The Relationship Between Bilingual Language Control and Language Dominance: An Empirical Study of Visual Language Perception

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Received August 14, 2023; Revised December 20, 2023; Accepted December 26, 2023

Abstract. Bilingual visual perception is an under-researched area in psycholinguistics and has yielded contradictory results regarding language control. Two theories were developed to account for visual language perception in bilinguals – the Inhibitory Control model (Green, 1986) and the Bilingual Interactive Activation model (Grainger and Dijkstra, 1992). Even though these two accounts have opposite predictions for asymmetrical language control (different for the bilingual's L1 and L2), most research up to date found evidence only for symmetrical control (Macizo et al., 2012; Orfanidou and Summer, 2005). This study aims to investigate the influence of language dominance on the visual language perception of bilinguals and providing evidence for the accountability of the models mentioned above. Thirty-one Hungarian-English bilinguals were recruited for this study. Participants' language dominance was operationalized by a complex score using the Bilingual Language Profile questionnaire (Birdsong et al., 2012). The bilingual lexical decision task was used to investigate the differences in the cognitive processing of the two languages. Target stimuli were carefully matched for their visual and linguistic features to eliminate the potential confounding influences on their perception during task performance. For unbalanced, L1 dominant bilinguals, asymmetrical, dominance-related switching cost was observed, indicating the relevance of the Inhibitory Control model. Faster L2 processing correlated with a richer history of L2-associated experiences and more balanced bilingualism. However, no correlations were found with the frequency of language use, language attitudes, and only weak correlations were observed with language proficiency. The current research proposes a methodological framework for measuring the influence of linguistic background on language switching cost that could ensure comparability between further studies.

Keywords: *bilingual, language control, switching cost, language background, visual perception, language dominance.*

Ревнюк Володимир, Батий Сільвія. Зв'язок між двомовним мовним контролем і мовним домінуванням: емпіричне дослідження візуального сприйняття мови.

Анотація. У статті здійснено теоретичне та практичне дослідження проблеми двомовного візуального сприйняття, яка недостатньо досліджена у психолінгвістиці та має суперечливі результати у контексті контролю мови. Проаналізовано дві теорії щодо візуального контролю мови двомовними людьми – модель інгібіторного контролю (Green, 1986) і модель двомовної інтерактивної активації (Grainger & Dijkstra, 1992). Хоча ці дві моделі мають протилежні

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East European Journal of Psycholinguistics, 10(2), 144–162. https://doi.org/10.29038/eejpl.2023.10.2.rev

прогнози стосовно асиметричного контролю мови, пізніші дослідження мають докази лише стосовно симетричного контролю (Macizo et al., 2012; Orfanidou & Summer, 2005). Метою статті є дослідження впливу мовного домінування на візуальне сприйняття мови двомовцями та доведення релевантності однієї із вищезгаданих моделей. Для практичного дослідження залучено угорсько-англійських двомовців. Діагностування мовного домінування учасників здійснено за допомогою опитувальника двомовного мовного профілю (Birdsong et al., 2012). Для дослідження відмінностей у когнітивній обробці мов використано завдання двомовного лексичного вибору. Щоб усунути потенційні додаткові впливи під час виконання завдання, використано цільові стимули, подібні за їхніми візуальними та лінгвістичними характеристиками. Виявлено, що для незбалансованих двомовців з домінуючою першою мовою, властива асиметрична, домінантно-направлена тривалість переключення, що доводить відповідність моделі інгібіторного контролю. Також виявлено, що триваліша історія другої мови і більш збалансована двомовність, корелює з її швидшою обробкою. Однак, не було виявлено жодних кореляцій із частотою використання мови, ставленням до мови і лише слабкі кореляції спостерігалися з рівнем володіння мовою. У дослідженні запропоновано методологічну основу для вимірювання впливу мовного досвіду на тривалість переключення мови, яка може бути використана для подальших досліджень.

