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Reversed asymmetrical switch costs in voluntary language switching - Evidence from typed responses

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Abstract

Aims and Objectives/Purpose/Research Questions: Prior research has put forward that asymmetrical switch costs in language switching do not occur when bilinguals are in a voluntary language switching context. While several studies have provided evidence along these lines, two very recent studies have put this into question. This study further investigates the possibility that voluntary language switching abolishes asymmetrical switch costs.

Design/Methodology/Approach: We presented German-English bilinguals ($n = 79$) with pictures that had to be named in either German or English, whichever they chose, by typing.

Data and Analysis: Reaction times (both the latency of the first keystroke and inter-keystroke intervals) were analyzed using linear mixed-effects regression modeling with the factors Trial type (switch vs. repetition trial) and Language (German vs. English), whereas the error rates were analyzed using logistic mixed-effects regression modeling.

Findings/Conclusions: The onset latencies and inter-keystroke intervals both showed larger second language (English) than first language (German) switch costs (i.e., reversed asymmetrical switch costs). As switch costs were modulated by language dominance in a voluntary language switching context, this study provides evidence that voluntary language switching is not a boundary condition for asymmetrical switch costs.

Originality: In contrast to most previous language-switching studies, we used typed rather than vocal responses in a voluntary language-switching paradigm. Additionally, our findings further support and generalize very recent findings of (reversed) asymmetrical switch costs in voluntary language switching.

Significance/Implications: Since asymmetrical switch costs, an important measure of bilingual inhibitory control, are not consistently observed throughout the language switching literature, it is essential to understand its boundary conditions.

Keywords: Bilingualism; Voluntary language switching; Asymmetrical switch costs; Typing

Introduction

Since bilinguals tend to activate both languages (e.g., Costa et al., 2000; Hoshino & Kroll, 2008), even when the goal is to solely process the target language, cross-language interference can impede bilingual language production. The process that is implemented to reduce cross-language interference, namely language control, is typically assumed to rely on inhibition of the non-target language (e.g., Grainger et al., 2010; Green, 1998; Declerck et al., 2015). The most prominent effect related to bilingual inhibitory control, and thus of great theoretical importance, are asymmetrical switch costs. Asymmetrical switch costs entail worse performance when switching to the first language (L1) than to the second language (L2), relative to staying in the same language. While much has been written about this effect (for reviews, see Bobb & Wodniecka, 2013; Declerck & Koch, 2023; Gade et al., 2021), the boundary conditions (i.e., circumstances/characteristics that make it unlikely or likely to observe the effect) of asymmetrical switch costs are still very much unclear (for a discussion, see Declerck & Koch, 2023). One of the few boundary conditions that seemed to hold up across studies was voluntary language switching, a situation in which bilinguals can choose whichever language to use at any given point. However, recently this boundary condition for asymmetrical switch costs has been put into question (Liu et al., 2021; Sánchez et al., 2022). In the current study, we set out to further investigate asymmetrical switch costs during voluntary language switching. Unlike prior studies that mainly relied on vocal responses, the current study set out to investigate this issue with typed responses.

In a language switching task, bilingual participants are usually asked to name pictures in either of their two languages based on a visual cue (e.g., differently colored backgrounds for each language; e.g., Costa & Santesteban, 2004; Declerck et al., 2012; Meuter & Allport, 1999; Peeters & Dijkstra, 2018). In contrast to cued language switching, participants can choose the target

language to name each picture in a voluntary language switching task (Blanco-Elorrieta & Pyllkänen, 2017; de Bruin et al., 2018, 2020; Gollan et al., 2014; Gollan & Ferreira, 2009; Gross & Kaushanskaya, 2015; Grunden et al., 2020; Jevtović et al., 2019; Kleinman & Gollan, 2016; Liu et al., 2020, 2021; Sánchez et al., 2022; Reverberi et al., 2018; see also Declerck & Kirk, 2023). Along the lines of other variants of the language switching paradigm, such as cued language switching (e.g., Costa & Santesteban, 2004; Declerck et al., 2012; Meuter & Allport, 1999), switching languages across trials usually leads to a cost when bilinguals can freely choose which language to use on each trial, relative to when the same language is used in two subsequent trials (e.g., de Bruin et al., 2018, 2020; Gollan et al., 2014; Grunden et al., 2020; Jevtović et al., 2019; however, see Blanco-Elorrieta and Pyllkänen, 2017). This switch cost effect has been taken as a measure of language control (e.g., Declerck & Philipp, 2015a; Green, 1998).

