Language context flexibly modulates language control mechanisms.

Kalinka Timmer[1, †, *], Agata Wolna[2, 3, 4, *], Jakub Szewczyk[4], Zofia Wodniecka[4, †]

[1] Faculty of Psychology, University of Warsaw, Warsaw, Poland

[2] Department of Brain and Cognitive Sciences, MIT, Cambridge, MA, United States

[3] McGovern Institute for Brain Research, MIT, Cambridge, MA, United States

[4] Psychology of Language and Bilingualism Lab, Jagiellonian University, Krakow, Poland

E-mails: k.timmer@uw.edu.pl, awolna@mit.edu, jakub.szewczyk@gmail.com, and zofia.wodniecka@uj.edu.pl

† Corresponding authors

* First authors

Competing interests: The author(s) declare none.

Data availability: All data and scripts necessary for reproducing the analyses and plots in this paper are available at: https://osf.io/84stp/?view_only=24ded32ece214ddda02b291b90ebb297.

Upon acceptance, the repository will be made publicly available.

Acknowledgements: The National Science Center (Narodowe Centrum Nauki) funded the research with the SONATA BIS grant (2015/18/E/HS6/00428) and OPUS grant (2017/27/B/HS6/00959), awarded to Zofia Wodniecka. The National Science Centre (Narodowe Centrum Nauki) supported Kalinka Timmer with an OPUS grant (2022/45/B/HS6/01931). We thank Kinga Masłowska for her help with data decoding.

Abstract

Does a bilingual's language environment, whether L1- or L2-dominant, modulate their use of language control mechanisms in speech production? The language-switching task (LST) typically assesses two indices of language control: asymmetric switch costs, where switching into L1 incurs greater costs than switching into L2, and reversed language dominance, where L1 becomes slower than L2. We ask if these measures are affected by the language context a bilingual is in and whether the relative balance between languages is sustained after mixed language use. Polish-English unbalanced bilinguals performed the LST in L1- and L2-dominant contexts. We found that language context modulated the magnitude of language control indices. In the L1-dominant context, we replicated effects typical for unbalanced bilinguals: asymmetric switch costs and reversed language dominance. However, in the L2-dominant context, the asymmetry of switch costs was reversed, and the reversed dominance effect decreased. Furthermore, to measure if language dominance reversed from their usual dominance and whether the language context modulations were sustained after leaving, participants named pictures in pure language blocks before (pre-LST) and after (post-LST) LST. Initially, unbalanced bilinguals exhibited a typical L1 dominance (i.e., faster L1 than L2 naming) which reversed during LST and remained reversed post-LST. The modulations of bilingual language control suggest that immediate language context flexibly shapes control mechanisms for effective production, with adjustments persisting beyond the L1- or L2-dominant context. Thus, mechanisms of control are highly adaptive to contextual demands rather than being solely determined by the language proficiency or other fixed speaker traits.

Introduction

Due to increasing globalization, many bilinguals who have learned one native language at home and a second language later in life reside in bilingual environments. While living in the country of origin, other languages, such as English as a lingua franca, are also present in the environment through entertainment, advertising, social media, international business, etc. Consequently, even if bilinguals mainly use their dominant language and reside in a dominant L1 context, they often change their language environment to a non-dominant L2 context. For example, when going on holidays, having international business meetings/university classes, or watching a movie in a foreign language, the second language of a bilingual becomes temporarily dominant in their environment. An increasing body of research has shown that bilinguals flexibly adapt their domain-general cognitive system depending on the language environment they are in (for a review see Wodniecka et al., 2020). Surprisingly, most studies focused on how the current language environment affects domain-general cognitive mechanisms (e.g., Jiao et al., 2019, 2020; Kałamała et al., 2022; Timmer, Costa, et al., 2021; Timmer, Wodniecka, et al., 2021; Wu & Thierry, 2013), rather than language control mechanisms. To our knowledge, only two studies have examined the impact of the predominant language context (L1 or L2) on mechanisms of language regulation during bilingual language contexts with two languages intermixed (Olson, 2016; Timmer, Christoffels, et al., 2018).To address this gap, the present study aimed to better understand how bilingual language control (BLC) mechanisms are impacted by a bilingual speaker's immediate linguistic context (i.e., predominantly L1 or L2 context) and to test how long-lasting this impact is (i.e., whether it lingers after the context has changed).

Within the last decade, researchers have investigated how short-term changes in immediate language use of a bilingual individual affect cognitive control mechanisms (for a review, see Wodniecka et al., 2020). Most studies indicated that general cognitive control is enhanced in a bilingual context (which involves language switching) compared to a monolingual context (in which participants only use one language). This has been shown in a wide variety of mechanisms, such as interference control (Wu & Thierry, 2013; Yang et al., 2018), monitoring (Jiao et al., 2019; Timmer, Costa, et al., 2021; Timmer, Wodniecka, et al., 2021), and reactive control (Timmer et al., 2019). Interestingly, similar effects can be triggered even by short-term exposure to different language contexts. Kałamała et al. (2022) demonstrated that neural efficiency increased not only after immersion in a bilingual context but also after an exclusively second language context, while Han et al. (2023) found reduced interference control after listening to a story in a bilingual context with languages alternated at the sentence level but not when languages are intermixed at grammatical and lexical levels (i.e., dense code-switching context). The available evidence suggests that short-term language contexts can modulate the ability to resolve non-linguistic conflict.

If language context flexibly modulates the domain-general cognitive mechanisms, it should also modulate indices of bilingual language control (BLC) mechanisms as they should directly reflect adjustments needed to adapt to the current environmental (i.e., context) demands. Two most commonly used task measures that have been considered as indices of language control are the reversed language dominance effect (sometimes also referred to as global slowing of L1), considered an index of global control, and the switch cost, which is a form of local control (Bobb & Wodniecka, 2013; Green, 1998). Unbalanced bilinguals who are more proficient in one language than in the other (e.g., Christoffels et al., 2007; Costa & Santesteban, 2004; Verhoef et al., 2009) typically show faster naming latencies in L1 than in L2 when only one language is present in an environment (75% of studies show this dominant language advantage in a meta-analysis by Goldrick & Gollan, 2023). However, when the same bilinguals are immersed in a bilingual context, requiring frequent switches between languages, their language dominance with slower naming latencies in L1 than in L2 (78% of studies in the meta-analysis by Goldrick & Gollan, 2023).According to Goldrick & Gollan - can best be explained by the inhibition account, which predicts that the more dominant language needs to be inhibited to enable production in the weaker language.[1] In line with this account, Christoffels et al. (2007) showed that the reversed language dominance effect, occurring in a bilingual context, sustains afterward when the bilingual has left the bilingual context and is in a pure language context. They argued that this finding was due to bilinguals' sustained suppression of the dominant language more strongly than the non-dominant one.

Next to the reverse language dominance, another index of language control frequently studied in bilingual speech production contexts is the switch cost. This effect refers to slower response latencies when switching to a new language compared to staying in the same language (Calabria et al., 2011; Meuter & Allport, 1999; Philipp et al., 2007; Timmer, Calabria, et al.,

[1] Previously, it has been suggested that both inhibition (Green, 1998) and threshold/activation accounts (Costa et al., 2006; Philipp et al., 2007) could potentially account for the revered language dominance. Goldrick and Gollan (2023) recently argued that the increased activation accounts is at odds with the finding that outside of mixing contexts, L2 speakers are slower in blocks of pure L2 naming. According to Gollan & Goldrick, one of the findings that makes this explanation unlikely is that if speakers can increase activation of their weaker language at will, then they should not struggle when producing their nondominant language even in pure-language contexts. Because they often do, this – according to Goldrick and Gollan – suggests that mechanisms other than just the increased activation of nondominant language are at play and responsible for the reversal of language dominance during switching and therefore inhibition seems the most plausible candidate for such a mechanism.

2018; Timmer et al., 2017b). The magnitude of the switch to L1 and L2 has been suggested to be modulated by a bilingual's language balance, specifically how proficient they were in their L2 (compared to the L1). Unbalanced bilinguals, with a lower L2 proficiency, showed a larger switch cost to L1 than L2 (i.e., asymmetric switch cost), while balanced bilinguals, equally proficient in their languages, show similar switch costs to L1 and L2 (i.e., symmetric switch cost) (Costa et al., 2006). However, unlike in the case of the reverse dominance effect, the switch cost patterns (i.e., symmetric or asymmetric) have not been consistently found throughout studies (Gade et al., 2021b) and have been explained by both the inhibition (Green, 1998) and threshold account (Costa et al., 2006) or persisting activation account (Philipp et al., 2007). The inhibition account (Green, 1998) posits that increased inhibition of the dominant language is necessary when naming in the non-dominant language. This inhibition carries over to the subsequent trial, leading to a larger switch cost when returning to the dominant language. In contrast, naming in the dominant language requires less inhibition of the non-dominant language, resulting in a smaller cost when switching back. Alternatively, activation-based accounts propose that the non-dominant language requires stronger activation to compete with the dominant language (e.g., Philipp et al., 2007). Consequently, residual activation from the non-dominant language carries over, making it more difficult to re-engage the dominant language, leading to larger switch costs.

