LANGUAGE, COGNITION AND NEUROSCIENCE, 2018
VOL. 33, NO. 2, 139–147
https://doi.org/10.1080/23273798.2017.1363401

Routledge
Taylor & Francis Group

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Language selection errors in switching: language priming or cognitive control?

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ABSTRACT

Although bilingual speakers are very good at selectively using one language rather than another, sometimes language selection errors occur. We examined the relative contribution of top-down cognitive control and bottom-up language priming to these errors. Unbalanced Dutch-English bilinguals named pictures and were cued to switch between languages under time pressure. We also manipulated the number of same-language trials before a switch (long vs. short runs). Results show that speakers made more language selection errors when switching from their second language (L2) to the first language (L1) than vice versa. Furthermore, they made more errors when switching to the L1 after a short compared to a long run of L2 trials. In the reverse switching direction (L1 to L2), run length had no effect. These findings are most compatible with an account of language selection errors that assigns a strong role to top-down processes of cognitive control.

ARTICLE HISTORY
Received 27 January 2017
Accepted 27 July 2017

KEYWORDS
Language switching; language selection errors; cognitive control; language priming; switch cost asymmetry

Introduction

When you go to a Dutch café and the waiter offers you "coffee of tea", do not be surprised and expect it to be something fancy on the menu – it might simply be a language slip, accidentally using the Dutch translation of the English word "or". These so-called language selection errors sometimes occur when we just finished a long conversation in a language and then need to switch to another one, or when we have to switch back and forth frequently between two languages. Bilinguals are quite skilled at controlling and selecting their languages in use (Poulisse, 1999; Poulisse & Bongaerts, 1994). Nevertheless, every now and then they still make involuntary switching errors during language selection, especially when one of their languages is more dominant. It is still unclear why language selection errors happen and when they are more likely to happen.

In order to correctly speak one language at a time, bilinguals need to take control of their languages and avoid interference from the nontarget language. Bilingual language control is commonly investigated with a language switching paradigm that makes use of a picture naming task. In such a task, speakers alternately name pictures in their first (L1) and second language (L2) according to a given language cue (a flag, a colour patch, or similar). As expected, speakers become slower when they have to name the picture in a different language than the one they have just used, called *switch cost*. More intriguingly, and unexpectedly, the switch costs are often asymmetrical: Switching from the weaker L2 to the stronger L1 is more costly than vice versa, resulting in *slower* responses when switching from the L2 to the L1 than the other way around (e.g. Gollan, Kleinman, & Wierenga, 2014; Meuter & Allport, 1999; but see Costa & Santesteban, 2004; Costa, Santesteban, & Ivanova, 2006, for evidence on symmetrical switch costs in balanced bilinguals). Given that speaking in the L1 is usually faster and easier than in the L2, this seems to be paradoxical. This *switch cost asymmetry* is explained in terms of inhibition of the nontarget language or enhancement of the target language (Allport & Wylie, 1999; Green, 1998). When bilingual speakers name pictures in one language, they actively enhance the language in use or inhibit the competing language. When they have to switch to the previously competing language, the persistent inhibition of that language or the persistent enhancement of the previous language will hamper the switch. Naming in the weaker L2 requires more enhancement of that weaker L2 or more inhibition of its stronger competitor L1. Consequently, it takes longer to overcome the previous inhibition or enhancement when switching from the L2 to

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Supplemental data for this article can be accessed at https://doi.org/10.1080/23273798.2017.1363401

the L1 than vice versa, and this results in a switch cost asymmetry (Meuter & Allport, 1999). The asymmetry caused by differential inhibition or enhancement is further reflected in a reversed dominance effect: During language switching experiments, bilingual speakers tend to be *slower* in general (i.e. not only on switch trials) in their dominant language than in the nondominant language (Christoffels, Firk, & Schiller, 2007; Costa & Santesteban, 2004; Verhoef, Roelofs, & Chwilla, 2009). Moreover, speakers more often replace words in the dominant language by words in the nondominant language than vice versa (Gollan & Goldrick, 2016; Gollan, Schotter, Gomez, Murillo, & Rayner, 2014, using a read-aloud task).

