Bilingualism: Language and Cognition

cambridge.org/bil

Research Article

Cite this article: Koch, I., Sánchez, L.M., Koch, C., Roembke, T.C., Philipp, A.M. and Declerck, M. (2026). Persistence of situational language balance in bilingual switching: Evidence from carryover of proactive language control. *Bilingualism: Language and Cognition* 1–9. https://doi.org/10.1017/S1366728925100874

Received: 25 October 2024
Revised: 5 November 2025
Accepted: 19 November 2025

Keywords:
bilingualism; language switching; reversed language dominance; L1 slowing; blocked language order

Corresponding author:
Iring Koch;
Email: koch@psych.rwth-aachen.de

This research article was awarded Open Data badge for transparent practices. See the Data Availability Statement for details.

Persistence of situational language balance in bilingual switching: Evidence from carryover of proactive language control

Iring Koch[1], Luz María Sánchez[2], Chiara Koch[1], Tanja C. Roembke[1], Andrea M. Philipp[1] and Mathieu Declerck[2]

[1]Institute of Psychology, RWTH Aachen University, Germany and [2]Linguistics and Literary Studies, Vrije Universiteit Brussel, Belgium

Abstract

Proactive language control is thought to regulate the interference from the nontarget language in bilingual contexts in a sustained way. This study examined the persistence of proactive control in cued picture naming. Participants first named pictures in L1 (German) and L2 (English) in pure blocks, then in mixed language blocks and finally again in pure blocks. In mixed blocks, there were language switch costs, and L1 responses were generally slower than L2 responses ("L1 slowing"). Critically, L1 remained slower than L2 even in postmixing single-language blocks. This persisting L1 slowing suggests overshooting control that downregulates lexical access to L1 representations in a sustained manner. Yet, this persistence of L1 slowing was found only in the first single-language block after the mixed language blocks and no longer in the second postmixing block, suggesting that proactive control has inertia but dissipates over time.

1. Introduction

The term bilingualism denotes the ability to communicate in more than one language, and following this definition, more than half of the world's population is bilingual (e.g., Grosjean, 2010). Yet, bilingualism refers to a complex and graded experience based on factors like age of acquisition of a second language, frequency of use, frequency of code switching, etc. (see, e.g., de Bruin, 2019; Kałamała et al., 2023; Marian & Hayakawa, 2021). Depending on these factors, bilinguals are rarely completely "balanced," implying that their first language (L1) is typically dominant relative to a second language (L2; see Treffers-Daller, 2019). Yet, there is evidence suggesting that in bilinguals, the known languages are typically simultaneously available, so that words are usually activated to some degree also in the nontarget language even in single-language contexts (e.g., Costa et al., 2000; Meade et al., 2017). This poses particular problems because speaking in L2 thus requires language control processes to overcome competition from the dominant L1 and thus to change the situational language balance in favor of L2 (Green, 1998). These flexible language control processes in bilingual situations have mainly been examined using the language switching paradigm (see Declerck & Koch, 2023 for a review).

In the language-switching paradigm, participants are usually asked to name language-unspecific stimuli, such as digits or pictures. In cued language switching, for instance, an explicit language cue, such as a national flag, precedes or is presented simultaneously with the to-be-named stimulus, indicating the current target language. Such studies revealed two general findings. First, reaction times (RTs) and error rates are typically higher in language switch trials, which require a different language as the previous trial, than in language-repetition trials, thus showing switch costs (e.g., Costa & Santesteban, 2004; Heikoop et al., 2016; Meuter & Allport, 1999; Peeters & Dijkstra, 2018; Timmer et al., 2019). Second, even though L1 responses are typically faster than L2 responses in single-language conditions, in mixed language conditions, L1 responses are often generally slower than L2 responses ("L1 slowing," e.g., Christoffels et al., 2007; see also Goldrick & Gollan, 2023).

Switch costs are often attributed to the control requirements needed to downregulate activation of the currently not intended language (see, e.g., Declerck & Philipp, 2015; Green, 1998; Green & Abutalebi, 2013; Kleinman & Gollan, 2018; Koch et al., 2024; Kroll et al., 2008; Meuter & Allport, 1999; Philipp et al., 2007). A major theoretical account assumes "reactive" inhibition of the nontarget language (Green, 1998). This account has also been used to explain that switch costs can be larger for the dominant L1 than for the nondominant L2 (Meuter & Allport, 1999), but there are alternative, noninhibitory accounts (see also Blanco-Elorrieta & Caramazza, 2021; Finkbeiner et al., 2006; Koch et al., 2010; Philipp et al., 2007), and this asymmetry of switch costs does not seem to be reliable (see Bobb & Wodniecka, 2013 for a review; see Gade et al., 2021 for a meta-analysis).

In this study, we specifically focus on the second major finding in language switching, which is the general L1 slowing effect in mixed language conditions, sometimes also called "reversed language dominance effect" (see Declerck & Koch, 2023 for a review). These more sustained, general "L1 slowing" effects can be considered representing "proactive" control (see, e.g., Declerck, 2020). Generally, L1 slowing can be explained by an inhibitory control input specifically applied to L1 to facilitate access to L2 representations (i.e., lexical access, lemma activation) in a more proactive, sustained manner across language switch trials *and* repeat trials in mixed language conditions. Thus, examining L1 slowing represents a promising approach to understand better how bilinguals proactively control their language balance and how they make sure that the usually dominant L1 does not prevail when the target language is actually L2.