Ключові слова: *двомовний, мовний контроль, тривалість переключення, мовний досвід, візуальне сприйняття, мовне домінування.*

Introduction

As a result of the multilingual turn (May, 2014), bi- and multilingualism is seen more as the norm rather than the exception in many domains. Consequently, understanding bilingual processing is imperative, and the topic has been attracting increased attention from scholars. In psycholinguistic and neurolinguistic research, it has been well established that bilingual language users' languages are always active in their cognitive system, even when using only one language. This parallel activation is present both in perception (e.g., de Bot & Schreuder, 1993; Grosjean, 1997; Hermans et al., 1998; Kroll & Stewart, 1994; Smith, 1997) and in production (Costa & Santesteban, 2004; de Bot and Bátyi, 2022; Kroll et al., 2006), and several factors have been suggested to influence the levels of language activation, such as language proficiency, the context of the acquisition, etc. (Heredia, 1997; Kroll et al., 2006; Pavlenko, 2004). Cross-linguistic influence (CLI) is constantly present in bilingual processing, and one would expect a high number of errors and a heavy cost associated with bilingualism due to these interferences; however, bilinguals are good at activating and selecting the intended language at will. This is possible because they developed a system of cognitive control that is used to negotiate the competition between their known languages (Grainger & Dijkstra, 1992; Green, 1986). Several models have been developed to account for this control, and the present study aims at testing the most influential ones in bilingual visual perception. Empirical research in this area is still scarce, and as Borragan et al. (2018) note, language inhibition during bilingual comprehension is less consistent and less understood than bilingual production.

The Interactive Activation (IA) model (McClelland & Rumelhart, 1981) was originally designed to explain the mechanism of language perception of monolinguals.

Later, the IA theory was extended into the Bilingual Interactive Activation (BIA) model (Dijkstra and van Heuven, 1998; Grainger & Dijkstra, 1992; van Heuven et al., 1998) to account for the language perception of bilinguals. According to the BIA, language control is achieved by developing and manipulating the 'language nodes' – an extra representational level in the mental lexicon that connects all representations belonging to one language. Activation or inhibition of these language nodes corresponds to the activation or inhibition of the entire vocabulary of one or another language. The variety of activities on the level of language nodes is called the 'language control mechanism', which is dynamic and varies among individuals as it depends on factors such as the frequency of language use and language proficiency.

An alternative account of language control in perception was an extension of the Inhibitory Control (IC) model (Green, 1986, 1998). According to this model, using a language requires the activation of the so-called 'cognitive task schema' (Norman & Shallice, 1986; Shallice, 1988). Similarly to language nodes, in this model, separate task schemas are developed for each of the known languages, and language control is achieved by activating and inhibiting task schemas. While originally being developed for language production, the IC model could also be a viable account of language perception (Green, 1998). With the help of language tags attached to each word in the bilingual mental lexicon, the language of the perceived words is identified, and the task schema activates the corresponding language while inhibiting the irrelevant language.

Generally, the two models are functionally equivalent (Green 1998) as they both presuppose the same combination of activation and inhibition processes in the core of language control. However, the predictions for differences in language control of the more dominant language (L1) and less dominant language (L2) are the opposite. According to the IC model, it is expected that more active representations from the dominant L1 would require stronger inhibition during language control while controlling the already less active L2 would be less effortful. Contrastingly, the BIA model indicates that a stronger inhibition is being applied to L2, while better proficiency and richer experience (higher activity) with the dominant language result in less effortful control. Recent bilingual language control studies attempted to validate one of these models by empirical research.

The bilingual lexical decision task was developed to measure the language inhibition *direction* predicted by the models mentioned above. In this task, participants are instructed to decide whether the presented strings of letters are words or non-words. Subsequent stimuli belong to the same language (*repetition trials*, e.g., L1–L1) or different languages (*switch trials*, e.g., L2–L1). The difference in reaction times between repetition and switch trials in one language is called the *switching cost*, and it reflects how much inhibition is being applied to L1 and L2. Higher switching cost for a particular language means that it has to be inhibited more when using another language and requires more effort to reactivate it. To date, only a few studies have addressed the question of switching cost in bilingual recognition. Research measuring switching cost in perception mainly reported symmetrical switching cost, namely similar strength of inhibition for bilinguals' known languages (Macizo et al., 2012; Orfanidou & Sumner, 2005; Thomas & Allport, 2000; von Studnitz & Green, 1997, 2002). The IC and BIA models both predict that such an outcome is possible, yet it does not specify which account corresponds to the real-life bilingual language processing.