Both the enhancement of the target language and the inhibition of the nontarget language mentioned above are supposedly top-down mechanisms through which cognitive control is taken of the language to be selected for production. Apart from this top-down control, an alternative explanation of (asymmetrical) switch costs is the bottom-up (i.e. stimulus-driven) selective activation of one language relative to the other. This so-called language priming undoubtedly plays a crucial role in language switching as well: After repeated use of one language, this language is highly activated/primed (Grainger & Dijkstra, 1992; Grosjean, 1998, 1999); as a consequence, it is hard to deactivate the current language and activate the other language at the switch. Presumably, this bottom-up activation or priming has a larger effect on a weak language (like L2) than a stronger language (like L1; cf. Yeung & Monsell, 2003), as effects of additional activation level off for already highly activated representations. Therefore, it is relatively more difficult to deactivate the L2 at a switch to the L1, causing higher costs than the reverse switching direction. Nowadays, researchers tend to consider language selection errors as a failure of (top-down) language control (e.g. Allport & Wylie, 1999; Gollan, Sandoval, & Salmon, 2011; Meuter & Allport, 1999). However, the effect of bottom-up language priming should also not be overlooked (see Monsell, Yeung, & Azuma, 2000; Ruthruff, Remington, & Johnston, 2001; Sohn & Anderson, 2001; Yeung & Monsell, 2003 for related research on task switching).

Interestingly, the bottom-up priming and top-down control factors are inversely related: On the one hand, after using a language for a long time, this target language is highly primed (or activated). On the other hand, because top-down control is effortful, the amount of control is adjusted in this case such that only the minimum of control is applied that is needed for correct performance (e.g. to avoid interference from the other language, see Yeung & Monsell, 2003). Therefore, top-down control is demanded to a lesser degree after a long sequence of same-language trials.

To better understand why language selection errors occur, we should know how bottom-up priming and top-down control interact in causing such errors. A problem is that bilingual speakers hardly make any errors in standard laboratory language switching experiments (e.g. 1.4% in Christoffels et al., 2007; 0.3–0.6% in Meuter & Allport, 1999; 4.1% in Verhoef et al., 2009). Therefore, previous studies mainly focused on the analysis of naming latencies only. In contrast, detailed statistical analyses on error rates were usually not available (e.g. Christoffels et al., 2007; Gollan, Kleinman, et al., 2014; Meuter & Allport, 1999) or failed to reach significance because of small statistical power (e.g. Costa & Santesteban, 2004). Moreover, different types of errors were usually combined to attain higher power in statistical analyses (e.g. Declerck, Koch, & Philipp, 2012; Heikoop, Declerck, Los, & Koch, 2016; Verhoef et al., 2009), and thus even less information for language selection errors was available (but see Declerck, Lemhöfer, & Grainger, 2016; Gollan & Goldrick, 2016, for evidence from different tasks).

In the current study, we investigated when and how bilingual speakers encounter difficulties in a cued language switching task. Different from most previous studies on language switching in naming, we focused on language selection errors rather than naming latencies. Language selection errors in switching can help us investigate actual failures of the language control system, rather than a delay of the system, as reflected by naming latencies. The first question we sought to answer was whether bilingual speakers make more language selection errors when switching from the weaker L2 to the stronger L1 than vice versa, which would be in line with the switch cost asymmetry and reversed dominance effect found in naming latencies. By applying time pressure in the experiment, we tried to elicit a high rate of language selection errors and to conduct statistical analyses on error rates with relatively high statistical power (also see, e.g. Dhooge & Hartsuiker, 2012).

Second, we wanted to examine the contribution of two fundamental variables, namely the top-down cognitive control and the bottom-up language priming, to the language selection errors. To this end, we compared situations where speakers have to switch to the target language after a long sequence of trials in the nontarget language to switching after a small number of nontarget language trials (long vs. short run length). A language will be primed more (i.e. the activation state of the language is better established) when the preceding run of trials in that language is longer; therefore, the subsequent switch to the other language will be harder. If the amount of language priming determines the number of language selection errors in switching, then more errors are expected in the long than in the short run condition.

