language switching and language competition. *Second Language Research*, 28(2), 131–149. <https://doi.org/10.1177/0267658311434893>
- Marian, V., Blumenfeld, H. K., & Kaushanskaya, M. (2007). The Language Experience and Proficiency Questionnaire (LEAP-Q): Assessing Language Profiles in Bilinguals and Multilinguals. *Journal of Speech, Language, and Hearing Research*, 50(4), 940–967. [https://doi.org/10.1044/1092-4388\(2007/067\)](https://doi.org/10.1044/1092-4388(2007/067))
- McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: I. An account of basic findings. *Psychological Review*, 88(5), 375–407. <https://doi.org/10.1037/0033-295X.88.5.375>
- Meuter, R. F. I., & Allport, A. (1999). Bilingual Language Switching in Naming: Asymmetrical Costs of Language Selection. *Journal of Memory and Language*, 40(1), 25–40. <https://doi.org/10.1006/jmla.1998.2602>
- Mosca, M., & de Bot, K. (2017). Bilingual Language Switching: Production vs. Recognition. *Frontiers in Psychology*, 8, 934. <https://doi.org/10.3389/fpsyg.2017.00934>
- Norman, D. A., & Shallice, T. (1986). Attention to Action: Willed and Automatic Control of Behavior. B. R. J. Davidson, G. E. Schwartz, & D. Shapiro (Ed.), *Consciousness and Self-Regulation* (pp. 1–18). Springer US. https://doi.org/10.1007/978-1-4757-0629-1_1
- Orfanidou, E., & Sumner, P. (2005). Language switching and the effects of orthographic specificity and response repetition. *Memory & Cognition*, 33(2), 355–369. <https://doi.org/10.3758/BF03195323>

- Pavlenko, A. (2009). Conceptual Representation in the Bilingual Lexicon and Second Language Vocabulary Learning. In Nancy H, Hornberger and Colin Baker (Ed.), *Bilingual Education & Bilingualism* (pp. 125-160). Bangor University; Wales, UK
- Peeters, D., Runnqvist, E., Bertrand, D., & Grainger, J. (2014). Asymmetrical switch costs in bilingual language production induced by reading words. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 40(1), 284–292. <https://doi.org/10.1037/a0034060>
- Philipp, A. M., Gade, M., & Koch, I. (2007). Inhibitory processes in language switching: Evidence from switching language-defined response sets. *European Journal of Cognitive Psychology*, 19(3), 395–416. <https://doi.org/10.1080/09541440600758812>
- Reynolds, M. G., Schlöffel, S., & Peressotti, F. (2016). Asymmetric Switch Costs in Numeral Naming and Number Word Reading: Implications for Models of Bilingual Language Production. *Frontiers in Psychology*, 6. <https://doi.org/10.3389/fpsyg.2015.02011>
- Rogers, R. D., & Monsell, S. (1995). Costs of a predictable switch between simple cognitive tasks. *Journal of Experimental Psychology: General*, 124(2), 207–231. <https://doi.org/10.1037/0096-3445.124.2.207>
- Thomas, M. S. C., & Allport, A. (2000). Language Switching Costs in Bilingual Visual Word Recognition. *Journal of Memory and Language*, 43(1), 44–66. <https://doi.org/10.1006/jmla.1999.2700>
- van Heuven, W. J. B., Dijkstra, T., & Grainger, J. (1998). Orthographic Neighborhood Effects in Bilingual Word Recognition. *Journal of Memory and Language*, 39(3), 458–483. <https://doi.org/10.1006/jmla.1998.2584>
- von Studnitz, R. E., & Green, D. W. (1997). Lexical Decision and Language Switching. *International Journal of Bilingualism*, 1(1), 3–24. <https://doi.org/10.1177/136700699700100102>
- von Studnitz, R. E., & Green, D. W. (2002). The cost of switching language in a semantic categorization task. *Bilingualism: Language and Cognition*, 5(3), 241–251. <https://doi.org/10.1017/S1366728902003036>