However, proactive control can have aftereffects extending into situations where it seems no longer needed. Such aftereffects have been shown in several contexts, differing in terms of their time scale (see Wodniecka et al., 2020 for a review).[1] For example, several studies examined aftereffects of L2 on subsequent L1 performance in picture-naming paradigms in single-language contexts, in which the target language remained constant across blocks of trials. For example, Misra et al. (2012) asked Chinese-English bilinguals to name pictures, and half of the participants started in their L1 in an entire block of trials, followed by a block of L2 naming, whereas the other participants started with L2 followed by L1. Naming in L2 after L1 showed a general repetition benefit; yet, naming in L1 after L2 did not show a benefit, suggesting that facilitation due to stimulus repetition was offset by a more sustained downregulation of L1 based on the preceding L2 exposure (see also Casado et al., 2022; Guo et al., 2011; van Assche et al., 2013; Wolna et al., 2024 for similar designs). Similarly, Branzi et al. (2014) had their participants name picture in three blocks with languages alternating, starting either with L1 followed by L2 and then L1 again or with L2 followed by L1 and L2 again. They found that performance in L1 was worse after L2 exposure in-between, whereas there was no such aftereffect from L1 on subsequent L2 (see also Degani et al., 2020, 2024; Ivanova et al., 2023).

Hence, while L1 slowing in mixed language blocks demonstrated immediate effects of L2 on L1 in mixed language blocks themselves (i.e., trial-by-trial level), such effects can also be demonstrated on a somewhat longer time scale based on the aftereffect of L2 performance on subsequent L1 performance in single-language conditions. In this study, we aimed at examining the persistence of L1 slowing after preceding mixed language blocks.

This study was inspired by a study of Christoffels et al. (2016) reported in a book chapter. In their study, in a pretest, Dutch-English bilinguals named pictures in single-language blocks in their L1 and their L2, with order counterbalanced across participants (i.e., L1 first vs. L1 second), and then performed in mixed language blocks. In the mixed blocks, the target language was indicated by a color cue, which was presented simultaneously with a target picture. Finally, the participants named pictures again in single-language blocks in a posttest. The pretest showed better performance for L1 than for L2; yet, in the posttest, this L1–L2 difference was reversed. This finding represents a different version of L1 slowing (i.e., aftereffect of mixed language blocks on performance in subsequent single-language blocks) and is consistent with a sustained inhibitory bias against L1 that persists even into subsequent language-pure conditions.

However, given the previously reported effects of L1 versus L2 block order (e.g., Branzi et al., 2014; Misra et al., 2012), it is notable that Christoffels et al. (2016) did not focus on the order of the single-language blocks in their study. They report only in a footnote that in their first experiment eight participants started with L1 and ten with L2, but that including block order in the analysis did not show effects of block order. However, this between-subject comparison of block order effects, which was not the focus of Christoffels et al. (2016), is limited by small sample sizes and correspondingly limited statistical power.

Importantly, our study goes beyond that of Christoffels et al. (2016) by examining order effects of L1 versus L2 in the single-language blocks (L1 first vs. L1 second), using a larger sample (n = 50) of German-English unbalanced bilinguals. Specifically, "premixing single-language (i.e., 'pure') blocks" preceded mixed language blocks, which were followed by "postmixing pure blocks." Generally, we expected the typical switch costs and L1 slowing in the mixed blocks, but our focus was on the pre–post comparison of the pure blocks. We expected a sustained L1 slowing in terms of faster L2 naming than L1 naming in pure blocks even after the mixed blocks. Critically, we also compared pure-block performance immediately after the mixed blocks, which is L1 in the L1 first group and L2 in the L1 second group. Hence, we explored whether the L1 slowing is present in the first postmixing pure block after the mixed language block and whether it would persist even into the second postmixing pure block.

2. Method

2.1. Participants

Fifty-four participants aged between 18 and 64 years were tested (M_{age} = 22.72, SD = 7.46, 32 women and 22 men), but data from four participants could not be included in the analyses due to excessive microphone errors (one participant with 13.6% of such trials and three participants with over 50% of all trials), so the final sample size consisted of n = 50 participants (M_{age} = 22.02, SD = 6.54, 18–54 years, 30 women and 20 men). They were mostly psychology students of RWTH Aachen University and participated for partial course credit. They were German native speakers. English is taught in school for all pupils in Germany, and English text reading is often required in psychology university classes. We assessed their proficiency level with subjective self-ratings on a 7-point scale for L2 English with respect to hearing and reading comprehension and speaking and writing ability. As an objective proficiency measure for lexical knowledge, we used a paper and pencil version of the LexTALE for L1 German and L2 English (Lemhöfer & Broersma, 2012). Together, the descriptive data show that the sample consists of unbalanced German-English bilinguals with overall good L2 proficiency (see Table 1).

2.2. Stimuli and procedure

The stimuli were 20 pictures taken from the MultiPic database (Duñabeitia et al., 2018). The stimuli were selected so that their names are noncognates in German and English, with an orthographic Levenshtein Distance of at least 4, that they have similar frequency (*LogFreq*(*Zipf*) > 4) and have one or two syllables (4–12 letters; see Appendix Table A1 for a complete list). Pictures were presented

[1]For example, on the longer term end of this continuum, it has been shown that extended L2 immersion and how bilinguals use their languages (i.e., what their typical interactional contexts are) can have long-term effects on how bilingual interference is regulated (e.g., Beatty-Martínez et al., 2020; Zhang et al., 2021).

https://doi.org/10.1017/S1366728925100874 Published online by Cambridge University Press

Table 1. Description of language proficiency across L1 German and L2 English (mean [SD])

Proficiency measure	L1 (German)	L2 (English)
LexTALE	86.15 (7.26) Range = 62.5–95.0	78.21 (11.69) Range = 55.0–96.25
Subjective self-rating (7-point scale)		
Writing	6.06 (0.97)	4.78 (1.01)
Speaking	6.42 (0.89)	4.92 (1.23)
Hearing	6.48 (0.70)	5.56 (1.10)
Reading	6.60 (0.60)	5.44 (0.92)

Note: LexTALE data are only from 49 participants for both L1 and L2 because one participant did not complete the task, but self-report data are from all 50 participants.

individually in white on a black background (approximately 6 mm high) at the center of a 17-inch screen (Samsung SyncMaster 740B). The German and British national flags (approximately 25 mm × 38 mm) served as language cues. The cues were surrounded by a white margin to be clearly demarcated from the black background. In each trial, four identical flags were presented 8 cm to the left and right and 5.3 cm above and below the target picture, measured from center to center. The target picture was thus enclosed by the cues. Participants were seated in a sound-insulated cabin. The experimenter sat outside the cabin and could hear the participants via headphones. The onset of the vocal naming responses not only was recorded by a voice key (using RockHouse DM-223 microphone), but was also recorded and offline checked for accuracy.