Another measure of language control, more specifically of inhibitory control on the non-target language, that has been found with several variants of language switching is an asymmetry of switch costs across languages, with L1 switch costs generally being larger than L2 switch costs (e.g., Meuter & Allport, 1999; Macizo et al., 2012; Philipp et al., 2007). This pattern is typically explained by assuming that producing in a specific language requires the inhibition of the non-target language (Green, 1998; Meuter & Allport, 1999). This inhibition is assumed to persist into the next trial, making it more difficult when switching to a language that was recently inhibited (switch trials) than staying in the same language (repetition trial). Furthermore, bilinguals are assumed to apply more inhibition on their L1 when producing in their L2 than vice versa, because L1 should have a higher base activation and thus cause more cross-language interference. In turn, it will be more effortful to overcome the prior inhibition when switching back to L1 than when switching back to L2.

While asymmetrical switch costs are the most prominent effect in the language control literature, this pattern is not always found (Bobb & Wodniecka, 2013; Declerck & Koch, 2023; Gade et al., 2021). Hence, one area of research has looked into the conditions in which this effect is present and the conditions under which it is absent. Regarding the latter, it has long been proposed that voluntary language switching is one of the few boundary conditions that results in consistently absent asymmetrical switch costs (i.e., symmetrical switch costs), as such a pattern was typically not observed in a multitude of voluntary language switching studies (e.g., de Bruin et al., 2018, 2020; Gollan & Ferreira, 2009; Grunden et al., 2020; Jevtović et al., 2019). It should be noted that several of the voluntary language switching studies that observed symmetrical switch costs relied on highly proficient bilinguals, which could have led to this pattern regardless of whether a cued or voluntary language switching paradigm is used (e.g., Costa et al., 2006; Costa & Santesteban, 2004). Though, this was not the case for all voluntary language switching studies that observed symmetrical switch costs (e.g., Liu et al., 2020; Reverberi et al., 2018).

Unlike these studies, two recent voluntary language switching studies did observe an asymmetry of switch costs across languages (Liu et al., 2021; Sánchez et al., 2022). In Liu et al. (2021), 33 Chinese-English bilinguals performed a production-based voluntary language switching experiment that was interspersed with comprehension trials (Experiment 1: passive listening to words; Experiment 2: animacy judgment task). Their results showed asymmetrical switch costs when producing language in Experiment 1 and symmetrical switch costs in Experiment 2. The animacy judgement task in Experiment 2 resulted in reversed asymmetrical switch costs (i.e., larger L2 than L1 switch costs). The latter pattern was also observed by Sánchez and colleagues (2022). In this study, 28 Spanish-English bilinguals were asked to describe the route of a dot over a network of different types of lines and pictures in either language on a

voluntary switching basis. This sentence production study also showed larger L2 than L1 switch costs.¹ Together, these two recent studies indicate that switch costs might be modulated by language dominance in a voluntary language switching setting.

Current study

To further investigate the possibility of (reversed) asymmetrical switch costs during voluntary language switching, we set out to investigate a relatively large group of German-English bilinguals. This would help us determine whether voluntary language switching is a boundary condition for asymmetrical switch costs.

Unlike the studies discussed above, we relied on typed responses instead of spoken responses to further increase the generalizability of (a)symmetrical switch costs during voluntary language switching. A recent study has indicated that switch costs can be observed when bilinguals type their responses in a cued language switching experiment (Römbke et al., 2023; for a similar effect with handwriting, see Wong & Maurer, 2021). While many similarities can be observed between spoken and typed responses, prior research has also indicated distinct differences (e.g., Pinet & Nozari, 2018; Scaltritti et al., 2016, 2018). For instance, based on a finger-twisting task, Pinet and Nozari (2018) provided evidence for feedback between postlexical and lexical layers during typing, similar to what has been suggested during spoken production (e.g., Dell, 1984). Yet, this study also showed differences between typing and speaking. The authors observed a substantial number of phonotactic violations during typing, a phenomenon that is hardly ever observed in studies focused on spoken production (e.g., Warker & Dell, 2006). This finding

¹ This reversed asymmetrical switch cost pattern has also been found in non-voluntary language switching studies (e.g., Declerck, Stephan, et al., 2015; Zheng et al., 2020; see also Struck & Jiang, 2021), and has been explained through instances that make L2 the more dominant language.

indicates differences in postlexical representations between typing and writing. The latter finding is important, as prior studies of language switching have observed evidence for an important role of postlexical representations (e.g., Declerck & Philipp, 2015b). Moreover, the fact that other intrinsic differences have been observed across studies that focused on spoken and typed production that have not been investigated but might also influence language control (e.g., Scaltritti et al., 2018), indicates the necessity to generalize production-based language control to other modalities than spoken production, such as typing.