We propose that factors other than language proficiency may impact the language switch cost that the immediate language context may be a key player. Language context can be considered a factor within *language mode* used in psycho-social and linguistic research (Grosjean, 2001) – as revealed in two earlier studies (Timmer, Christoffels, et al., 2018; Timmer et al., 2017a). Language mode refers to the social and linguistic environment of a speaker, such as the form and content of a message, which in turn affect the activation level of each language (Green & Abutalebi, 2013; Grosjean, 2001), and has been shown to modulate bilingual language control (Timmer et al., 2017a). We focus on language context, one of the factors of *language mode*, which refers to the languages individuals use in a bilingual's direct surroundings at a specific moment in time (Timmer et al., 2017a). It emphasizes the relative presence of each language within a specific environment (Olson, 2016; Timmer, Christoffels, et al., 2018). In a study by Timmer and colleagues (2019), the effect of context was tested on language- and non-linguistic task switching. The language switch cost was reduced following a bilingual language context (i.e., naming pictures in two languages) compared to a monolingual language context (i.e., naming pictures in a single language). Moreover, this study also showed that domain-general task switch costs diminished after a bilingual, compared to a monolingual context. The reduction of the engagement of cognitive control in speech production is also supported by other studies that focused on the impact of monolingual versus bilingual language contexts on domain-general cognitive mechanisms (Timmer, Wodniecka, et al., 2021; Wu & Thierry, 2013). Thus, existing empirical evidence suggests that language context can modulate the magnitude of language switch costs.

While bilinguals can be in purely monolingual or bilingual situations, their bilingual environment can also be dominantly in one language, with the other only present occasionally. Is the context effect only triggered by a bilingual compared to single language exposure, or is it also sensitive to the proportion of languages present in a bilingual environment? The two previous studies mentioned earlier (i.e., Olson, 2016; Timmer, Christoffels, et al., 2018) have examined the impact of being predominantly in the L1 or L2 context on bilingual language regulation in mixed language contexts . Both provided evidence that L1- vs. L2-dominant language context modulates BLC indices. However, in Olsen's (2016) study, language context (the proportion of L1 to L2 trials) was confounded with the proportion of switch/repeat trials, complicating the interpretation of the results as driven solely by the language context. This limitation has been addressed by a study by Timmer and colleagues (2018), which revealed that the Dutch-English unbalanced bilinguals placed in a predominantly L1 context show a typical pattern of language control engagement for this population (Christoffels et al., 2007): a reversed language dominance and symmetric switch costs. Importantly, bilinguals placed in a predominantly L2 context showed a different pattern of indices related to language control: equal language dominance (L1 = L2 naming speed, thus no reversed dominance anymore) and asymmetric switching costs with larger costs of switching to L2 than L1. Interestingly, the reversed language dominance increased the longer participants were in the L1 context. In the L2 context, L1 and L2 were equalized, and over time, L1 became faster than L2, reversing the control pattern compared to the L1 context.

The present study investigated whether language control mechanisms remain stable within an individual or flexibly adjust to environmental demands and, if so, how long-lasting these adaptations are. We first ask whether unbalanced Polish-English bilinguals reveal a typical L1 dominance before engaging in the LST. Language dominance was measured with naming speed in pure L1 and L2 blocks preceding the LST. Second, we asked whether immediate language context impacts the mode in which bilingual language control operates in a situation that requires frequent switching between languages. To this aim, we measured how L1- versus L2-dominant context modulated indices of BLC: reversed language dominance and (a)symmetry of switch costs in LST with naming mainly in L1 or L2. Third, we investigated how long the context-induced modulation of cognitive control remains. More specifically, we tested whether changes in the reversed language dominance measure, which can also be measured when only one language is present in a block, continued after bilinguals had left the bilingual contexts.

We predicted that our unbalanced Polish-English bilinguals would reverse their typical language dominance (L1 faster than L2) during bilingual language contexts.

Crucially, based on the findings by Timmer et al. (2018), we predicted that during the bilingual contexts, the L1- vs. L2-dominant contexts would further modulate reversed language dominance and the asymmetric switch costs. We predicted a reversed language dominance effect and asymmetric switch costs (L1 > L2) in the L1-dominant context compared to the absence of reversed language dominance and reversed asymmetric switch costs (L1 < L2) in the L2-dominant context. Notably, unlike Timmer et al. (2018), we manipulated language context within the same participants instead of between participants. Furthermore, we predicted that differences in this global measure (i.e., reversed language dominance) in diverse, bilingual contexts with a different proportion of L1 and L2 present are also sustained after leaving the environment. We also explore the dynamic adaptations throughout the LST contexts as Timmer et al. (2018) revealed the reversed language dominance increased when longer present in the L1-dominant context, albeit not for the L2-dominant context. This would suggest that bilinguals are not only impacted by having two languages present in their environment but that subtle differences in the relative presence between the two languages also modulate BLC mechanisms, which are sustained for some time. Furthermore, we carefully consider how global control (e.g., reversed language dominance) and local control (e.g., asymmetric switch costs) relate to each other and provide novel ways of exploring the complex pattern of results and how they relate to inhibition and activation frameworks of bilingual language control.

Methods

Participants

Ninety Polish-English bilinguals took part in the study. Two participants resigned after the first session and data from an additional six were unusable due to missing voice recordings or other procedural errors. Five participants were excluded based on their low accuracy (see *Data analysis* for details), yielding a final sample of seventy-seven subjects (60 females, 11 males, 6 non-binary, age M=22.52, SD=3.40, range 18-33). All participants were native Polish speakers who learned English as their second language. To participate in the experiment, they had to declare intermediate to high proficiency in English and obtain at least 18/25 points on the General English Test by Cambridge Assessment (mean score = 22.45, SD = 1.99). During the experiment, English proficiency was additionally assessed using LexTale (mean score = 75.91%, SD = 11.39%; Lemhöfer & Broersma, 2012). In addition, participants completed a questionnaire in which they rated their proficiency for all languages they indicated to know. They rated their proficiency in reading, writing, listening, speaking, and the level of a foreign accent. They also gave information on their daily use of all languages and the age at which they started to learn each. Detailed information on the participants' proficiency, age of acquisition, and daily use of languages can be found in Table 1. All participants gave written consent to participate in the study. The Ethics Committee of the XXX approved the study concerning experimental studies with human subjects.

Table 1. Language experience of the study's participants. Information on self-rated proficiency, language learning, and daily use of languages is given for all languages participants declared to know. L1 always refers to Polish and L2 to English. L3 and L4 were various languages (incl. German, French, Italian, Spanish, Russian, Czech, Japanese, Korean, Norwegian, Latin, and Esperanto). Not all the participants reported knowing an L3 or L4 – in those cases, the means are reported for the number of subjects that have declared knowing an L3 and/or L4.

Language	**L1** (Polish)	**L2** (English)	**L3** (various)	**L4** (various)
N	77	77	67	32
Self-rated proficiency (1-10)				
Reading	9.79	8.31	4.69	3.87
Listening	9.74	7.90	3.85	3.55
Writing	9.49	7.38	3.29	2.39
Speaking	9.68	7.23	3.74	3.19
Accent	9.57	5.69	3.45	3.65
Language learning				
Age of acquisition onset of learning	0.00	5.81	14.27	16.50
Age of acquisition: onset of using	3.53	9.36	15.42	17.50
Daily use of languages				
Passive	57.88%	37.99%	3.45%	2.72%
Active	79.82%	18.38%	1.70%	0.78%

Procedure and design

The overview of the experimental design is presented in Figure 1A. All participants completed two sessions of language naming corresponding to a different language context in each session, L1- and L2-dominant sessions. Each session started with a pure language task (pre-LST) in which all the pictures were to be named in one language (a different language in each session with the order counterbalanced between subjects), followed by the language switching task (LST), in which participants named pictures in two languages. LST consisted of eight blocks. Following LST, participants completed a pure language task (post-LST) in two blocks – in L1 followed by L2 or L2 followed by L1. After pre-LST and each block within LST and post-LST, participants could take a short break.