However, language errors may also occur because of a carry-over effect of top-down control for the previous trial when switching to the other language (e.g. Meuter & Allport, 1999). If language control determines the number of language selection errors in switch, then the prediction would be reversed: After a long run, the (bottom-up) activation of the language of that run will be so high that probably only little cognitive control is required, i.e. there is little inhibition applied to the irrelevant language, or little (additional) enhancement of the relevant one. As a consequence, when switching to the other language, little inhibition or enhancement has to be overcome. Therefore, the control account predicts fewer language selection errors after a long than a short run. Additionally, because priming is assumed to have larger effects for the L2 than for the L1, it is possible that the effect of run length will be asymmetrical, with stronger effects when switching from the L2 to the L1 than vice versa.

Method

Participants

Twenty-five participants took part in the experiment for course credit or vouchers. All were native Dutch speakers, were raised monolingually, and spoke English as their most proficient nonnative language. All had normal or corrected-to-normal vision. Data from one participant were excluded because of a change in the testing procedure, leaving a final set of 24 participants ($M_{age} = 22.3$, six males). Table 1 shows all participants' language background and their English vocabulary size measured by the LexTALE test (Lemhöfer & Broersma, 2012).

Materials

Critical stimuli consisted of 40 black-and-white line drawings, representing 40 pairs of Dutch–English non-cognate words (e.g. Dutch word "boom", English word "tree"). We first selected the pictures from the international picture naming project (IPNP) database (Bates et al., 2003) with highest naming agreements in both Dutch and English (Bates et al., 2003; Severens, Van Lommel, Ratinckx, & Hartsuiker, 2005), and then further restricted that selection to those with highly frequent names (CELEX database; Baayen, Piepenbrock, & Gulikers, 1995). We also matched all the Dutch and English picture names as closely as possible on number of syllables and the phonological onset categories, so that possible differences between Dutch and English naming latencies could not be explained by word length or differences in voice-key sensitivity (e.g. /f/ and /s/ have a delayed voice-key onset compared to /p/ and /t/). Given the restrictions above, we used some additional pictures that were not contained in the database. Another 40 pictures with cognate names were included as fillers to pretest stimuli for another study (see Appendix A for the full set of stimuli). All the pictures were edited to a size of 300 × 300 pixels.

Table 1. Participants' language background and English proficiency.

Characteristic	Mean	SD	Range
Years of experience with English	10.5	3.4	6–20
Self-rated frequency of using English[a]			
• speaking	3.2	1.0	1–5
• listening	4.4	.8	2–5
• reading	3.7	1.2	1–5
Self-rated proficiency of English[a]			
• speaking	3.9	.8	3–5
• listening	4.2	.6	3–5
• writing	3.8	.8	3–5
• reading	4.2	.7	3–5
English vocabulary size			
• LexTALE test	77.4	11.2	58–100

Note. *SD* = Standard Deviation.
[a]Self-ratings were given on a scale from 1 = *very rare/bad* to 5 = *very often/good*.

Design

There were two types of trials: switch trials, where the response language was different from that of the previous trial, and repeat trials, where the response language was the same as the previous one. In the current study, we mainly focused on switch trials. Depending on which language was required on the current trial, we further categorised switch trials as "switch to Dutch (L1)" and "switch to English (L2)".

Another factor we manipulated was *run length*, that is, the number of consecutive repeat trials (i.e. in the same language) preceding a switch trial. The run length could be long (i.e. five or six repeat trials before a switch) or short (i.e. two or three repeat trials). Each type of run length occurred an equal number of times. Overall, 23.75% of trials in the experiment were switch trials.

Each experimental list had 640 trials, divided into eight blocks. Each stimulus appeared once in a block (i.e. repeated eight times within a list). Each list had 152 switch trials, 120 of which were used as critical switch trials. At a critical switch, the stimuli on the current (switch) and the preceding trial were both non-cognates. In total, we constructed eight pseudo-randomized lists to make sure that each critical stimulus occurred equally often in both languages and after all types of run length across participants. Within each block, participants would name half of the stimuli in English, and the other half in Dutch. Other requirements in constructing the lists included: (1) there were no more than four subsequent stimuli with the same cognate status; (2)

no stimuli of the same semantic category, or semantically related ones, followed each other; (3) no stimuli names with the same phonetic onset followed each other; (4) repetition of a picture was separated by at least four intervening trials.