The study was conducted in November and December 2022 in a laboratory setting. Participants first gave their informed consent and signed a data protection document, indicating that their data would be analyzed in a pseudonymized way. Then, they first filled in the subjective proficiency rating scales for German and English followed by the LexTALE tasks.

Then, the participants were instructed that their task would be to name, as fast and correctly as possible, individually presented pictures in German or English as indicated by the national flags. Following these general instructions, the participants were shown all pictures, and the correct names in German and English were explained to achieve naming agreement.

The actual experiment was programmed in PsychoPy3 (Peirce et al., 2019). In an individual trial, the language cue was first presented for 300 ms (i.e., cue–stimulus interval) followed by the target picture, which both remained on the screen until the participants responded by vocally naming it or until maximally 4000 ms elapsed. There was no error feedback. The subsequent response–cue interval was 1000 ms. The actual experiment began with 20 unrecorded practice trials in the same language as the subsequent first single-language pure block, followed by an L1 and L2 pure block of 40 trials each. Half of the participants started with L1 and the other with L2 (L1 First Group vs. L1 Second Group). Note that participants who started with L1 in the premixing pure blocks had L2 in the second block, whereas those participants who started with L2 had L1 in the second block. These "premixing" pure language blocks were followed by four mixed language blocks with 80 trials each. For these mixed language blocks, trial sequence was randomized with the constraints that both languages, language transitions (i.e., switch vs. repeat trial) and their combination occurred equally often. Moreover, in each block, each picture occurred twice for each language, once in a switch trial and once in a repeat trial. Finally, in "postmixing" pure blocks (i.e., after the mixed language blocks), there were again two pure blocks with 40 trials each, which were presented in the same order as at premixing. Participants had the opportunity for a short break between blocks.

2.3. Design

The main analysis focused on the pure blocks at pretest and at posttest as a function of language order of L1 and L2 testing. The independent variables thus were language (L1 vs. L2), time of testing (pretest vs. posttest) and testing order (first pure blocks vs. second pure blocks). Note that participants who started with L1 in the pure blocks had L2 in the second pure blocks, whereas those participants who started with L2 had L1 in the second pure blocks, so that this represents a between-subject comparison. The main dependent variable was RT. We did not analyze error rates because of the low number of errors (<5%), so that we only present the descriptive data on error percentages.

To estimate statistical power, we based our estimation on a recommendation by Brysbaert and Stevens (2018) for mixed effects modeling. They suggested that an experiment should have at least 1600 observations, calculated as the multiplication of the number of participants with the number of observations in each experimental cell for each participant, in order to be sufficiently powered for detecting small-to-medium effects of $d \approx .4$. If we take the 40 trials in the pure blocks as number of observations, with our 50 participants this would result in 2000 observations for within-subject effects. However, given that our design includes a between-subject comparison, we assume that our design is at least sufficiently powered to detect larger effect sizes of $d \approx .8$.[2]

2.4. Transparency and openness

All procedures contributing to this work complied with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975 and its newer versions. We report how we determined our sample size, all data exclusions, all manipulations and all measures in the study. Data were analyzed using R (R Core Team, 2024). This study's design and its analysis were not pre-registered. The data are available at https://doi.org/10.23668/psycharchives.15525.

3. Results

For RT analyses, the error trials and trials following errors were excluded. Furthermore, trials with RTs 2.5 SD above and below the grand mean were discarded as RT outliers. Taking these criteria into account, a total of 12.2% of the RT data was excluded from the mixed language block analysis and 10.3% of the RT data from the pure-block analyses. The RTs were analyzed using linear mixed effects regression modeling (Baayen et al., 2008). Both participants

[2]Considering the between-subject nature of the differential aftereffects of language mixing on L1 and L2 and using independent samples t test procedure of GPower (Faul et al., 2007) as a proxy, our sample size would still allow us to detect between-subject differences with an effect size of $d = .8$ with a sufficient power of .79 when assuming alpha = .05. Yet, note that it is unclear whether simulations with GPower fully transfer to mixed effects modeling, which might have a slightly better power.

https://doi.org/10.1017/S1366728925100874 Published online by Cambridge University Press

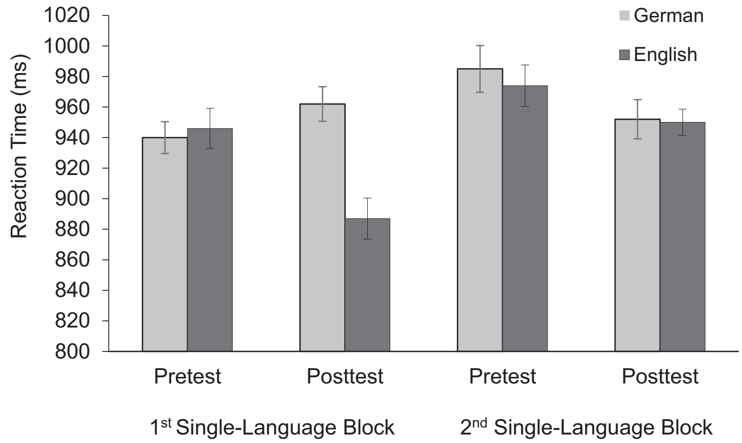


Figure 1. RT data of single-language (pure) blocks based on language (L1 German vs. L2 English), time of test (pretest vs. posttest) and testing order (first single-language block vs. second single-language block). Error bars indicate 95% confidence intervals (Cousineau, 2005).

and items were considered random factors with all fixed effects and their interactions varying by all random factors (Barr et al., 2013). We used the following strategy in case of an issue with the fully randomized model (cf. Barr et al., 2013; Matuschek et al., 2017): We first excluded random effects for the item-specific random slopes, starting with the higher order interactions. If the issue was not resolved, we moved on to the higher order interactions of the participant-specific random slopes. If this did not resolve the issue, we removed lower order terms, again starting with the item-specific random slopes before moving on to the participant-specific random slopes.