The language context was manipulated in two ways: (1) by the filler trials in the LST and (2) by the language of naming preceding the LST (pre-LST). The filler trials in LST were used to introduce the L1- or L2-dominant context in LST. This was done by having six single-language filler trials named in the context-congruent language followed by 12 experimental trials (repeat and switch) equally divided between both languages. This sequence was repeated four times within a block. Thus, two-thirds of trials in each LST context consisted of naming in one language. Second, the language of naming in pre-LST block was always synchronized with the language of the filler language trials within LST blocks. The order of languages in the post-LST blocks was counterbalanced between participants, but the order was kept the same for each participant in both sessions. An overview of the language switching block is presented in Figures 1B and 1C.

For each picture, in all picture naming tasks, the language of naming was indicated by the color of a frame around the picture – red or blue – which appeared on the screen simultaneously with the picture. The assignment of color to language was counterbalanced across participants. In each trial, a fixation cross was presented (jittered between 800-7800ms with a mean of 2861ms), followed by the presentation of the picture and the frame, which appeared simultaneously on the screen and was displayed for 2,500ms.

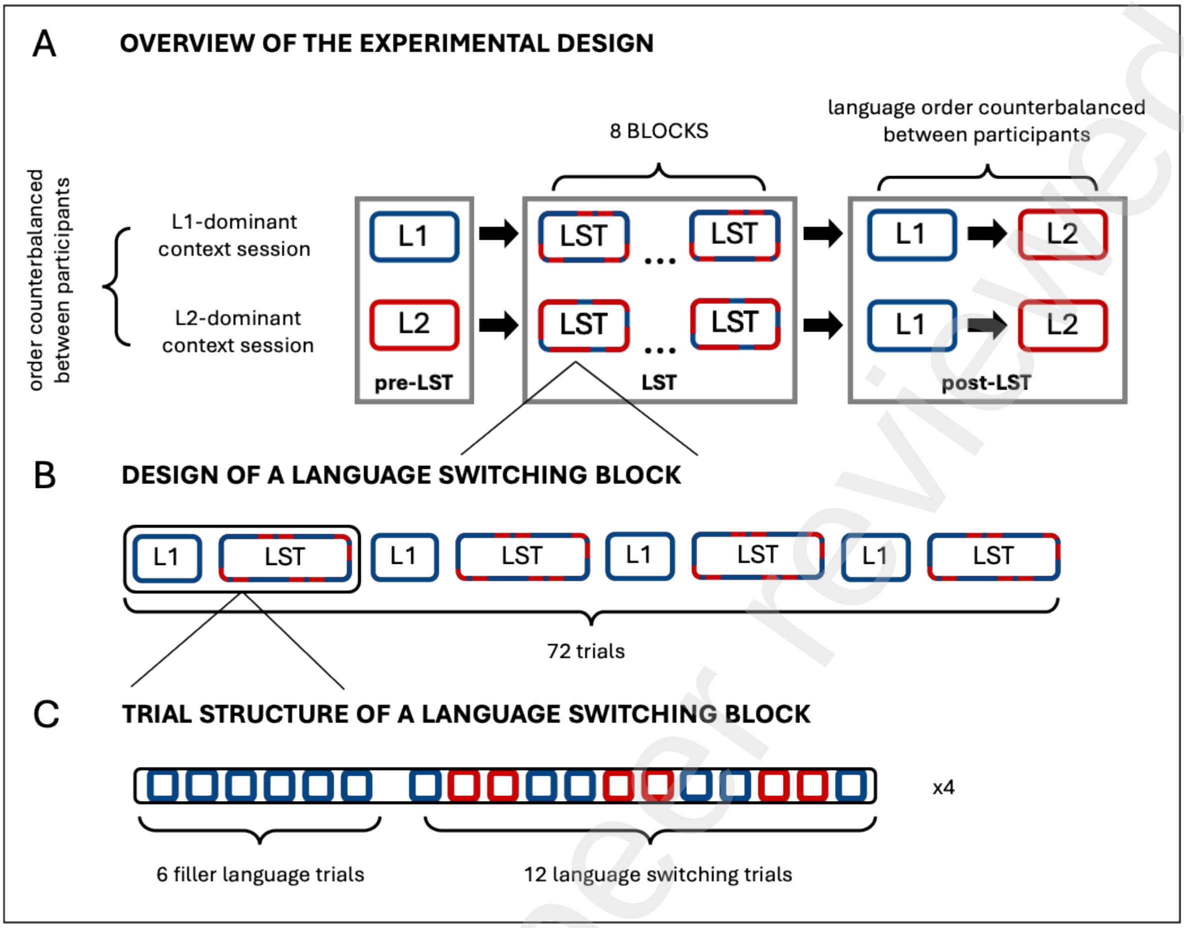


Figure 1. Summary of the experimental design. The top panel (A) presents the overview of the entire experimental design over the two experimental sessions, where each box corresponds to one picture naming block. The middle panel (B) presents a design of an example language-switching block in the L1-dominant context where each box corresponds to a series of filler trials (n=6) or language-switching trials (n=12). The bottom panel (C) presents the trial-by-trial structure of a series of filler trials followed by the switching trials (each color corresponds to a different language).

Materials

Each picture naming task – pre-LST, LST, and post-LST – consisted of 72 pictures. For pre-LST, 144 pictures from the MultiPic database (Duñabeitia et al., 2018) were divided into two sets of 72 items matched on name agreement in Polish, lexical frequency, and picture familiarity. Each picture set was presented in one session only, counterbalanced between participants for L1 and L2. For the LST task and the two post-LST blocks, another set of 144 pictures from the CLT database (Haman et al., 2015; Wolna et al., 2022) were divided into two sets of 72 items matched on name agreement and mean naming latency in Polish, age of acquisition, lexical frequency, morphological complexity of the pictures' dominant names, imageability, goodness of depiction, image agreement, and image familiarity ratings for each picture. Each session used one of the picture sets, and the sets were counterbalanced between participants in the two sessions (i.e., language contexts). Each picture was repeated ten times (eight times in LST blocks and twice in post-LST blocks). From the 72 pictures used for LST, 48 pictures were used for the experimental switching trials, so they occurred in both languages and 24 pictures were used for the filler trials, which were always named in the context-congruent language.

Data analysis

Participant's responses in the picture naming task were manually coded and naming latencies were decoded using Chronset – an automated tool to detect speech onset (Roux et al., 2017). We excluded items with overall accuracy lower than 50% (24 out of 72 pictures in pre-LST and 8 out of 48 pictures in LST and post-LST). After the exclusion of these items, we excluded data from participants whose overall accuracy was lower than 50% in either or both L1 and L2 during the pre-LST pure language task (2 subjects) or lower than 75% in any of the conditions in the LST task (further 3 subjects) or post-LST task. This yielded a final sample of 77 participants included in the statistical analyses.

The accuracy of the participant's responses was assessed using the following criteria:

(i) correct response – target name or a synonym (93.70% of all responses);

(ii) incorrect response – unrelated words (0.73% of all responses);

(iii) incorrect language (1.02% of all responses);

(iv) no response – including inaudible or partial responses impossible to decode (4.37% of responses);

(v) hesitations or other sounds produced before the actual response (0.23% of all responses).

All incorrect responses (i.e., categories (ii)-(v), see above), as well as the after-error trials (i.e., trials that immediately followed incorrect responses from categories (ii)-(iv)), were excluded from the naming latencies analyses. We also excluded all responses faster than 350ms (0.14% of all the correct responses). Filler trials were not included in any statistical analyses. All analyses were conducted using linear mixed-effect models implemented in the *lme4* package in R (Bates et al., 2015). Post-hoc comparisons were conducted using *emmeans* package (Lenth, 2023). Prior to the analysis, the dependent variable – *Naming latency* – was log-transformed to reduce the skewness of the data. All categorical predictors were dummy coded using a sum contrast: *Language* (L1 = -0.5. L1 = 0.5); *Language context* (L1 = -0.5. L2 = 0.5); *Trial type* (repeat = -0.5. switch = 0.5), and the continuous variable of Trial number was demeaned. In all analyses, we first fitted the maximal model and then identified the best random-effects structure following the recommendation of Bates et al. (2018). Below, we operationalize the research questions. The data and code necessary to reproduce the statistical analyses are available at https://osf.io/84stp/?view_only=24ded32ece214ddda02b291b90ebb297.