Method

Participants

88 German natives that spoke English as a second language took part in this study. Six of these participants were not taken into the final analyses because they had not finished the experiment and another two participants were not included due to an excess of errors (> 40%). Finally, one participant was not included in the final analysis due to a very low number of language switches (< 1%). The remaining 79 German-English bilingual participants consisted out of 38 woman and 41 men that were on average 23.4 years old ($SD = 3.2$). Prior to the main experiment, the participants also filled in a questionnaire about their English experience and proficiency (see Table 1). Participants were rewarded with 8€/h (as the experiment was combined with two other, completely independent experiments (cf. section Procedure), the total payment for a participant was between 24 and 30 €).

Table 1. Overview of the demographic information (SD in brackets). The information consists of the average years of formal English education, English age-of-acquisition, and average self-rated scores for speaking, understanding, writing, and reading English.

	English
Formal education (years)	8.6 (1.9)
Age-of-acquisition (years)	10.5 (1.2)
Speaking *	5.0 (1.2)
Understanding *	5.7 (1.1)
Writing *	4.8 (1.3)
Reading *	5.8 (1.1)

* 1 being *very bad* and 7 being *very good*

Materials and task

Ten pictures (black line drawings, Snodgrass & Vanderwart, 1980) were used in this study, each name of which consisted of five letters in German (word frequency per million: 41.6; Brysbaert et al., 2011) and in English (word frequency per million: 84.7; Brysbaert & New, 2009; see appendix for an overview of the picture names in German and English). To make sure we had enough stimuli that had an equal number of letters in both languages, half of the names were cognates. Additional analyses with cognate status added as a factor to each of the analyses showed that cognate status did not significantly influence the switch costs or their asymmetry ($t_s < 1.551$; $z_s < 0.925$), similar to several other spoken production studies (e.g., Santesteban & Costa, 2016; Verhoef et al., 2009; see also Li & Gollan, 2018). Hence, we did not include this factor in the final analysis.

Procedure

The study reported here was conducted in combination with two other studies. The other two tasks involved a persistence task (symbol coding) and a decision-making task and, thus, are completely independent from the language-switching experiment. Testing sessions were conducted with four participants sitting in a 24 m² room, with desks oriented to the walls in order to minimize distraction and/or interaction. Including breaks of 15 min between each sub-study, the whole testing session lasted for about three hours on average. The three parts were balanced using a latin-square approach. Prior to starting the sessions, participants gave written informed consent, and the study was conducted in accordance with the declaration of Helsinki.

The language-switching experiment started off with the instructions. The instructions for the voluntary language switching, which was run based on E-Prime, entailed the following: “When naming the pictures, you should always switch back and forth between German and English and decide for yourself when and how often you change the language. However, make sure that you use both languages about equally often and avoid a fixed rhythm, such as changing the language after every (second) picture.” Participants were also informed that each word contained five letters and that corrections were not possible. Furthermore, we asked the participants to type all letters in lower case (even the first letters for the German words) on a German QWERTZ keyboard. Participants did not receive visual feedback when typing.

Following the instructions, a practice block was presented in which each picture was presented twice for a total of 20 trials. Finally, the 14 experimental blocks, with 40 trials each (total number of trials per participant = 560), were presented. In each of the experimental blocks, every picture was presented four times.

Each trial started with a fixation cross in the middle of the 22"-screen (white background colour, viewing distance approximately 60 cm). The fixation cross was replaced by a picture after 500 ms. The picture was visible while participants typed their response and disappeared after the participant's last (i.e., fifth) keystroke, which in turn was followed by the next trial after 1000 ms.

Data analyses

The first trial in each block (2.5% of all data) was excluded from the reaction time (RT) and error rate analyses because these were neither switch nor repetition trials. In the RT analyses, error trials and trials immediately following an error were excluded (17.6% of all data), as were trials with an RT faster than 20 ms or 2.5 standard deviations below and above the mean of each keystroke across participants (4.2% of the data for onset latencies and 1.7% of the data for inter-keystroke intervals).