What becomes clear from previous studies is that the research methodology had some limitations in terms of stimuli design and the exploration of the linguistic background of bilingual participants. Reynolds et al. (2016), in their thorough review of research methodology, highlighted inconsistencies with features of the used stimuli and their order of presentation, which were taken into account in the design of later studies (e. g. the present study). For example, Mosca and de Bot (2017) conducted a carefully controlled lexical decision experiment in which English-Dutch bilinguals were tested. They found that switching cost was asymmetrical and significantly higher for L1, which served as evidence for the relevance of the IC model.

The definition of participants' language dominance is another important factor in language control studies, which has not been receiving enough attention, considering its significance. For a long time, language control mechanism research only investigated the participants' relative proficiencies in the two languages (e. g. von Studnitz & Green, 1997). However, it has been argued that the cognitive organization of languages is heavily influenced by a variety of language-related background factors (e.g., Kaushanskaya et al., 2020; Luk & Bialystok, 2013) and some positive development in recognition of the importance of these factors has already been made (e.g., Mosca & de Bot, 2017). Nonetheless, the question of the influence of various linguistic backgrounds has not been studied explicitly yet.

To date, there is still no final consensus on what should be included in the definition of language dominance (Gollan et al., 2012; Kaushanskaya et al., 2020; Luk & Bialystok, 2013; Sheng et al., 2014). Some general agreement has been achieved on several components of linguistic background: age of language acquisition, exposure to the language at the time of inquiry, the length of exposure to languages and estimated levels of language proficiency. Considering these factors, standardized models of linguistic background measurement were developed in order to facilitate the comparability among studies. One of the first such systems widely used in bilingual research is the Language Experience and Proficiency Questionnaire (LEAP-Q) (Marian et al., 2007). It is designed to collect data on bilinguals' language competence, acquisition, and exposure with 18 questions of varying complexity. It gives a broad picture of individual experiences with their second language, with relevant data on L1, but in relation to language control studies, it has one but significant flaw. As was highlighted by Birdsong et al. (2012), the LEAP-Q was not designed to provide a measure of language dominance. The data collected via LEAP-Q provide a lot of important information on bilinguals' experiences with L2, but the measurement of language dominance is supposed to include an equal comparison of participants' L1 and L2.

Therefore, a new system has been explicitly designed to solve the aforementioned problem – the Bilingual Language Profile (BLP) questionnaire (Birdsong et al., 2012). Within this system, the authors organized a clear-cut separation of questions into four paired 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 have different numbers of questions, they are also given different weighting to ensure the same amount of influence on the final language dominance score. Additionally, avoiding the open-ended questions, the BLP questionnaire provides the most detailed and systematic approach, specifically designed to evaluate language dominance.

The Current Study

The main aim of this study is to investigate the mechanism of bilingual language control in perception within a new context of linguistically distant languages (Hungarian and English), with special attention to the evaluation and analysis of the relation with language dominance. Hungarian-English bilingual perception was previously studied regarding the homograph effect (Navracsics & Sáry, 2013; Ihász et al., 2023), and longer RTs were found for L1; however, RTs for non-homograph real words showed no difference, suggesting symmetric language control.

The main goal of the present study is to find out which model is more viable to account for the mechanism of language control.

The questions of the research are as follows:

RQ1. Is there a language switching cost during language control in perception for unbalanced bilinguals?
RQ2. Is switching cost asymmetry dominance-related (in line with the IC model) or dominance-reversed (in line with the BIA model)?
RQ3. What is the relation between language dominance and switching cost mechanism?