We focused on testing order of the pure blocks, examining the effect of pure blocks separately at pretest and at posttest as a function of testing order (see Figure 1). The independent variables thus were language (L1 vs. L2), time of testing (pretest vs. posttest) and testing order (first pure blocks vs. second pure blocks).

Importantly, the results showed a three-way interaction between the three variables (b = 82.14, SE = 32.67, t = 2.515, p < .05), qualifying all main effects and two-way interactions. Therefore, here we focus on the three-way interaction and decompose it as a function of testing order (i.e., first pure blocks vs. second pure blocks), which represents the critical information about the persistence of the aftereffect of mixed language exposure specifically on L1.

Specifically, in the first single-language blocks of the premixing and postmixing blocks, we found no main effect of Language (b = 33.24, SE = 26.20, t = 1.269, p = .209) and Time of Test (b = 19.55, SE = 11.09, t = 1.763, p = .084), but a significant interaction between Language and Time of Test (b = 77.58, SE = 25.76, t = 3.012, p < .01), with no significant RT difference between L1 and L2 in the first premixing block (940 ms vs. 946 ms for L1 vs. L2; b = 6.43, SE = 31.90, t = 0.202, p = .841) but significantly faster L2 (887 ms) than L1 (962 ms) in the postmixing block, after the mixed language blocks (b = 72.29, SE = 27.12, t = 2.666, p < .05).

In contrast, in the second blocks of the premixing and postmixing single-language blocks, we found a significant main effect of Time of Test (b = 33.06, SE = 10.92, t = 3.027, p < .01), with slower responses in the premixing (980 ms) than the postmixing (951 ms) blocks. Yet, there was no significant main effect of Language (b = 6.17, SE = 27.85, t = 0.221, p = .826) and we no longer found a significant interaction between Language and Time of Test (b = 5.04, SE = 23.08, t = 0.218, p = .828). Hence, the L1 slowing effect diminished in the second postmixing block.[3]

For the sake of completeness, we also analyzed the mixed language blocks as a function of Language (L1 vs. L2), Trial Type (switch vs. repetition) and Order (i.e., group starting with L1 vs. with L2). Note that both groups showed very similar performance in the mixed blocks (see Table 2). There was a significant main effect of Language, b = 51.11, SE = 10.45, t = 4.890, p < .001, with longer RTs for L1 than for L2 (1052 ms vs. 999 ms). This indicates a general L1 slowing effect in the mixed language blocks. There was also a significant main effect of Trial Type, b = 47.01, SE = 5.62, t = 8.362, p < .001, with longer RTs for switches than for repetitions (1048 ms vs. 1002 ms). The interaction was also significant, b = 14.42, SE = 6.48, t = 2.226, p < .05, suggesting slightly smaller switch costs for L1 (39 ms) than L2 (54 ms). While the opposite pattern has been observed across several studies, this specific pattern has also been noted more recently (e.g., Bonfieni et al., 2019; Zheng et al., 2020; for meta-analyses, see Gade et al., 2021; Goldrick & Gollan, 2023). Yet, both groups showed a similar pattern, and the main effect and interaction effects of Order were not significant, p > .117.

No detailed analyses were conducted on the error data because these were generally low (<5%) and showed a pattern that did not oppose the interpretation of the RT data. Here we only briefly summarize the basic pattern, averaged across the two language order groups (see Table 3), but for completeness we present the full pattern split by order group in Table A2 in the Appendix.

In the premixing pure blocks the error data showed less errors in L1 than in L2, suggesting generally better performance in L1 than in L2. In postmixing pure blocks, the error rates are fairly similar for L1 and L2, but the reduction from premixing to postmixing was generally larger for L2 than for L1. In the mixed language blocks, error rates are higher in L1 than in L2, but switch costs were fairly

[3]Our focus was on the aftereffect of the mixed language context on subsequent postmixing single-language performance, for which we need the premixing performance as a baseline. Yet, it is interesting to note that we observed some indication for a generic, unspecific blocked language order effect in the premixing blocks. That is, the main effect of Language and the interaction of Language and Block was not significant (p > .8), but RT was generally longer in the second premixing block than in the first premixing block, regardless of whether it was L1 or L2 (b = 39.68, SE = 10.85, t = 3.657, p < .01).

Table 2. Mean performance (RT in ms [SD]) of condition L1 first and condition L1 second in mixed language blocks

	Mixed language blocks		
Group	Repeat trials	Switch trials	Switch costs
L1 first			
L1	1037 (125)	1071 (139)	34
L2	987 (101)	1034 (121)	47
L1 second			
L1	1028 (104)	1072 (102)	44
L2	958 (93)	1018 (106)	60

Table 3. Mean (SD in parentheses) error rates (in %) of condition L1 first and L1 second in pure and mixed language blocks averaged across order groups

		Mixed language blocks		
	Premixing pure block	Repeat trials	Switch trials	Postmixing pure block
L1	3.2 (3.7)	4.0 (4.1)	6.5 (6.0)	2.0 (3.6)
L2	5.0 (7.3)	3.0 (4.6)	5.1 (6.0)	2.1 (4.8)

similar for L1 and L2 (2.5% vs. 2.1%), so that these effects resemble the pattern of RT data very closely.

4. Discussion

The aim of this study was to examine L1 slowing as a measure of proactive language control in cued bilingual picture naming. Specifically, we examined L1 slowing and its persistence from mixed language blocks into subsequent single-language blocks. To this end, using a pretest–posttest design, we first established single-language baseline performance and then examined the aftereffect of subsequent mixed language exposure on final single-language conditions. Moreover, by exploring whether these aftereffects on L1 would appear only immediately after mixed blocks, in the first postmixing pure block, or extend into the second postmixing pure block, we also analyzed how enduring this persisting L1 slowing would be.