1. What is the baseline language dominance in unbalanced Polish-English bilinguals?

Before evaluating the effects of language context and language switching paradigm on language dominance, it is helpful to establish the *baseline*, typical language dominance in a given sample of bilinguals (Goldrick & Gollan, 2023), for us unbalanced Polish-English bilinguals. To this aim, we checked the effect of *Language* (L1 vs L2) in pre-LST in which all pictures were named in only one language in each session (each participant named pictures in L1 in one session and L2 in another). The dependent variable in this analysis was the *Naming latency* in L1 and L2 during the first pre-LST block. The model used in this analysis was fitted using the following formula:

Naming latencies ~ Language + (1 + Language | Subject) + (1 + Language | Item)

2. Does bilingual language control flexibly adapt to a bilingual's language context (L1- vs. L2-dominant)?

To test this research question, we checked whether the *Language context* (L1-dominant vs. L2-dominant language context) affects the interaction between *Trial type* and *Language* (which is indicative of the asymmetry of switch cost), as well as the effect of *Language* (which is indicative of language dominance). Additionally, including the *Trial number* in the model allowed us to test whether the effects of interest remain stable over time. The dependent variable in this analysis was the *Naming latencies* measured in LST. The final model was fitted using the following formula:

*Naming latencies ~ Trial type * Language * Language context* Trial number +*
(1 + Trial type + Language + Language context + Trial number | Subject) +
(1 + Trial type + Language + Language context + Trial number | Item)

3. Is the reversed language dominance sustained after leaving the L1- or L2-dominant context?

In this analysis, we explored whether language switching may induce a long-lasting change in the balance between languages that persists even after the language switching task is over and when participants have moved into a single language context. Furthermore, we explored whether the specific language context modulations continued after participants had left the language switching context.

To test whether the reversed language dominance established during LST results in a lingering change in activation between languages (e.g., an L2 after-effect; refs) and whether the language context modulates this after-effect of language switching, we looked at the differences in naming latencies in L1 and L2 in the first and second pure language blocks *after* the language switching task and consider the language context of the session. Note that any given participant completed the first and second post-LST blocks in the same language order in both sessions. Language order was counterbalanced across the participants. Thus, the effect of *Language* constitutes a between-subject variable in this analysis: To test how language context can modulate the language dominance measured in after-LST blocks, we fitted two separate models – one for the first after-LST block and one for the second after-LST block – using the same formula:

*Naming latencies ~ Language * Language context +*
(1 + Dominant Language | Subject) +
*(1 + Language * Language context | Item).*

Results

1. What is the baseline language dominance in unbalanced Polish-English bilinguals?

The analysis of the naming latencies in the pre-LST pure language block – named in L1 or L2 – showed a significant effect of *Language* ($\beta = 0.115$, $t = 6.945$). This effect confirms that bilinguals in our sample were language-unbalanced as they were faster in naming pictures in L1 (951ms) than in L2 (1197ms).

2. Does bilingual language control flexibly adapt to a bilingual's language context (L1- vs. L2-dominant)?

The results of the analysis of naming latencies in LST are summarized in Table 2 and Figure 3. We found a significant effect of *Language*, with slower naming latencies in L1 (1071ms) than in L2 (945ms), which shows that during LST our participants reversed their language dominance (compared to pre-LST), as typically found in the literature (Goldrick & Gollan, 2023). We also found a significant effect of *Trial type*, with slower naming latencies in switch (1074ms) than repeat trials (943ms), as well as a significant effect of *Language context* with overall slower naming latencies in the L2-dominant context (1058ms) than in the L1-dominant context (957ms). We also found a significant effect of *Trial number,* showing that participants named pictures faster as the experiment progressed.

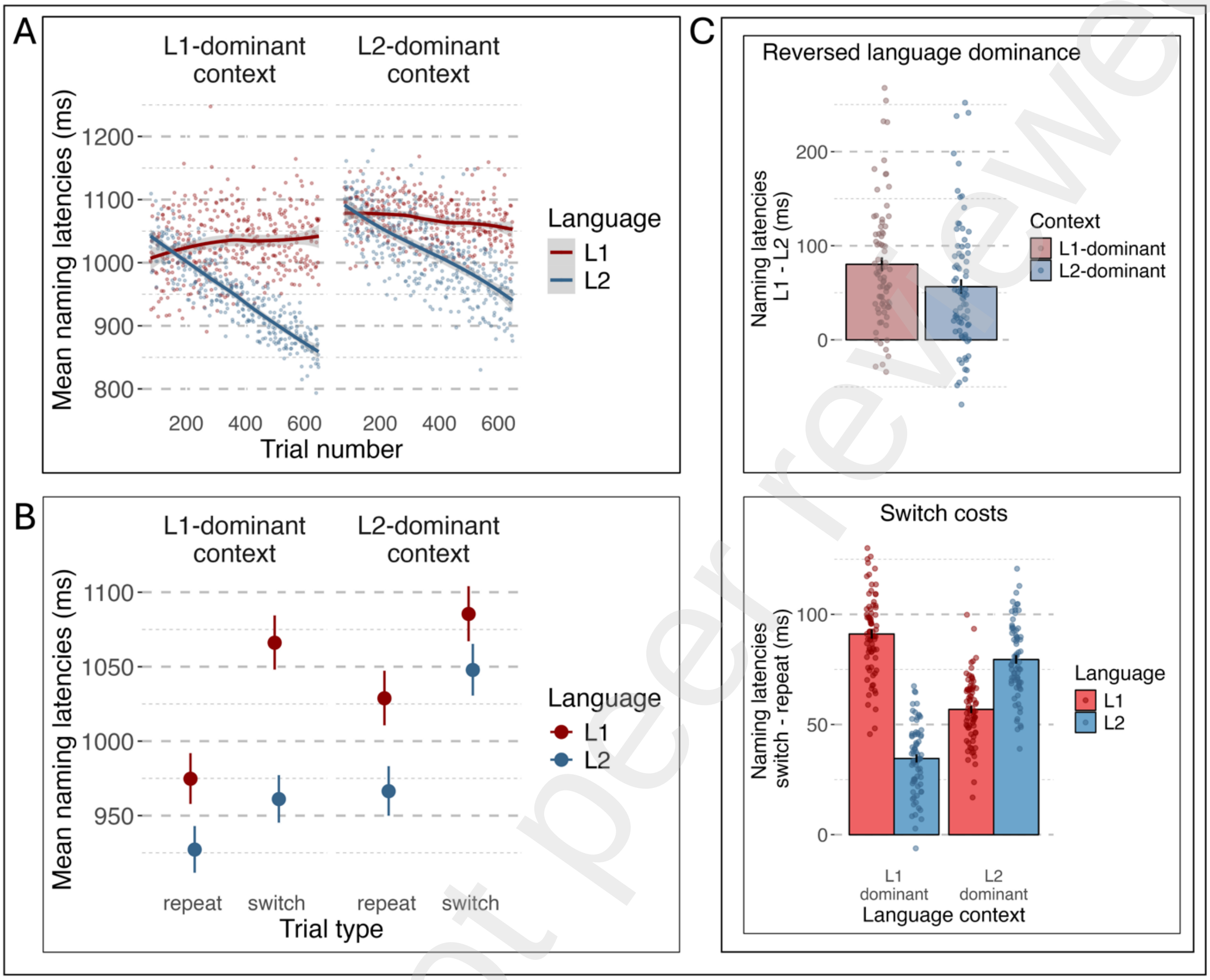
What is more, we found a significant interaction between *Language* and *Trial type*, i.e., the effect of *asymmetry of the switch costs*, with larger switch costs when switching to L1 (75ms; $\beta = 0.072$, $z = 18.284$, $p < 0.001$) than to L2 (57ms; $\beta = 0.058$, $z = 14.666$, $p < .001$). Crucially, we also observed a significant interaction between *Language context* and *Language*: the *reversed language dominance* (i.e., slower naming times in L1 than in L2) was larger in the L1-dominant context (76ms; $\beta = 0.077$, $z = 7.455$, $p < .0001$) than in the L2-dominant context (51ms; $\beta = 0.049$, $z = 4.743$, $p < .0001$; see Figure 2C). The reduction of the reversed language dominance in the L2- compared to L1-dominant context is driven primarily by a slow-down in L2 (L1-context = 944ms; L2-context = 1006ms; $\beta = -0.064$, $z = -6.078$, $p < .0001$) rather than in L1 (L1-context = 1019ms; L2-context = 1057ms; $\beta = -0.036$, $z = -3.428$, $p = .0006$). Interestingly, this 2-way interaction was qualified by *Trial number,* suggesting that the effects of language context on language dominance became larger as the experiment progressed (see Figure 3B).