A separate RT analysis was conducted for onset latencies, which consisted of the interval between picture onset and the first keystroke, and inter-keystroke intervals, which consisted of the intervals between consecutive keystrokes while producing a word (e.g., keystroke 1 -> keystroke 2 and keystroke 2 -> keystroke 3; cf. Scaltritti et al., 2016), with factors Trial type (switch vs. repetition trial) and Language (German vs. English). The latter is a novel dependent variable that has not been used in language switching research yet, but can provide additional insight into whether language control also affects the actual execution of a word. Finally, one overall error analysis was conducted with the factors Trial type (switch vs. repetition trial) and Language (German vs. English), since assigning errors to a keystroke (initial vs. keystroke 2-5) is not always straightforward because mistakes were sometimes made at several keystrokes or a keystroke was missing. Furthermore, most of these more specific analyses would be underpowered due to a lack

of errors. In total, we had 43.134 data points across all participants to analyze error data, 33.490 data points across all participants to analyze the onset latencies data, and 138.478 data points across all participants to analyze the inter-keystroke intervals data.

The RTs were analyzed using linear mixed-effects regression modeling, whereas the error rates were analyzed using logistic mixed-effects regression modeling. Both participants and items were considered random factors with all fixed effects and their interactions varying by all random factors. Yet, convergence and singularity issues were taken into account.² We used effect coding for all two-level factors (i.e., -0.5 and 0.5). Finally, t - and z -values larger or equal to 1.96 were deemed significant (Baayen, 2008).

Results

Before we discuss the analyses, we first provide an overview of the switch rate. The overall switch rate was 38.7%, which entails that 38.7% of trials were in a different language than the previous trial. When dividing the data up based on language, we observed a somewhat higher switch rate for English (42.9%) than for German (35.2%) trials.

Table 2. Average error rates in percentage (SE in brackets) as a function of Trial type (switch vs. repetition trial) and Language (German vs. English).

	German	English
Switch	8.2 (1.0)	7.8 (0.5)

² The following strategy will be used in case of an issue with the fully randomised model (cf. Barr et al., 2013; Matuschek et al., 2017): We first exclude random effects for the item-specific random slopes, starting with the higher-order interactions. If the issue is not resolved, we move on to the higher-order interactions of the participant-specific random slopes. If this does not resolve the issue, then we remove lower-order terms, again starting with the item-specific random slopes before moving on to the participant-specific random slopes.

Repetition	7.6 (0.5)	7.6 (0.5)
Switch costs	0.6	0.2

In the error rate analysis, no effects were significant ($z_s < 1.212$; see Table 2).

The RT analysis of the onset latencies showed a significant effect of Trial type, $b = 26.24$, $SE = 2.95$, $t = 8.888$, with slower responses in switch (447 ms) than repetition (424 ms) trials (see Table 3). No significant overall difference was observed between German and English trials, $b = 3.97$, $SE = 5.70$, $t = 0.696$. However, the interaction between Trial type and Language was significant, $b = 11.57$ $SE = 5.14$, $t = 2.249$, with larger English (29 ms) than German (17 ms) switch costs.

Table 3. Average RTs in ms (SE in brackets) for onset latencies and inter-keystroke intervals, as a function of Trial type (switch vs. repetition trial) and Language (German vs. English).

	German	English
Onset latencies		
Switch	447 (14)	446 (14)
Repetition	428 (14)	417 (13)
Switch costs	17	29
Inter-keystroke intervals		
Switch	138 (3)	147 (3)
Repetition	139 (3)	145 (4)
Switch costs	-1	2

In the RT analysis of the inter-keystroke intervals, a significant effect of Trial type was observed, $b = 0.77$, $SE = 0.37$, $t = 2.065$, with slower responses in switch (142 ms) than in repetition (141 ms) trials. A significant effect of Language was also found, $b = 10.24$, $SE = 0.31$, $t = 33.581$, with slower English (146 ms) than German (138 ms) responses. Finally, the interaction between Trial type and Language was significant, $b = 1.22$, $SE = 0.61$, $t = 2.014$, with larger English (2 ms) than German (-1 ms) switch costs.

Discussion

In the present study, we investigated asymmetrical switch costs during voluntary language switching with typed responses. The results showed that switch costs can be modulated by language dominance in a voluntary language switching setting. More specifically, we observed reversed asymmetrical switch costs (i.e., L2 switch costs > L1 switch costs) in both the onset latencies and inter-keystroke intervals.

(Reversed) Asymmetrical switch costs

So, in line with Liu et al. (2021) and Sánchez et al. (2022), we found that switch costs can be modulated by language dominance in a voluntary language switching setting, resulting in larger switch costs for L2 compared to L1. This is, however, not in line with the voluntary language switching studies that came before those studies, which all observed symmetrical switch costs (de Bruin et al., 2018, 2020; Gollan & Ferreira, 2009; Gollan et al., 2014; Gross & Kaushanskaya, 2015; Grunden et al., 2020; Jevtović et al., 2019). One possible explanation for this discrepancy across voluntary language switching studies is that studies that observed symmetrical switch costs typically relied on highly proficient bilinguals, whereas the three studies that observed (reversed) asymmetrical switch costs relied on participants that would more likely be characterized as second

language learners (Declerck & Koch, 2023). Prior research has indicated that highly proficient bilinguals tend to show symmetrical switch costs and second language learners asymmetrical switch costs (e.g., Costa et al., 2006; Costa & Santesteban, 2004). This explanation could clarify the discrepancy across studies, and thus also indicate that voluntary language switching is not a boundary condition for asymmetrical switch costs.