In the mixed language blocks, we found language switch costs (which were slightly asymmetric, being larger for L2 than for L1), and, more important for the present purpose, we also found general L1 slowing in both language switches and repetitions. Importantly, in the postmixing pure blocks, there was still L1 slowing, even though this aftereffect diminished in the second postmixing pure block. In the following we first discuss L1 slowing and then turn to its carryover to subsequent pure blocks.

4.1. L1 slowing as a measure of proactive language control

In the mixed language blocks, we found that L1 responses were generally slower than L2 responses, that is, in both switch and repeat trials (L1 slowing, see Christoffels et al., 2007). Finding this "reversed" language dominance is generally in line with the idea that L2 exposure triggers proactive language control to reduce the accessibility of L1 entries in the mental lexicon in a more sustained way to facilitate performing in L2. This relative downregulation of L1 may be particularly important in contexts that require frequent switches from L1 to L2 and back, such as it is required in mixed language blocks (see also Timmer et al., 2019). One difficult question refers to the exact mechanism underlying this L1 downregulation. In line with an inhibitory account, it is suggestive to assume that this downregulation is achieved in terms of inhibition of L1. However, given that a functionally similar effect would be achieved when simply increasing the overall activation of L2 (e.g., Blanco-Elorrieta & Caramazza, 2021; Philipp et al., 2007; for discussion), the mere finding of L1 slowing is consistent with an inhibitory account but does not exclude noninhibitory accounts. Therefore, at this point it seems prudent to remain agnostic about the exact mechanism underlying L1 slowing, whether it is sustained L1 inhibition or sustained competition based on heightened L2 activation (see Declerck & Koch, 2023).

However, it is important to emphasize that L1 slowing in language-switching contexts (i.e., mixed blocks) does not simply represent a short-lived effect of reactive control to overcome language competition in a language switch trial, but that it rather extends to language-repetition trials. In this sense, L1 slowing represents an effect of proactive language control. Yet, repetition trials in mixed language blocks still occur within a time frame of seconds, so that L1 slowing in mixed language blocks might still represent a fairly short-lived effect. Kleinman and Gollan (2018) found that effects of L1 slowing grow over the course of an experiment, but they used mixed language blocks for their analyses, so that the need for reactive control was probably still very recently required in preceding language-switch trials and therefore the degree of persistence of L1 slowing in the absence of the need for reactive control in language switches remained unknown. In this study, we examined the aftereffect of proactive language control in mixed language conditions by testing the carryover of L1 slowing into subsequent single-language block performance.

4.2. Persistence of proactive control: Carryover of L1 slowing

The present data show that L1 slowing still occurred after the mixed language blocks and thus shows a temporally more extended persistence of proactive language control. These findings critically extend an initial report by Christoffels et al. (2016) on the aftereffect of mixed language blocks on subsequent single-language blocks by showing that, in our study, this effect is largely confined to the first postmixing single-language block (40 trials) and diminishes in the second postmixing block.

We found persisting L1 slowing only in the first postmixing pure block, but no longer in the second block. Two issues require consideration. First, we used a relatively small set of 20 pictures that were repeated across the experiment. For example, Misra et al. (2012) argued that item repetition would benefit L2 more than L1. In their study, they found this repetition facilitation across repeated items for L2 but not for L1, suggesting that L2-based downregulation of L1 worked against a similar practice-related facilitation in L1. Similarly, in our study, focusing on the first pure blocks, we found that the pretest–posttest performance difference for L1 (in the L1 First group) was negative (i.e., a slight RT increase by 22 ms), while for L2 there was a substantial gain of 59 ms. Critically, while stronger repetition facilitation effects for L2 than for L1 might be expected, this effect alone could not explain why L2 was actually even 75 ms *faster* than L1 in the first postmixing pure block. This "relative" L1 slowing speaks in favor of a sustained L1 downregulation and cannot be explained simply by stronger repetition effects for L2 alone. This line of argument is also supported by findings of

https://doi.org/10.1017/S1366728925100874 Published online by Cambridge University Press

Degani et al. (2020), showing that detrimental effects of L2 exposure on subsequent L1 performance occurred in the subsequent test phase both for old items and for new transfer items that were introduced only at the test phase (see also first evidence on that issue reported by van Assche et al., 2013). Together, the evidence suggests that L1 slowing based on preceding L2 performance is at least to some degree due to "whole-language control mechanisms" (Degani et al., 2020, p. 173). We would like to note though that L1 slowing and L2 facilitation may represent two sides of the same coin and are thus hard to distinguish, and it is likely that both processes contributed to our findings.

A second issue, intimately tied to the issue of blocked language order, is whether our premixing blocks represent a good "pure" baseline condition. The different (counterbalanced) orders of L1 and L2 seem to have generated already some language order aftereffects. Generally, RT increased slightly from the first to the second block, but this effect was independent of language (i.e., not specific to L1) and thus cannot explain our finding of a large reversed language dominance in the first postmixing single-language block, which we attribute to exposure to the preceding language-mixing context. Moreover, before starting with the actual picture naming experiment, our participants were shown the pictures together with their L1 and L2 names (to ensure naming agreement across participants), and they also performed the LexTALE task, which is a lexical decision task on visually presented words versus nonwords. Thus, some pre-experimental exposure to L2 took place before the actual experiment started, which might have affected language activation. Some researchers suggested to avoid any specific L2 "pretraining" (e.g., Misra et al., 2012), yet our data seem to suggest that the influence of our naming agreement procedure, if any, did at least not wipe out any systematic aftereffects that we did observe in the course of our subsequent picture-naming experiment. In addition, it is less clear whether a different bilingual task, which was nonspeeded, used visual–verbal stimuli and nonvocal, manual responses, would produce significant transfer effects on a subsequent picture-naming task. Future research could examine whether such cross-task transfer represents a critical issue in cued bilingual picture naming.