Finally, we observed a three-way interaction between Language context, Language, and Trial type, indicating that in addition to the reversed dominance effect, the language context also modulated the asymmetry of switch costs (see Figure 3C). In the L1-dominant context, the switch cost was larger to L1 (91ms) than to L2 (34ms; $\beta = 0.054$, $z = 8.792$, $p < .001$) whereas the pattern was reversed in the L2-dominant context with larger switch costs to L2 (57ms) than to L1 (81ms; 027, $z = 4.456$, $p = .027$). To better understand the three-way interaction, we conducted two follow-up post-hoc pairwise comparison analyses which showed that both types of contexts exerted the same impact for L1 and L2 repeat trials (naming latencies were longer in L2-dominant context both for L1 (53ms, beta = -0.54, z = -4.94, p < .001) and for L2 (46ms, beta = -0.04, z = -3.78, p < .001) and there was no difference in the magnitude of these effects (7ms, $\beta =$ —0.013, z = -2.05 p = .170). However, in the switch trials, the impact of context (i.e., slower naming in L2- compared to L1- context) was greater for L2 trials (89ms, beta = -0.09, z = -7.88, p < .001) than L1 (22ms, beta = -0.02, z = -1.65, p < .01; 67ms, $\beta = 0.07$, z = 11.19 p < .001). What is more, we have also found that for the repeat trials, there was a larger difference between L1 and L2 in the L2 context (62ms) than in the L1 context (48ms, $\beta = -0.013$, $z = -2.051$, $p = .040$), while for the switch trials, there was a larger difference between L1 and L2 in the L1 context (105ms) and the L1 context (38ms, $\beta = -0.068$, $z = -11.190$, $p < .001$).

Table 1. Results of a linear mixed-effect model evaluating predictors of naming latencies in the language switching task. The model was run on log-transformed data (see *Data analysis* for details of data transformations). The ms scale presented in the table is based on an exponential transformation of the model's predictions.

	Naming latencies		Std. Error	*t*-value	*p*-value
	log(RT)	ms*			
(Intercept)	**6.914**	**1006.07**	**0.015**	**453.344**	**<.001**
Language	**-0.062**	**-64.68**	**0.010**	**-6.182**	**<.001**
Trial type	**0.065**	**63.29**	**0.003**	**19.629**	**<.001**
Language context	**0.050**	**49.02**	**0.010**	**4.861**	**<.001**
Trial number	**-0.017**	**-16.84**	**0.002**	**-6.895**	**<.001**
Language x Trial number	**-0.032**	**-32.52**	**0.001**	**-24.354**	**<.001**
Trial type x Trial number	0.000	0.43	0.001	0.324	.746
Language context x Trial type	-0.001	-1.22	0.001	-0.932	.352
Language x Trial type	**-0.013**	**-13.46**	**0.004**	**-3.076**	**.002**
Language x Language context	**0.028**	**27.40**	**0.004**	**6.391**	**<.001**
Trial type x Language context	0.004	4.47	0.004	1.032	.302
Language x Trial type x Trial number	0.005	4.78	0.003	1.817	.069
Language x Language context x Trial number	**0.019**	**18.64**	**0.003**	**7.133**	**<.001**
Trial type x Language context x Trial number	0.001	1.30	0.003	0.492	.623
Language x Trial type x Language context	**0.081**	**78.36**	**0.009**	**9.366**	**<.001**
Language x Trial type x Language context x Trial number	-0.007	-6.88	0.005	-1.295	.195

* The statistical analyses were run on log-transformed RTs, hence the original estimates are presented on the model's scale - log(RT). However, for simplicity in grasping the magnitude



of the effects, we also include the estimates on the millisecond scale, which were obtained by applying an exponential transformation to the estimates from the model.

Figure 2. Results of naming latencies analysis in the language switching task. Panel (A) presents predicted mean naming latencies corresponding to switch and repeat trials in L1 and L2 in two different language contexts. Panels (B) presents the influence of the trial number on the naming latencies corresponding to switch and repeat trials in L1 and L2 in two different language contexts. Panel (C) presents switch costs and language dominance indices in the two different language contexts.

3. Is the reversed language dominance sustained after leaving the L1- or L2-dominant context?

In the analysis of the after-effects of switching– i.e., naming latencies in the first and second language, during post-LST blocks *following* the language switching task – we observed the continuation of the reversed language dominance effect (1st after-LST block: *Language*; β = -0.092, t = -2.801; 2nd after-LST block: β = -0.083, t = -2.742) with slower naming latencies in L1 (1st after-LST block: 878ms; 2nd after-LST block: 903ms) than in L2 (1st after-LST block: 800ms; 2nd after-LST block: 831ms). Neither in the first or second post-LST blocks is there a main effect of *Language context*, however, in both, we found a significant interaction between *Language context* and *Language* (1st after-LST block: $\beta = 0.059$, $t = 2.294$; 2nd after-LST block: $\beta = 0.081$, $t = 2.298$; Figure 2B). Pairwise comparisons revealed that in both post-LST following L1-dominant context, participants were slower to name pictures in L1 than in L2 (i.e., reversed language dominance; 1st post-LST block: L1 = 885ms, L2 = 784ms; $\beta = 0.121$, $z = 3.318$, $p < .001$; 2nd post-LST block: L1 = 923ms, L2 = 815ms; $\beta = 0.124$, $z = 3.567$, $p < .001$). In contrast, in post-LST blocks following the L2-dominant context, there was no reversed language dominance with similar latencies in both languages in both the first and second post-LST blocks (1st post-LST block: L1 = 869ms, L2 = 816ms; $\beta = 0.034$, $z = 1.843$, $p = .065$; 2nd post-LST block: L1 = 883ms, L2 = 8146ms; $\beta = 0.043$, $z = 1.353$, $p = .176$). The difference in the reversed language dominance after the two contexts was driven by significantly slower L2 naming in the L2- than L1-context (L1-context = 784ms; L2-context = 816ms; $\beta = -0.041$, $z = -2.199$, $p < .05$) while naming in L1 was the same across contexts (L1-context = 885ms; L2-context = 869ms; $\beta = 0.018$, $z = 1.008$, $p = .3133$). However, in the 2nd post-LST block we observed a reverse effect, with no differences in response latencies in L2 between the L2- and L1 contexts (L1-context = 816ms; L2-context = 846ms; $\beta = -0.036$, $z = -1.869$, $p = .062$) but significantly slower response in L1 in the L1- than L2-context (L1-context = 923ms; L2-context = 883ms; $\beta = 0.045$, $z = 2.300$, $p = .021$). The results of these analyses are presented in **Figure 3.**

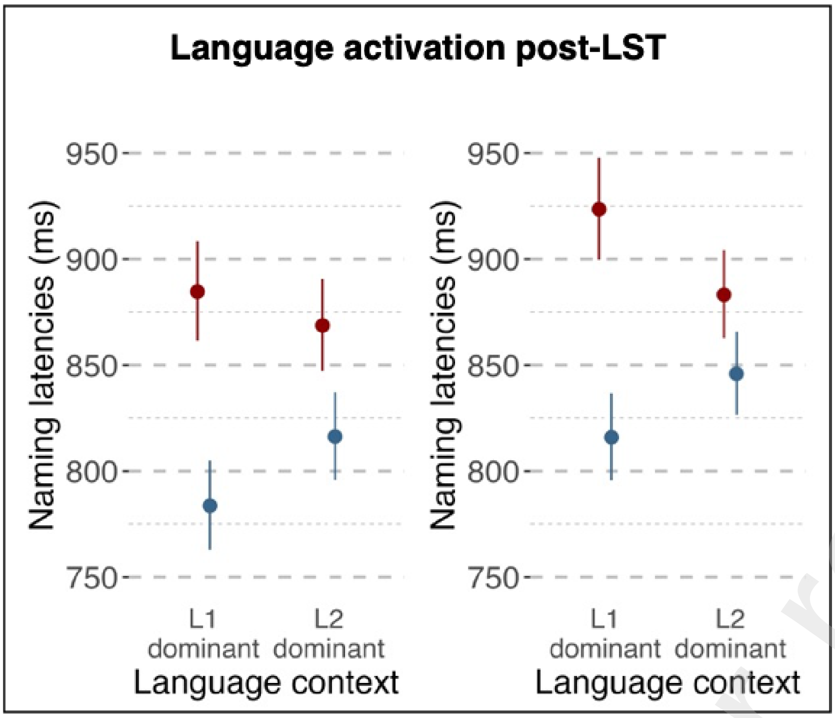


Figure 3. Results of language balance during pure blocks after L1- or L2-dominant language context. The mean naming latencies in L1 and L2 pure blocks of picture naming in the first and second pure blocks post-LST – represent language balance after language switching. All panels present the means derived from the statistical models. Whiskers correspond to the standard errors.