That still leaves the question of why the asymmetrical switch cost pattern was reversed (L2 switch costs > L1 switch costs) in the current study from what is typically observed (L1 switch costs > L2 switch costs) in non-voluntary language switching studies (e.g., when using cued language switching or alternating language sequences). Yet, larger L2 than L1 switch costs is not unique to voluntary language switching. There have been several language switching studies that relied on other variants of language switching that also observed a reversed asymmetrical switch cost pattern (e.g., Declerck, Stephan, et al., 2015; Timmer et al., 2019; Zheng et al., 2020). These studies typically explained this pattern through conditions that make L2 the relatively more activated language, for instance through L1 proactive language control or through a high L2 proficiency/exposure. While it seems unlikely that the reversed asymmetrical switch cost pattern in the current study is due to a very high L2 proficiency/exposure, since these were second language learners that lived in Germany and were tested by a German experimenter at a German speaking university, it could very well be that the participants implemented L1 proactive language control throughout the experiment to make both languages equally accessible. An argument against this explanation is that one would expect to observe overall faster L2 than L1 responses if this were the case. However, it could very well be that the typical language dominance pattern (i.e., faster L1 than L2 responses) would only be slightly affected by L1 proactive language control,

which in turn would not necessarily result in overall faster L2 than L1 responses (cf. Declerck et al., 2020).

Another possibility is that the bilinguals strategically avoided producing the more “difficult” words (e.g., words with a low word frequency) in their L2, and thus chose to mainly produce these in their L1 (Gollan & Ferreira, 2009; Sánchez et al., 2022). The choice to produce these “difficult” words in their L1 would stem from the fact that these words should be easier to produce in their L1 than their L2, since their L1 is the more dominant and more used language. Together, this should result in a relatively higher L2 activation, at least for the words used in the task. According to the inhibitory account of asymmetrical switch costs (Green, 1998; Meuter & Allport, 1999), this should lead to more inhibition on L2, and thus result in more persisting inhibition to overcome for L2 than L1 switch trials. In turn, larger L2 than L1 switch costs should be observed, which was the case in the current study.

Language control can also affect execution

It is typically assumed that language control is implemented during word selection, and thus prior to execution. Our results show that language control can also have an influence on the execution process of language production. More specifically, switch costs and their reversed asymmetry were also observed in the inter-keystrokes (i.e., the intervals between the five keystrokes). Since the word should already be selected at this point, this indicates that execution is also affected by language control.

There are several ways of interpreting this result. On the one hand, it could be that there is spillover of language control from the word selection process into the execution process. On the other hand, it could be that language control has a direct influence on language execution. While

the current study does not provide evidence for either interpretation, there is some evidence along the lines of the latter: Using a go/no-go delay (100 ms or 1500 ms) setup in a language switching task, Philipp and Koch (2016) showed that when a response was selected, but not produced, no switch costs were observed in the next trial. On the other hand, when the response was produced, substantial switch costs were observed. While this indicates that language control can occur at the execution level, it does not preclude the possibility that there is spillover from word selection to execution.

Conclusion

Prior research seemed to indicate that voluntary language switching is a boundary condition of asymmetrical switch costs. More specifically, for some time no asymmetrical switch costs (i.e., symmetrical switch costs) had been observed when bilinguals performed a voluntary language switching task. Yet, two recent voluntary language switching studies did find (reversed) asymmetrical switch costs (Liu et al., 2021; Sánchez et al., 2022). In the current study, we set out to further investigate this issue. Based on both onset latencies and inter-keystroke intervals of typed responses, we observed (reversed) asymmetrical switch costs (i.e., larger L2 than L1 switch costs). These results indicate that switch costs can be modulated by language dominance while in a voluntary language switching context.

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Declaration of Conflicting Interest

The authors declare that there is no conflict of interest.

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Appendix

German	English
Blitz	Flash
Geist	Ghost
Honig	Honey
Licht	Light
Pferd	Horse
Rauch	Smoke
Schal	Scarf
Stuhl	Chair
Tish	Table
Wolke	Cloud