The hypotheses of the research are based on previous studies:

(1) It is expected that even in the case of linguistically distant languages, in which words could potentially initiate earlier and faster language recognition, switching cost should be present, as the language control mechanism seems to rely on additional extra-linguistic control mechanisms (Green, 1998; Orfanidou & Sumner, 2005; Thomas & Allport, 2000).
(2) Considering that asymmetrical switching cost for language perception is expected, in line with former studies (Jackson et al., 2004; Mosca & de Bot, 2017), they should be dominance-related, as predicted by the IC model.
(3) Language dominance that has an effect on various aspects of language use (e.g., Bullock et al., 2006; Filippi et al., 2012) should definitely influence language switching cost. Except for overall language dominance, which should have positive correlations with switching cost (the higher the dominance in one of the languages – the higher the switching cost), it is also expected that specific elements of linguistic background: language history, and language use, would have significant influence on the reaction times and switching cost.

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

Method

Thirty-one 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). The participants performed a lexical decision task and were administered the Bilingual Language Profile questionnaire (Birdsong et al. 2012). In the following, the instruments of the study will be described.

Instruments

A *bilingual lexical decision* experiment was used in this research, in which participants were asked to decide whether the presented string of letters was a word or a pseudoword. The list of stimuli consisted of 28 real words and 28 pseudowords. The list of real words included 14 English and 14 Hungarian words – all 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=.88, p>.05). Information about English word frequencies (M=7.85, SD=2.84) was derived from the British National Corpus (BNC) (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= .55) words were matched for orthographic length, ensuring no significant difference between the two languages (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, ó) were not used for words or pseudowords. The list of all stimuli used in the experiment is available in Appendix A.

All items were presented in the centre of a 15-inch computer screen set to 1,366 × 768 pixel resolution, and 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.

Bilingual Language Profile Questionnaire

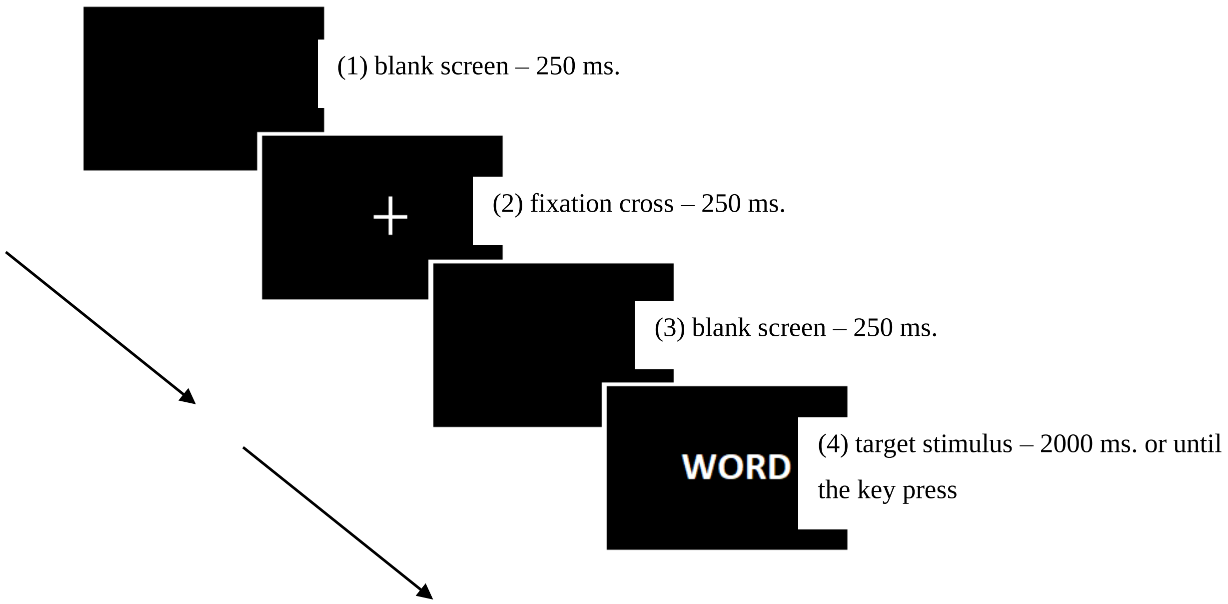
The BLP questionnaire consisting of 48 questions in total was used, inquiring about relevant personal information and linguistic background data of both languages on language history, language use, language proficiency, and language attitudes. In the BLP, numerical values are assigned to each element of background, and their sum constitutes the value of the total linguistic background for a language. Language dominance is calculated as the difference in total linguistic backgrounds of L1 and L2. Therefore, better language balance is associated with lower scores of language dominance, and stronger language imbalance would be associated with higher language dominance scores. Every set of bilingual linguistic backgrounds was individually weighted so, for example, the influence of language use cannot outweigh the influence of language performance (for more details, see https://sites.la.utexas.edu/bilingual/).