Discussion

We examined whether bilingual language control (BLC) mechanisms remain relatively stable within an individual or flexibly adjust depending on the relative presence of a given language in a context. We focused on two indices of BLC typically assessed in studies employing the language switching paradigm: reversed language dominance—assumed to reflect global language control—and asymmetry of switch costs—taken as a manifestation of local control. We used manipulation of immediate language context (predominantly L1 vs. L2) to contribute to the ongoing discussion of to what extent these indices of control work in tandem or dissociate under different experimental demands. We first investigated whether our group of presumably unbalanced Polish-English bilinguals indeed showed a language (un)balance with an advantage for the L1 over L2. Next, we investigated how global and local language control adapts to language contexts and whether they vary with respect to the relative language presence in participants’ dominant vs. non-dominant language. Finally, we explored whether changes in language balance induced by different bilingual language contexts persisted after bilinguals had left those contexts. We found that our group of bilinguals was indeed unbalanced and showed a dominance for L1 (over L2) in pure language context (pre-LST). In the bilingual contexts of LST, this L1 dominance reversed to dominance for L2 (over L1). Importantly, we found that the magnitude of this dominance reversal was modulated by the relative presence of each language in the L1/L2-dominant contexts, with a greater reversed dominance in the L1-dominant than in the L2-dominant context. We also found that the language context also affected the asymmetry of switch costs, with larger switch costs observed for the language most present in the language context, which indicates that the context manipulation also results in changes in local control engagement. Finally, the global control adjustments during diverse language contexts (L1- and L2-dominant) lingered in subsequent monolingual contexts. We discuss the detailed results below through the lens of three research questions.

1. What is the baseline language dominance in unbalanced Polish-English bilinguals?

The baseline language activation was assessed via picture naming latencies in pure language blocks at the beginning of the experiment (for a discussion of the advantages of this method over different ways of balance assessment, see Casado et al., 2020; Goldrick and Gollan, 2023). The results confirmed that our bilinguals were more faster in naming pictures in L1 than in L2, thus L1-dominant. Our participants were late unbalanced bilinguals because they started learning their L2 (i.e., English) around the age of six and could use the language for basic level communication after the age of nine. Their L2, English - a modern lingua franca, was passively present in almost 40% and actively in nearly 20% of their typical daily language interactions. However, despite their relatively frequent L2 language use, they were L1-dominant, which was confirmed by faster picture naming in L1 (Polish) than in L2 (English) by 246 ms in the single language blocks before the language switching task. This magnitude of L1 dominance over L2 is in line with other studies on Polish unbalanced bilinguals (Casado et al., 2022; Wolna et al., 2024a) and consistent with the findings on unbalanced bilinguals worldwide (Christoffels et al., 2007; Gollan et al., 2014; Hanulovà et al., 2011; Jylkkä et al., 2018; Massa et al., 2020; Mosca & Clahsen, 2016; Zhang et al., 2020).

2. Does bilingual language control flexibly adapt to a bilingual's language context (L1- vs. L2-dominant)?

Global language control*, as indexed by the reversed language dominance, was affected by the immediate language context.* Our L1-dominant participants reversed their language dominance during LST, as demonstrated by slower naming in L1 than in L2. The finding that during language mixing (e.g., in language switching tasks), naming in L1 can become slower than naming in L2 has been observed frequently (e.g., Christoffels et al., 2007; Costa et al., 2006; Costa & Santesteban, 2004; Tarłowski et al., 2013; see Bobb & Wodniecka, 2013 and Declerck et al., 2020 for reviews; Goldrick & Gollan, 2023). It is typically explained as occurring due to inhibition of the whole L1 system (Green, 1998) although alternative explanations have also been put forward (Branzi et al., 2014; Costa et al., 2006; Verhoef et al., 2009). Crucially, we revealed that the reversed language dominance is prominent in the L1-dominant context but diminished in the L2-dominant context. This difference between contexts is driven by a greater slowdown for L2 (62 ms) than L1 (38 ms) in the L2-dominant compared to the L1-dominant context (see Figure 3C). This is in line with the results of Timmer and colleagues (2018), who observed that unbalanced Dutch-English bilinguals not only reduced the reversed language dominance in the L2-dominant context but disappeared, resulting in both languages being equally fast. The difference between contexts came from a slowdown for L2 (60 ms) while L1 speeded up (57 ms) in the L2- compared to the L1-dominant context. The slower naming of L2 in the L2-dominant context (compared to the L1-dominant context) suggests that L2 is less available when it is more omnipresent in the environment. The greater presence of L2 in the environment can make the L2 behave as if it is a bilingual's dominant (instead of the non-dominant) language (Timmer et al., 2018). It is likely that inhibition is applied to the L2 when L2 is more present.

A bilingual's time spent in one of the dominant LST contexts increased the reversed language dominance effect and showed no signs of saturation even after 600 trials (see Figure 3A). The findings are consistent with Timmer et al. (2018) observed a more substantial change in global language control between the language contexts compared to the current study. This may have been caused by the fact that the induced dominance of language contexts was likely stronger, as it required more responses in one language (83 % compared to only 67% in the current study). The interesting dynamic developing throughout the present experiment came from an overall speedup throughout the experiment, which can be due to both training and picture repetition effects as participants got familiar with the task and each picture was repeated eight times (four times within each language) within LST. Crucially, the rate at which L2 naming gained speed through the LST task was higher in the L1- than in the L2-dominant context. In contrast, L1 naming does not show a picture repetition benefit in the L1- and L2-dominant contexts and even slows down slightly in the L1-dominant context (see Figure 3A).

The underlying mechanism could possibly be that L1 is the dominant language with faster naming at baseline, it could gain less from repetition than L2. This is in line with evidence that repetition priming in L2 tends to be larger than in L1 (Kleinman & Gollan, 2018; Francis, Augustini & Sáenz, 2003) – an effect that has proposed to be driven by overall lower baseline activation level of the non-dominant language and hence a larger repetition benefit (Kleinman & Gollan, 2018; Gollan et al., 2008; Gollan et al., 2011; Christoffels et al., 2016).

However, this is unlikely the whole story because, in our data, L1 did not benefit from repetition at all (not just less than L2)—and crucially, L1 was also significantly slower than L2 overall. That L1 is slower than L2 suggests that the repetition benefits (due to training and/or picture repetition) are likely eliminated (canceled out) by global L1 inhibition (see Christoffels et al., 2016). As the same pictures are named in different languages we cannot exclude that the co-activation of the words in the two languages impacts naming in each language differently. The competitors from L2 might affect L1, while the competitors from L1 might not affect L2.

Overall, the results suggest that BLC must strike a balance in preventing interference between the two languages. Although the most notable effect is the control exerted over L1 (the more automatized language), yet when L2 dominates in the context, some control must also be applied to L2 to facilitate occasional L1 naming. In other words, the greater presence of L2 in the language mixing environment can initiate control processes typically applied for the dominant language (see Timmer et al., 2018 for a similar suggestion that under the L2 dominant environment, the L2 starts 'behaving' like L1). We propose that these processes likely involve inhibition that is applied to the L2 when participants are required to use the L2 more but still switch between the languages.

Local control, *as indexed by the asymmetric switch costs, is also affected by the immediate language context.* Our results indicate that the language switch cost changed with changes in the language context. In the L1-dominant context, we found greater switch costs for L1 than L2, which is a typical finding for unbalanced bilinguals. (Philipp et al., 2007). In the L2-dominant context, the effect was reversed with greater switch costs for L2 than for L1, replicating previous results by Timmer and colleagues (2018), but this time using a within-subject design. Such a reversed asymmetrical switch cost has not only been found when bilinguals are in an L2-dominant context an L2-dominant context (Timmer, Christoffels, et al., 2018) but also when cultural faces (i.e., Asian and Caucasian) (Liu et al., 2019) or linguistic questions (Timmer et al., 2024) indicated which language to speak in, or when more preparation time was available (Ma et al., 2016; Verhoef et al., 2009). Our findings provide new evidence that the context in which a participant is switching can impact the size of the switch cost as well as the asymmetry of the switch cost between the dominant and non-dominant language. As such, we want to highlight that the likely differences between language contexts across different studies may explain some of the inconsistent results within the literature (Gade et al., 2021a, 2021b; Goldrick & Gollan, 2023).