As a more general point, given the prevalence of bilingual language inputs in times of smartphones and other Internet-based devices, it will be increasingly difficult to assess a pure, "uncontaminated" baseline for L1 (or for L2) performance, given that typical unbalanced bilinguals, at least in Germany and presumably in many other countries, are exposed to bilingual contexts on an everyday basis, which most likely affects how bilinguals regulate bilingual interference (e.g., Beatty-Martínez et al., 2020). Moreover, it might be seen as a potential limitation of this study that we tested only unbalanced German-English bilinguals but no balanced bilinguals, for whom differential aftereffects for L1 and L2 might be less expected. On this background, it is informative to see that the aftereffects of mixed language exposure, in terms of L1 slowing, extended into a subsequent pure block, but it did not persist into the second postmixing pure block. This limit of persistence suggests that 40 trials of picture naming in a single language is sufficient to drive the L1–L2 language balance back into a state in which L1 is again no longer significantly downregulated to favor L2.

In summary, our findings suggest that proactive language control is an important mechanism to reduce the availability of the "dispositionally" dominant L1 to create a current language balance in favor of L2, so that, in the current situation, L2 can become situationally dominant and can, obviously, replace the otherwise dominant L1 as target language. This enables, or at least facilitates, flexible switching and use of more than one language in bilingual speakers. Yet, the reverse side of the coin is that this flexibility is bought at the price of a more enduring bias against L1 which apparently persists across some time (and a good number of trials) even when the proactive bias against L1 is no longer needed. It is interesting to see that this delicate balance of control and interference is similarly discussed in research on nonlinguistic task switching (e.g., Kiesel et al., 2010; Koch et al., 2018; Koch & Kiesel, 2022 for reviews) and suggests that persisting but dissipating aftereffects of control are pervasive across both nonlinguistic task control and bilingual language control.

5. Conclusions

This study showed that performance in mixed language contexts was generally worse for L1 than for L2. This "reversed" language dominance effect suggests the influence of proactive language control to downregulate access to L1 across both switch trials and repeat trials in mixed language blocks in order to facilitate L2 performance. Yet, the most important and novel contribution of this study is that reversed language dominance, as a measure of proactive language control, shows some persistence even into postmixing single-language blocks. Yet, this persistence of L1 downregulation was limited to a first block of 40 trials and did not extend into a second block, suggesting that the bias exerted by proactive control against L1 dissipates within minutes. Hence, language control endows bilingual speakers with remarkable linguistic flexibility, but at the same it seems as if proactive language control can overshoot and produce detrimental aftereffects in L1 performance. That is, language control shows both flexibility and inertia. Future studies will have to examine the time course of proactive language control in more detail in order to get an even better understanding of this delicate balance between flexible control and inflexible temporal inertia of control settings.

Data availability statement. The data that support the findings of this study are openly available in PsychArchives at https://doi.org/10.23668/psycharchives.15525.

Acknowledgements. Parts of these data have been presented at the ESCoP conference in September 2023 in Porto, Portugal. The authors thank Vuslat Karaaslan and Wolfgang Scharke for their help in the study. MD was supported by the Strategic Research Program of the Vrije Universiteit Brussel, Grant No. SRP88. LMS was supported by the Research Foundation – Flanders (FWO), Grant No. FWOTM1127.

Competing interests. The authors declare none.

References

Baayen, R. H., **Davidson, D. J.**, & **Bates, D. M.** (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language*, **59**(4), 390–412. https://doi.org/10.1016/j.jml.2007.12.005.

Barr, D. J., **Levy, R.**, **Scheepers, C.**, & **Tily, H. J.** (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, **68**, 255–278. https://doi.org/10.1016/j.jml.2012.11.001.

Beatty-Martínez, A. L., **Navarro-Torres, C. A.**, **Dussias, P. E.**, **Bajo, M. T.**, **Guzzardo Tamargo, R. E.**, & **Kroll, J. F.** (2020). Interactional context mediates the consequences of bilingualism for language and cognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **46**(6), 1022–1047. https://doi.org/10.1037/xlm0000770.

Blanco-Elorrieta, E., & **Caramazza, A.** (2021). A common selection mechanism at each linguistic level in bilingual and monolingual language production. *Cognition*, **213**, 104625. https://doi.org/10.1016/j.cognition.2021.104625.

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. *Journal of Cognitive Psychology*, **25**, 568–585. https://doi.org/10.1080/20445911.2013.792822.

Bonfieni, M., **Branigan, H. P.**, **Pickering, M. J.**, & **Sorace, A.** (2019). Language experience modulates bilingual language control: The effect of proficiency, age of acquisition, and exposure on language switching. *Acta Psychologica*, **193**, 160–170. https://doi.org/10.1016/j.actpsy.2018.11.004.

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

Brysbaert, M., & **Stevens, M.** (2018). Power analysis and effect size in mixed effects models: A tutorial. *Journal of Cognition*, **1**(1), 9. https://doi.org/10.5334/joc.10.

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**, 1–16. https://doi.org/10.1016/j.cognition.2022.105169.

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.), *Cognitive control and consequences of multilingualism* (pp. 171–192). John Benjamins Publishing Company. https://doi.org/10.1075/bpa.2.08chr.

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

Costa, A., **Caramazza, A.**, & **Sebastian-Galles, N.** (2000). The cognate facilitation effect: Implications for models of lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **26**(5), 1283–1296. https://doi.org/10.1037/0278-7393.26.5.1283.

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.

Cousineau, D. (2005). Confidence intervals in within-subject designs: A simpler solution to Loftus and Masson's method. *Tutorial in Quantitative Methods for Psychology*, **1**(1), 4–45. http://doi.org/10.20982/tqmp.01.1.p042.

de Bruin, A. (2019). Not all bilinguals are the same: A call for more detailed assessments and descriptions of bilingual experiences. *Behavioral Sciences*, **9**, 33. https://doi.org/10.3390/bs9030033.