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 a main session of the lexical decision tasks. All participants were instructed to react as quickly and correctly as possible.

In the lexical decision task, the reaction times were measured as the time between the display of the stimulus on the screen and the pressing of one of the response buttons. As can be seen in 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. One-third 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 to the task.

Only one item was displayed at the time. To exclude the 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 one switch trial at the end. The whole test consisted of 252 repetition trials and 84 switch trials.

There were two 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 three 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 (Knight – Statue – Ball in Hungarian)).

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

• With the first three 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 (Knight – Statue – Ball in Hungarian));

• With the first three 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).

In order to counterbalance and limit the possible priming effect, for full-word chunks and two groups of partial-word chunks, each word was seen only once in each chunk position. 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 following five trials, and the same type of chunk never occurred more than twice in a row. Because of these constraints, the order of the trials was unpredictable.

Four lists of the tasks were created for testing. In order to perform the appropriate comparison of the switching 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.

Result Analysis Procedure

The data for the reaction times analysis was organized as follows. Each participant has finished one trial block of 336 trials, but the 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 two values each:

- Language of the stimulus: L1 or L2 (language of the original word for pseudoword stimuli);
- Type of the stimulus: Word or Pseudoword;
- Trial type: Repetition (e.g., L1 word – L1 pseudoword) or Switch (e.g., L1 word – L2 pseudoword) (relates only to the *language* of the previous trial, not the type);
- Response Priming: Response Repetition (e.g., L1 word – L2 word) or Response Change (e.g., L1 word – L1 pseudoword) (relates only to the *type* of the previous trial, not the language).

Each trial had a condition that was a combination of different values of 4 variables (e.g., L1-Word-Repetition- Response Repetition trial). The target conditions of trials for analysis included real word trials primed by real words of both languages and both trial types. Reaction times and switching cost were compared using t-test analysis.

In the correlation analysis, reaction times and switching cost for both languages were included as dependent variables, while the independent variables were: proficiency, use, history, and attitudes for each language; total linguistic background for each language; language dominance score (difference in total linguistic backgrounds for the two languages); differences in proficiency, use, history and attitudes for the two languages (for in-depth analysis of the influence of language dominance).

Results

BLP Questionnaire Analysis

This section presents the participants' language background in the L1 and L2 as measured by the BLP. As shown in Table 1, on average, participants were L1-dominant bilinguals, as their Hungarian score was significantly higher than the English score in all domains.

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<.001
Language Use	M=34.42	SD=6.85	M=19.90	SD=6.97	p<.001

Language Proficiency	M=52.06	SD=4.83	M=44.81	SD=7.55	p<.001
Language Attitude	M=46.86	SD=12.29	M=38.22	SD=11.31	p<.01
Total Language Background	M=178.93	SD=20.18	M=116.47	SD=22.94	p<.001

Two participants had negative BLP language dominance values, which meant that they were L2 dominant at the moment of testing. However their language balance value was under 30 points, which indicates that they are relatively balanced bilinguals. In total, 6 participants could be considered relatively balanced bilinguals.

Lexical Decision Accuracy Analysis

This section presents the accuracy of the participant's performance in the lexical decision task. On average, participants' mean accuracy was 93.95%.