Both inhibition (Green, 1998) and activation accounts (e.g., Costa et al., 2006) can explain local control modulations reflected in asymmetric switch costs, they primarily focus their interpretation on switch trials, as they explain the asymmetry through inhibition/activation from the previous trial carrying over into the current switch trial – which has a greater impact on L1 than L2. This potentially overlooks important effects observed in language-repeat trials. An alternative perspective, proposed by Verhoef et al. (2009), highlights the L1-repeat-benefit, suggesting that only L1-repeat trials fully benefit from extra preparation time and, therefore, the asymmetric costs can turn symmetric. Building on this, we propose that changes to the relative language activation should be considered across both repeat and switch trials to capture the dynamics of control mechanisms fully.

To better understand the reversed asymmetry in the L1- and L2-dominant language context, we examined the three-way interaction in a different way: We observed that on repeat trials, naming latencies in L2-dominant contexts were overall slower compared to L1-dominant contexts, and the magnitude of difference between L1 and L2 was similar across the context. This suggests that repeat-trial performance is not directly modulated by language context and that the presence of different L1/L2 ratios in the L1- and L2-dominant language contexts does not significantly impact local control mechanisms in repeat trials. In contrast, switch trials revealed a differential effect of language context, with a greater magnitude of the slowdown for L2 in the L2- vs. L1-dominant context. Therefore, the switch-trial performance is directly and immediately impacted by language context, which modulates the switch cost pattern (interpreted as local control). Examining the three-way interaction in yet another way, we observed a diminished reversed language dominance in the L2- compared to the L1-dominant context for switch (but the reversed pattern for repeat) trials. The reduced reversed language dominance in L2-dominant contexts for switch trials reflects the same pattern seen in the global control modulations, suggesting that local control adjustments in relative language activation on switch trials align with global control modifications. Consequently, the context-dependent modulation in switch costs is likely driven by the global inhibition of L1 in both contexts, accompanied by additional inhibition of L2 in the L2-dominant context. This may suggest that inhibition plays a role in local control modulations. Next, reversed dominance modulation for repeat trials (i.e., larger in L2- than L1-dominant context) shows that local and global control are at least partially dissociable mechanisms with diverse relative language activation patterns.

3. Is the reversed language dominance sustained after leaving the L1- or L2-dominant context?

Finally, we investigated whether the reversed language dominance effect, namely the slower naming in L2 than L1 often reported during language switching (LST), continues after bilinguals have left a mixed language environment. We expected to replicate a pattern reported in a seminal study by Christoffels et al. (2016) who observed a continuation of the reversed language dominance in pure language blocks following post-language switching. Our data replicated the pattern found by Christoffels et al., namely we found that the reversal of language dominance (observed initially under the language switching requirement) was further sustained in pure language blocks that followed. The effect persisted in a second pure language block when bilinguals have left the bilingual situation for an even longer period, for a total duration of around 20 minutes. Crucially, we found that not only the general pattern of language dominance reversal was sustained after the LST, but also the differences observed between the language contexts (i.e., L1-dominant or L2-dominant): similarly to the effects observed in LST, the reversed language dominance was still bigger after the L1-dominant context than after the L2-dominant context and maintained as such throughout both pure language blocks. This has implications for investigations of bilingual language use as language environment which directly precedes any experimental situation may fundamentally alter the results in any language task that follows.

In terms of the underlying mechanism, Christoffels et al. (2016) interpreted the continuation of the reversed language dominance in pure language blocks following post-language switching) as a consequence of sustained inhibition applied to L1 during LST that lingers after participants had left the mixed-language environment. They further supported the proposed mechanism of sustained inhibition with the finding that after LST naming in L1 was still slower than naming in L2, despite overall faster naming post-LST than pre-LST. The smaller benefits of repetition and training effects, with faster naming post-LST than pre-LST, could be explained by the fact that L1 can gain less from repetition than L2. However, this is unlikely to be the full explanation as L1 naming was still slower than L2 naming within the post-test. Thus, arguing for sustained inhibition as a crucial effect. Our results, showing that the reversed language dominance continues from LST to post-LST, albeit smaller in the L2-dominant context – confirm the suggestion of inhibition. In addition, here in the L2 context, inhibition was also applied to L2. The consequences of inhibition move beyond the situation that elicited inhibition in the first place and manifested by continuing in other environments.

To conclude, our study contributes to our understanding of how bilinguals flexibly adjust their bilingual control mechanisms (global and local) to maneuver effectively and efficiently between different language environments. We show that unbalanced bilinguals, dominant in their L1, could move from a dominant language advantage (i.e., faster naming in L1 than L2) to a reversed language dominance (i.e., slower naming in L1 than L2; global control) or equal language balance (i.e., similar naming in L1 and L2) during bilingual language contexts. These flexible adjustments to the cognitive control engagement continue after a bilingual has left the bilingual context. This is crucial as it reveals that bilinguals can reverse their language dominance after being in a bilingual language setting and can explain why a recent meta-analysis revealed that only 75% of bilingual studies showed a dominant language advantage (i.e., faster naming in L1 than L2) during picture naming in single-language blocks (Goldrick & Gollan, 2023). Overall, we have revealed that the demands on language control in bilinguals are not only modulated by stable features – like proficiency – but that they dynamically adjust to the requirements of the linguistic environment of the speaker.

The finding that immediate language context (i.e., the relative presence of a bilingual's language)alters language control mechanisms during speech production has important implications for further developing theoretical frameworks about bilingual language control that should account for this adaptive nature of control. Furthermore, including this factor, next to proficiency in the theoretical models, may create a more coherent explanation of the existing results. For example, theoretical frameworks considering either inhibition or activation predict asymmetric switch costs (i.e., larger to L1 than L2). However, the literature does not report consistently finding an asymmetric switch cost based on language proficiency. We propose that the immediate language context in which participants are can have consequences for subsequent language use, including the asymmetry of switch costs. Furthermore, global control sustains over some time after leaving the immediate context. Therefore, theoretical models should consider that language usage may impact bilingual language control in the longer term than is typically considered. Furthermore, we carefully consider how both global control (i.e., reversed language dominance) and local control (i.e., asymmetric switch costs) are related to each other and provide novel ways of exploring the complex pattern of results and how they relate to either inhibition or activation frameworks of bilingual language control. We propose that a full reversal of language dominance (i.e., global), the sustained effect after leaving the context, and a greater reduction of L2 speeding up throughout the experiment in the L2- than L1-dominant context may point towards inhibition. In contrast, asymmetric modulations (i.e., local control) can be explained by both accounts. Lastly, we propose that global and local control are influenced by each other but have separable origins.

References

Bobb, S. C., & Wodniecka, Z. (2013). Language switching in picture naming: What asymmetric switch costs (do not) tell us about inhibition in bilingual speech planning. *Https://Doi.Org/10.1080/20445911.2013.792822*, *25*(5), 568–585. https://doi.org/10.1080/20445911.2013.792822

Branzi, F. M., Martin, C. D., Abutalebi, J., & Costa, A. (2014). The after-effects of bilingual language production. *Neuropsychologia*, *52*(1), 102–116. https://doi.org/10.1016/J.NEUROPSYCHOLOGIA.2013.09.022

Calabria, M., Hernández, M., Branzi, F. M., & Costa, A. (2011). Qualitative differences between bilingual language control and executive control: Evidence from task-switching. *Frontiers in Psychology*, *2*(JAN), 12051. https://doi.org/10.3389/FPSYG.2011.00399/BIBTEX

Casado, A., Szewczyk, J., Wolna, A., & Wodniecka, Z. (2022). The relative balance between languages predicts the degree of engagement of global language control. *Cognition*, *226*, 105169. https://doi.org/10.1016/J.COGNITION.2022.105169

Christoffels, I., Firk, C., & Schiller, N. O. (2007). Bilingual language control: An event-related brain potential study. *Brain Research*, *1147*(1), 192–208. https://doi.org/10.1016/J.BRAINRES.2007.01.137

Christoffels, I., Ganushchak, L., & La Heij, W. (2016). When L1 suffers Sustained, global slowing and the reversed language effect in mixed language context. In J. W. Schwieter (Ed.), *The Cognitive Control and Consequences of Multilingualism*.