Declerck, M. (2020). What about proactive language control? *Psychonomic Bulletin & Review*, **27**, 24–35. https://doi.org/10.3758/s13423-019-01654-1.

Declerck, M., & **Koch, I.** (2023). The concept of inhibition in bilingual control. *Psychological Review*, **130**(4), 953–976. https://psycnet.apa.org/doi/10.1037/rev0000367.

Declerck, M., & **Philipp, A. M.** (2015). A review of control processes and their locus in language switching. *Psychonomic Bulletin & Review*, **22**, 1630–1645. https://doi.org/10.3758/s13423-015-0836-1.

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**, 153–183. https://doi.org/10.1017/S0142716419000444.

Degani, T., **Kreiner, H.**, & **Declerck, M.** (2024). L1 production following brief L2 exposure: Evidence for cross-talk across comprehension and production. *Psychonomic Bulletin & Review*, **32**(2), 749–759. https://doi.org/10.3758/s13423-024-02572-7.

Duñabeitia, J. A., **Crepaldi, D.**, **Meyer, A. S.**, **New, B.**, **Pliatsikas, C.**, **Smolka, E.**, & **Brysbaert, M.** (2018). MultiPic: A standardized set of 750 drawings with norms for six European languages. *Quarterly Journal of Experimental Psychology*, **71**(4), 808–816. https://doi.org/10.1080/17470218.2017.1310261.

Faul, F., **Erdfelder, E.**, **Lang, A.-G.**, & **Buchner, A.** (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, **39**, 175–191. https://doi.org/10.3758/BF03193146.

Finkbeiner, M., **Almeida, J.**, **Janssen, N.**, & **Caramazza, A.** (2006). Lexical selection in bilingual speech production does not involve language suppression. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **32**(5), 1075–1089. https://doi.org/10.1037/0278-7393.32.5.1075.

Gade, M., **Declerck, M.**, **Philipp, A. M.**, **Rey-Mermet, A.**, & **Koch, I.** (2021). On the existence of asymmetrical switch costs and reversed language dominance. *Journal of Cognition*, **4**, 55. https://doi.org/10.5334/joc.186.

Goldrick, M., & **Gollan, T.** (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.

Green, D. W. (1998). Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and Cognition*, **1**, 213–229. 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**, 515–530. https://doi.org/10.1080/20445911.2013.796377.

Grosjean, F. (2010). *Bilingual: Life and reality*. Harvard University Press. https://doi.org/10.4159/9780674056459.

Guo, T., **Liu, H.**, **Misra, M.**, & **Kroll, J. F.** (2011). Local and global inhibition in bilingual word production: fMRI evidence from Chinese–English bilinguals. *NeuroImage*, **56**, 2300–2309. https://doi.org/10.1016/j.neuroimage.2011.03.049.

Heikoop, K. W., **Declerck, M.**, **Los, S. A.**, & **Koch, I.** (2016). Dissociating language-switch costs from cue-switch costs in bilingual language switching. *Bilingualism: Language and Cognition*, **19**, 921–927. https://doi.org/10.1017/S1366728916000456.

Ivanova, I., **Seanez, A.**, **Cochran, M.**, & **Kleinman, D.** (2023). The temporal dynamics of bilingual language control. *Psychonomic Bulletin & Review*, **30**(2), 774–791. https://doi.org/10.3758/s13423-022-02168-z.

Kałamała, P., **Chuderski, A.**, **Szewczyk, J.**, **Senderecka, M.**, & **Wodniecka, Z.** (2023). Bilingualism caught in a net: A new approach to understanding the complexity of bilingual experience. *Journal of Experimental Psychology: General*, **152**(1), 157–174. https://doi.org/10.1037/xge0001263.

Kiesel, A., **Wendt, M.**, **Jost, K.**, **Steinhauser, M.**, **Falkenstein, M.**, **Philipp, A. M.**, & **Koch, I.** (2010). Control and interference in task switching: A review. *Psychological Bulletin*, **136**, 849–874. https://doi.org/10.1037/a0019842.

Kleinman, D., & **Gollan, T. H.** (2018). Inhibition accumulates over time at multiple processing levels in bilingual language control. *Cognition*, **173**, 115–132. https://doi.org/10.1016/j.cognition.2018.01.009.

Koch, I., **Declerck, M.**, **Petersen, G.**, **Rister, D.**, **Scharke, W.**, & **Philipp, A. M.** (2024). Re-assessing the role of language dominance in n-2 language repetition costs as a marker of inhibition in multilingual language switching. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **50**(9), 1516–1528. https://doi.org/10.1037/xlm0001333.

Koch, I., **Gade, M.**, **Schuch, S.**, & **Philipp, A. M.** (2010). The role of inhibition in task switching: A review. *Psychonomic Bulletin & Review*, **17**, 1–14. https://doi.org/10.3758/PBR.17.1.1.

Koch, I., & **Kiesel, A.** (2022). Task switching: Cognitive control in sequential multitasking. In A. Kiesel, L. Johannsen, I. Koch & H. Müller (Eds.), *Handbook of human multitasking* (pp. 85–144). Springer. https://doi.org/10.1007/978-3-031-04760-2_3

Koch, I., **Poljac, E.**, **Müller, H.**, & **Kiesel, A.** (2018). Cognitive structure, flexibility, and plasticity in human multitasking – An integrative review of dual-task and task-switching research. *Psychological Bulletin*, **144**, 557–583. https://doi.org/10.1037/bul0000144.

Kroll, J. F., **Bobb, S. C.**, **Misra, M. M.**, & **Guo, T.** (2008). Language selection in bilingual speech: Evidence for inhibitory processes. *Acta Psychologica*, **128**, 416–430. https://doi.org/10.1016/j.actpsy.2008.02.001.

Lemhöfer, K., & **Broersma, M.** (2012). Introducing LexTALE: A quick and valid lexical test for advanced learners of English. *Behavior Research Methods*, **44**, 325–343. https://doi.org/10.3758/s13428-011-0146-0.