Within the lexical decision task paradigm, to answer the research questions, we need to analyze the difference in the accuracy of reactions to stimuli in language repetition and language switch conditions, which were real words of one language, primed by other real words. The analysis revealed that the difference in the accuracy of reactions between repetition and switch trials was significant for both L1 ($t(30) = 4.79$, $p<.001$) and L2 ($t(30) = 5$, $p<.001$) words (Table 2), meaning that participants reacted more accurately to repetition trials in both languages.

Table 2
Participants' Accuracy Rates (Words Primed by Words, Within Language Comparison)

	M	SD	Significance
L1 repetition	99.88%	.64	p<.001
L1 switch	94.8%	5.78	
L2 repetition	95.22%	0	p<.001
L2 switch	91.94%	8.99	

Lexical Decision Reaction Times Analysis

The same pairs of stimuli were involved in the reaction times analysis as in the accuracy analysis. The analysis of the reaction times to word trials in response repetition condition revealed that the difference between language repetition and language switch trials was significant only for L1 (t (30) = 4.68, p<.001) but not for L2 (p>.05) words (Table 3). It means that while reactions to L1 words in the language repetition condition were significantly faster than in the language switch condition, reactions to the same two types of trials in L2 were similarly fast.

Table 3
Participants' Reaction Times (Words Primed by Words, Within Language Comparison)

Compared conditions	M	SD	Significance
L1 repetition	512.95	59.15	p<.001
L1 switch	557.4	79.87	
L2 repetition	588.23	62.3	p>.05
L2 switch	573.71	83.62	

Switching Cost Analysis

Previously, it was found that the switching cost was significant only for one language, but it is still unclear whether the switching cost for two languages differed significantly from each other. In order to investigate that, we have calculated the switching cost as the difference between reaction times in language switch and repetition conditions (Table 4). Additionally, if the average reaction times in the switch condition were faster than for the repetition condition, then the switching cost for such participants would be negative. On average, participants' switching cost for L1 words in the response repetition condition was significantly higher (M=44.45) than for L2 words (M= -14.52) in the response repetition condition (t (30) = 5.18, p<.001). This indicates that asymmetrical, dominance-related switching cost, i.e., it takes more time to reactivate the dominant L1.

Table 4
Participants' Mean Language Switching Cost

	L1	L2
Language repetition	512.95	588.23
Language switch	557.4	573.71
Switching cost	44.45***	-14.52

Note: p< .001***, p< .01**, p< .05*, p< .05

Correlations of RT with Linguistic Background

In order to find out which linguistic background component is associated with language control, correlation analyses were conducted between the BLP questionnaire data and the lexical decision task data (reaction times and switching cost included). The analyses revealed significant correlations with L2 language history. Richer L2 language history was associated with reduced RTs to L1 words in language repetition condition (r (29) = -.37, p<.05), L2 words in language repetition condition (r (29) = -.40, p<.05) and L2 words in language switch condition (r (29) = -.46, p<.01) (Table 5). No other significant correlations were observed.

Table 5
Correlations of RTs with Language Background

	Language history		Language use		Language proficiency		Language attitudes	
	L1	L2	L1	L2	L1	L2	L1	L2
L1 repetition	-.3	-.37*	.01	-.04	-.15	-.12	.04	.09
L1 switch	-.11	-.2	.05	-.05	-.07	-.21	-.03	.01
L2 repetition	.05	-.4*	.23	-.22	.18	-.28	.33	-.13
L2 switch	-.05	-.46**	.26	-.26	.07	-.31	.21	-.18
L1 switching cost	.17	.11	.07	-.02	.06	-.18	-.09	-.09
L2 switching cost	-.16	-.29	.16	-.16	-.11	-.17	-.06	-.15

Note: p< .001***, p< .01**, p< .05*, p< .05

Further analysis revealed that a *richer* (with higher associated values) L2 total language background was associated with reduced RTs to L2 words in the language switch condition (r (29) = -.4, p<.01). Additionally, it was found that increased L1 language dominance was associated with slower RTs to L2 words in the language repetition condition (r (29) = .41, p<.05) and L2 words in the language switch condition (r (29) = .38, p<.05) (Table 6).