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

Declerck, M., Kleinman, D., & Gollan, T. H. (2020). Which bilinguals reverse language dominance and why? *Cognition*, *204*, 104384. https://doi.org/10.1016/J.COGNITION.2020.104384

Degani, T., Kreiner, H., Ataria, H., & Khateeb, F. (2020). The impact of brief exposure to the second language on native language production: Global or item specific? *Applied Psycholinguistics*, *41*(1), 153–183. https://doi.org/10.1017/S0142716419000444

Gade, M., Declerck, M., Philipp, A. M., Rey-Mermet, A., & Koch, I. (2021a). Assessing the Evidence for Asymmetrical Switch Costs and Reversed Language Dominance Effects – A Meta-Analysis. *Journal of Cognition*, *4*(1), 1–32. https://doi.org/10.5334/JOC.186

Gade, M., Declerck, M., Philipp, A. M., Rey-Mermet, A., & Koch, I. (2021b). Erratum: Assessing the evidence for asymmetrical switch costs and reversed language dominance effects – A meta-analysis (Journal of Cognition (2021) 4:1 (55) DOI:10.5334/joc.186). *Journal of Cognition*, *4*(1). https://doi.org/10.5334/JOC.195

Goldrick, M., & Gollan, T. H. (2023). Inhibitory control of the dominant language: Reversed language dominance is the tip of the iceberg. *Journal of Memory and Language*, *130*, 104410. https://doi.org/10.1016/J.JML.2023.104410

Gollan, T. H., Kleinman, D., & Wierenga, C. E. (2014). What's Easier: Doing what you want, or being told what to do? Cued versus voluntary language and task switching. *Journal of Experimental Psychology: General*, *143*(6), 2167–2195. https://doi.org/10.1037/A0038006

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

Green, D. W., & Abutalebi, J. (2013). Language control in bilinguals: The adaptive control hypothesis. *Journal of Cognitive Psychology*, *25*(5), 515–530. https://doi.org/10.1080/20445911.2013.796377

Grosjean, F. (2001). One Mind, Two Languages: Bilingual Language Processing. In J. Nicol (Ed.), *The bilingual's language modes.* (pp. 1–22). Blackwell.

Hanulovà, J., Davidson, D. J., & Indefrey, P. (2011). Where does the delay in L2 picture naming come from? Psycholinguistic and neurocognitive evidence on second language word production. *Language and Cognitive Processes*, *26*(7), 902–934. https://doi.org/10.1080/01690965.2010.509946

Jiao, L., Grundy, J. G., Liu, C., & Chen, B. (2020). Language context modulates executive control in bilinguals: Evidence from language production. *Neuropsychologia*, *142*, 107441. https://doi.org/10.1016/J.NEUROPSYCHOLOGIA.2020.107441

Jiao, L., Liu, C., Liang, L., Plummer, P., Perfetti, C. A., & Chen, B. (2019). The contributions of language control to executive functions: From the perspective of bilingual comprehension. *Https://Doi.Org/10.1177/1747021818821601*, *72*(8), 1984–1997. https://doi.org/10.1177/1747021818821601

Jylkkä, J., Lehtonen, M., Lindholm, F., Kuusakoski, A., & Laine, M. (2018). The relationship between general executive functions and bilingual switching and monitoring in language production. *Bilingualism: Language and Cognition*, *21*(3), 505–522. https://doi.org/10.1017/S1366728917000104

Kałamała, P., Walther, J., Zhang, H., Diaz, M., Senderecka, M., & Wodniecka, Z. (2022). The use of a second language enhances the neural efficiency of inhibitory control: An ERP study. *Bilingualism*, *25*(1), 163–180. https://doi.org/10.1017/S1366728921000389

Ma, F., Li, S., & Guo, T. (2016). Reactive and proactive control in bilingual word production: An investigation of influential factors. *Journal of Memory and Language*, *86*, 35–59. https://doi.org/10.1016/J.JML.2015.08.004

Massa, E., Köpke, B., & El Yagoubi, R. (2020). Age-related effect on language control and executive control in bilingual and monolingual speakers: Behavioral and electrophysiological evidence. *Neuropsychologia*, *138*, 107336. https://doi.org/10.1016/J.NEUROPSYCHOLOGIA.2020.107336

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., & Clahsen, H. (2016). Examining language switching in bilinguals: The role of preparation time*. *Bilingualism: Language and Cognition*, *19*(2), 415–424. https://doi.org/10.1017/S1366728915000693

Olson, D. J. (2016). The gradient effect of context on language switching and lexical access in bilingual production. *Applied Psycholinguistics*, *37*(3), 725–756. https://doi.org/10.1017/S0142716415000223

Philipp, A. M., Gade, M., & Koch, I. (2007). Inhibitory processes in language switching: Evidence from switching language-defined response sets. *Http://Dx.Doi.Org/10.1080/09541440600758812*, *19*(3), 395–416. https://doi.org/10.1080/09541440600758812

Tarlowski, A., Wodniecka, Z., & Marzecová, A. (2013). Language Switching in the Production of Phrases. *Journal of Psycholinguistic Research*, *42*(2), 103–118. https://doi.org/10.1007/S10936-012-9203-9/METRICS

Timmer, K., Calabria, M., Branzi, F. M., Baus, C., & Costa, A. (2018). On the reliability of switching costs across time and domains. *Frontiers in Psychology*, *9*(JUN). https://doi.org/10.3389/fpsyg.2018.01032

Timmer, K., Calabria, M., & Costa, A. (2019). Non-linguistic effects of language switching training. *Cognition*, *182*. https://doi.org/10.1016/j.cognition.2018.09.001

Timmer, K., Christoffels, I. K., & Costa, A. (2018). On the flexibility of bilingual language control: The effect of language context. *Bilingualism*. https://doi.org/10.1017/S1366728918000329

Timmer, K., Costa, A., & Wodniecka, Z. (2021). The source of attention modulations in bilingual language contexts. *Brain and Language*, *223*, 105040. https://doi.org/10.1016/J.BANDL.2021.105040

Timmer, K., Grundy, J., & Bialystok, E. (2017a). The influence of contextual cues on representations in the mental lexicon for bilinguals. In *torrossa.comK Timmer, JG Grundy, E BialystokBilingualism: A framework for understanding the mental lexicon, 2017•torrossa.com*. https://doi.org/10.1075/bpa.6.06tim

Timmer, K., Grundy, J. G., & Bialystok, E. (2017b). Earlier and more distributed neural networks for bilinguals than monolinguals during switching. *Neuropsychologia*, *106*. https://doi.org/10.1016/j.neuropsychologia.2017.09.017

Timmer, K., Wodniecka, Z., & Costa, A. (2021). Rapid attentional adaptations due to language (monolingual vs bilingual) context. *Neuropsychologia*, *159*, 107946. https://doi.org/10.1016/J.NEUROPSYCHOLOGIA.2021.107946

Timmer, K., Wolna, A., & Wodniecka, Z. (2024). The impact of cues on language switching: do spoken questions reduce the need for bilingual language control? *Bilingualism: Language and Cognition*, 1–19. https://doi.org/10.1017/S1366728924000841

Verhoef, K., Roelofs, A., & Chwilla, D. J. (2009). Role of inhibition in language switching: Evidence from event-related brain potentials in overt picture naming. *Cognition*, *110*(1), 84–99. https://doi.org/10.1016/J.COGNITION.2008.10.013

Wodniecka, Z., Casado, A., Kałamała, P., Marecka, M., Timmer, K., & Wolna, A. (2020). The dynamics of language experience and how it affects language and cognition. In *Psychology of Learning and Motivation - Advances in Research and Theory* (Vol. 72, pp. 235–281). Academic Press. https://doi.org/10.1016/BS.PLM.2020.02.005

Wolna, A., Szewczyk, J., Diaz, M., Domagalik, A., Szwed, M., & Wodniecka, Z. (2024a). Domain-general and language-specific contributions to speech production in a second language: an fMRI study using functional localizers. *Scientific Reports 2024 14:1*, *14*(1), 1–17. https://doi.org/10.1038/s41598-023-49375-9

Wolna, A., Szewczyk, J., Diaz, M., Domagalik, A., Szwed, M., & Wodniecka, Z. (2024b). Tracking Components of Bilingual Language Control in Speech Production: An fMRI Study Using Functional Localizers. *Neurobiology of Language*, *5*(2), 315–340. https://doi.org/10.1162/NOL_A_00128

Wu, Y. J., & Thierry, G. (2013). Fast Modulation of Executive Function by Language Context in Bilinguals. *Journal of Neuroscience*, *33*(33), 13533–13537. https://doi.org/10.1523/JNEUROSCI.4760-12.2013

Yang, J., Ye, J., Wang, R., Zhou, K., & Wu, Y. J. (2018). Bilingual contexts modulate the inhibitory control network. *Frontiers in Psychology*, *9*(MAR), 301715. https://doi.org/10.3389/FPSYG.2018.00395/BIBTEX

Zhang, Y., Cao, N., Yue, C., Dai, L., & Wu, Y. J. (2020). The Interplay Between Language Form and Concept During Language Switching: A Behavioral Investigation. *Frontiers in Psychology*, *11*, 526133. https://doi.org/10.3389/FPSYG.2020.00791/BIBTEX