Marian, V., & **Hayakawa, S.** (2021). Measuring bilingualism: The quest for a "bilingualism quotient". *Applied PsychoLinguistics*, **42**(2), 527–548. https://doi.org/10.1017/S0142716420000533.

Matuschek, H., **Kliegl, R.**, **Vasishth, S.**, **Baayen, H.**, & **Bates, D.** (2017). Balancing type I error and power in linear mixed models. *Journal of Memory and Language*, **94**, 305–315. https://doi.org/10.1016/j.jml.2017.01.001.

Meade, G., **Midgley, K. J.**, **Sehyr, Z. S.**, **Holcomb, P. J.**, & **Emmorey, K.** (2017). Implicit co-activation of American sign language in deaf readers: An ERP study. *Brain and Language*, **170**, 50–61. https://doi.org/10.1016/j.bandl.2017.03.004.

Meuter, R. F. I., & **Allport, A.** (1999). Bilingual language switching in naming: Asymmetrical costs of language selection. *Journal of Memory and Language*, **40**, 25–40. https://doi.org/10.1006/jmla.1998.2602.

Misra, M., **Guo, T.**, **Bobb, S. C.**, & **Kroll, J. F.** (2012). When bilinguals choose a single word to speak: Electrophysiological evidence for inhibition of the native language. *Journal of Memory and Language*, **67**(1), 224–237. https://doi.org/10.1016/j.jml.2012.05.001.

Peeters, D., & **Dijkstra, T.** (2018). Sustained inhibition of the native language in bilingual language production: A virtual reality approach. *Bilingualism: Language and Cognition*, **21**, 1035–1061. https://doi.org/10.1017/S1366728917000396.

Peirce, J., **Gray, J. R.**, **Simpson, S.**, **MacAskill, M.**, **Höchenberger, R.**, **Sogo, H.**, **Kastman, E.**, & **Lindeløv, J. K.** (2019). PsychoPy2: Experiments in behavior made easy. *Behavior Research Methods*, **51**(1), 195–203. https://doi.org/10.3758/s13428-018-01193-y.

Philipp, A. M., **Gade, M.**, & **Koch, I.** (2007). Inhibitory processes in language switching: Evidence from switching language-defined response sets. *European Journal of Cognitive Psychology*, **19**, 395–416. https://doi.org/10.1080/09541440600758812.

R Core Team. (2024). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing.

Timmer, K., **Christoffels, I. K.**, & **Costa, A.** (2019). On the flexibility of bilingual language control: The effect of language context. *Bilingualism: Language and Cognition*, **22**(3), 555–568. 10.1017/S1366728918000329.

Treffers-Daller, J. (2019). What defines language dominance in bilinguals? *Annual Review of Linguistics*, **5**, 375–393. 10.1146/annurev-linguistics-011817-045554.

van Assche, E., **Duyck, W.**, & **Gollan, T. H.** (2013). Whole-language and item-specific control in bilingual language production. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **39**(6), 1781–1792. https://doi.org/10.1037/a0032859.

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 K. D. Federmeier and H. Huang (Eds.), *Psychology of learning and motivation* (Vol. **72**, pp. 235–281). Elsevier Academic Press.

Wolna, A., **Szewczyk, J.**, **Diaz, M.**, **Domagalik, A.**, **Szwed, M.**, & **Wodniecka, Z.** (2024). 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.

Zhang, H., **Diaz, M. T.**, **Guo, T.**, & **Kroll, J. F.** (2021). Language immersion and language training: Two paths to enhanced language regulation and cognitive control. *Brain and Language*, **223**, 105043. https://doi.org/10.1016/j.bandl.2021.105043.

Zheng, X., **Roelofs, A.**, **Erkan, H.**, & **Lemhöfer, K.** (2020). Dynamics of inhibitory control during bilingual speech production: An electrophysiological study. *Neuropsychologia*, **140**, 107387. https://doi.org/10.1016/j.neuropsychologia.2020.107387.

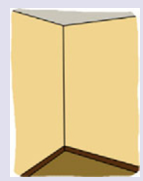
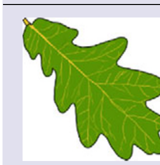
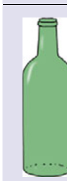
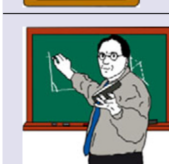
Appendix

Table A1. Selection of stimuli

	Name in German	Name in English
	Dusche	Shower
	Wüste	Desert

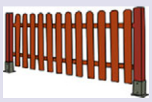
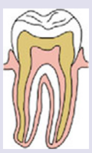
(*Continued*)

Table A1. (*Continued*)

	Name in German	Name in English
	Dach	Roof
	Pferd	Horse
	Stuhl	Chair
	Ecke	Corner
	Blume	Flower
	Blatt	Leaf
	Geschenk	Present
	Spiegel	Mirror
	Flasche	Bottle
	Schloss	Lock
	Lehrer	Teacher

(*Continued*)

Table A1. (*Continued*)

	Name in German	Name in English
	Seil	Rope
	Zaun	Fence
	Frühstück	Breakfast
	Zahn	Tooth
	Fenster	Window
	Kleid	Dress
	Brille	Glasses

(*Continued*)

Table A2. Mean (SD in parentheses) error rates (in %) of condition L1 first and L1 second in pure and mixed language blocks

	Premixing pure block		Mixed language blocks			Postmixing pure block	
Group	1	2	Repeat trials	Switch trials	Switch costs	1	2
L1 first							
L1	3.2 (3.6)		3.2 (4.9)	5.2 (5.4)	2.0	1.3 (2.2)	
L2		5.1 (8.5)	3.1 (4.7)	4.8 (6.8)	1.7		1.9 (4.0)
L1 second							
L1		2.9 (3.8)	4.9 (4.3)	7.7 (6.3)	2.8		2.6 (4.6)
L2	4.9 (6.0)		2.8 (4.6)	5.4 (5.3)	2.6	2.2 (5.5)	

https://doi.org/10.1017/S1366728925100874 Published online by Cambridge University Press