Table 6
Correlations of Reaction Times with Language Background and Dominance

	Total language Background		Language Dominance
	L1	L2	
L1 Repetition	-.09	-.11	.02

L1 Switch	-.05	-.13	.06
L2 Repetition	.33	-.34	.41*
L2 Switch	.22	-.4*	.38*
L1 Switching cost	.03	-.08	.07
L2 Switching cost	-.05	-.26	.14

Note: p< .001***, p< .01**, p< .05*, p< .05

In the analysis of correlations between the task performance and differences in linguistic backgrounds of the two languages, we found that increased imbalance in language history between L1 and L2 led to slower RTs to L2 words in language repetition condition (r (29) = .38, p<.05) and L2 words in language switch condition (r (29) = .36, p<.05). However, it was additionally found that unlike with separate values of L1 and L2 proficiency, the increased imbalance in language proficiency had a significant positive correlation (led to slower reactions) with reaction times to L2 words in language repetition condition (r (29) = .38, p<.05) (Table 7).

Table 7
Correlations of Reaction Times with Differences in Language History, Use, Proficiency, and Attitudes

	Language history difference	Language use difference	Language proficiency difference	Language attitudes difference
L1 Repetition	.11	.03	.02	-.03
L1 Switch	.09	.05	.16	-.03
L2 Repetition	.38*	.23	.38*	.31
L2 Switch	.36*	.26	.33	.26
L1 Switching cost	.02	.05	.21	-.01
L2 Switching cost	.14	.16	.09	.05

Note: p< .001***, p< .01**, p< .05*, p< .05)

Discussion and Conclusions

Most of the earlier research on language control in bilingual visual language perception reported symmetrical switching cost for the two languages, meaning that they did not differ significantly (Orfanidou & Sumner, 2005; Thomas & Allport, 2000; von Studnitz & Green, 1997). While these studies were crucial contributions to the understanding of the mechanism of language control, they did not specify which theoretical model, the IC or BIA, is a more viable account of language control (Mosca & de Bot, 2017; Reynolds et al., 2016). According to the BIA model, the inhibition of the less active L2 is stronger than the inhibition of the more active L1, while the opposite is predicted by the IC model. Both models predict the possibility for symmetrical switching cost, but only for balanced bilinguals, with similar activity levels for both languages that they know. The experiments reporting symmetrical switching cost indicated using the sample of unbalanced bilinguals, meaning that their findings challenge the validity of both models simultaneously. Language-specific features of the stimuli as an explanation for these inconsistencies were reported to have insignificant influence on task performance (Orfanidou & Sumner, 2005; Reynolds et al., 2016).

Only two research reported asymmetrical switching cost in perceptions: the study by Jackson et al. (2004) that used a different perception task, and the study by Mosca and de Bot (2017) that included a more frequently used lexical decision task. The uniqueness of the latter study was that participants' dominance in L1 was reported not only for language proficiency but also for length of language acquisition and daily language use. Also, the study included language non-specific stimuli, matched for their length and frequency of use in languages, with carefully controlled order of stimuli presentation. With such minimalized effects of potential confounding variables, asymmetrical, dominance-related switching cost was observed, validating the IC theory of language control.

This study aimed at investigating bilingual language control system in visual recognition in a different language context with careful methodological organization. More precisely, the goal was to find out which language control model, the Bilingual Interactive Activation or Inhibitory Control, is more viable to account for the mechanism of language control. Since the predictions of both models heavily rely on the presence of the dominant language, this study included language dominance as a main factor. In order to answer the three research questions of the study ((1) whether there is a switching cost during language control in perception for unbalanced bilinguals; (2) whether switching cost asymmetry is dominance-related (in line with IC model) or dominance-reversed (in line with BIA model); and (3) what is the relationship between language dominance and switching cost mechanism)) 31 Hungarian-English bilinguals were recruited. The Bilingual Language Profile questionnaire was adapted, and a bilingual lexical decision task was developed to gather the relevant data.

According to the results, the RT difference between repetition and switch trials was significant only for L1 words but not for L2 – i.e., significant switching cost was present only for L1, which should be considered a partial confirmation of the first hypothesis. The comparison of switching cost revealed that they differed significantly, which means that asymmetrical switching cost was observed. The observed asymmetrical switching cost was higher for the more dominant language of the participants. Even though the average reaction times to L1 words were faster, the difference in the reaction times in language repetition and switch conditions for L1 were higher than for L2. The obtained results replicate the findings by Mosca and de Bot (2017), validating the IC model of language control in visual language perception, in line with our second hypothesis.

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, which is the novelty of this research. As was mentioned before, mostly unbalanced, L1-dominant bilinguals participated in this study. Their L1 (Hungarian) linguistic background was less diverse than their L2 (English). It was hypothesized that language dominance, daily language use, language learning, and language history are associated with language control mechanism – i.e., the mentioned components of linguistic background should have significant correlations with LDT task performance. The hypothesis was partially confirmed. The reactions to L2 words were faster among people who studied and used L2 for longer. The reactions to L2 words were faster among people who are more balanced bilinguals. No correlations were observed with language attitudes and language use, which partially contradicts our hypothesis, as language use was expected to correlate with LDT performance. The absence of any significant correlations means that the performance of participants who used L2 more and less often was quite similar, as well as the performance of participants with better and worse attitudes to L2.

Neither L1 nor L2 language proficiencies had any significant correlations with LDT performance, but we have found a significant, positive correlation between language proficiency difference and RTs to L2 words in language repetition condition. Our finding means that bilinguals with more balanced language proficiencies tended to perform faster in LDT (in the case of L2 word stimuli). This finding once again signifies that analyses of bilingualism have to separately consider the differences between the L1 and L2 experiences. A more detailed investigation of language dominance might provide further insights into the investigation of language control mechanism.

In general, the results of this study show stronger inhibition of bilinguals' more dominant language in accordance with the Inhibitory Control model (Green, 1986, 1998). The novelty of the current study lies in the careful methodological considerations that helped to answer the research question promptly. First of all, shortcomings of previous studies have been addressed when designing the stimuli and the procedure of the lexical decision task. Secondly, special attention was paid to the detailed exploration of participants' linguistic backgrounds by using the BLP. The revised approach evaluating of participants' language dominance and linguistic backgrounds was operationalized as a continuous and not as a dichotomous variable that would have obscured crucial elements of bilingualism. Such an approach was adopted for the first time in language control studies. It helped us explain the obtained results, i.e., longer and richer L2 history and more balanced language proficiency lead to faster reactions. Consequently, the current research proposes a methodological framework for measuring the influence of linguistic backgrounds on language switching cost.

Disclosure Statement

No potential conflict of interest was reported by the authors.

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Appendix

The list of the used stimuli:

English Words: CANOE, CARROT, RAZOR, CANNON, ONION, CANDLE, BARREL, TOWEL, RULER, HAMMER, ARROW, PENCIL, BASKET, ORANGE.

Hungarian Words: SAROK, GALAMB, LOVAG, HARANG, KOCKA, MAJOM, GOMBA, MEDVE, KALAP, ALMA, LABDA, RUHA, MACSKA, SZOBOR.
(Translations of the Hungarian words in the corresponding order: Corner/heel, pigeon, knight, bell, cube, monkey, mushroom, bear, hat, apple, ball, clothes, cat, sculpture)

English Pseudowords: TAMBER, ARRAX, RAKAR, BARRIT, BANBLE, CAPEA, URAIRS, UNEIN, CANGIN, MENVIL, BARRAT, ROMER, BAMRET, TAMEL

Hungarian Pseudowords: MOROK, LOCSKA, GOMAR, LOTUR, GAZONG, KALUG, MAJAT, TOHA, PILLVE, TARANG, PURDA, FURKA, SZOTOL, ALKA