The dependent variables were error rates and naming latencies. Although we mainly focused on error rates, we also included naming latencies to make the link with previous studies. Given that the error rate in a cued switching task is usually relatively low (e.g. Christoffels et al., 2007; Meuter & Allport, 1999; Verhoef et al., 2009), we introduced time pressure in the current experiment to achieve that participants made more errors (see Procedure for details).

Procedure

We located the participants in a sound-proof booth and ran the experiment using the software package *Presentation* (Version 17.0, Neurobehavioural System Inc, Berkeley, U.S.). The computer screen (Benq XL2420Z, screen size 24 inch) was set to grey, with a resolution of 1920×1080 pixels, at a refresh rate of 120 Hz. Each session consisted of four parts: item familiarisation, cue familiarisation, speed training, and experimental blocks. To avoid the experimental stimuli being overtrained, we used an extra set of ten practice pictures for cue familiarisation and speed training.

First, we familiarised the participants with all picture names (including the practice items). Participants first named all the pictures in Dutch, then in English. The correct answer was provided on the screen after each response. Besides coding the responses, we also asked participants whether they knew the word or not. Incorrect items were repeated at the end of the familiarisation. After that, we calibrated the voice key for each participant, using a Shure SM-57 microphone to record their responses. We also instructed participants to name the pictures as quickly as possible in the language indicated by the cue (see below), and also not to correct themselves when they said something wrong. All the instructions were in English.

Then, we familiarised the participants with the colour cues. The picture appeared in the centre of the screen, with a 100-pixel-wide frame around the picture whose colour represented the response language (i.e. red and yellow indicated Dutch, and green and blue indicated English, or vice versa). Two colours were used to cue each language such that colour could alternate between each trial to avoid a confound of language switch and colour switch (Mayr & Kliegl, 2003). We counterbalanced the assignment of the colours to the response language across participants. Each trial started with the 500 ms presentation of a fixation cross, followed by a blank screen with a jitter of 500–1000 ms. The stimuli were presented together with a cue, staying on the screen till the experimenter pressed one of the coding buttons. Participants' responses were coded online as correct or incorrect. The cue familiarisation consisted of a minimum of 40 trials and ended when the participant's accuracy achieved 90% for the previous ten responses.

Afterwards, we trained the participants to respond within a time limit. Each trial started with the 250 ms presentation of a fixation cross, followed by a blank screen with a jitter of 250–500 ms. The stimuli were presented in a similar way as during cue familiarisation, however, participants had to respond within a time limit. The time limit was computed dynamically across the training and calibrated individually for each participant (based on the 80 percentile of previous ten trials, for more details see Appendix B). If participants failed to respond within a given time limit, they got a warning message for being "too late". The picture and the frame stayed on the screen until 550 ms after the voice key had registered the onset of speech, followed by an optional warning message of 1 s. If the voice key was not triggered within 2000 ms, the stimulus stayed for a total of 2550 ms and continued with the warning message and then another jittered blank screen of 250–500 ms. Then the next trial began. The speed training consisted of 80 trials.

In the experimental blocks, we assigned each participant to one of the eight pseudo-randomized lists. Stimuli were presented in the same way as during the speed training, with a constant time limit for each participant which was computed based on their performance in the training (for more details see Appendix B). In order to not interrupt the participants during the experiment, we no longer gave them feedback after each trial, but only after each block, indicating their percentage of on-time responses.

At the end of the session, the participants completed the LexTALE vocabulary test in English and a language background questionnaire. The entire session took approximately 1.5 hr.

Data analysis

We coded participants' responses as fluent, correct responses and incorrect responses. Incorrect responses were further categorised into language selection errors (i.e. complete, fluent responses in the nontarget language) and another twelve types of errors, such as self-corrections, disfluency, or using a wrong word in the correct language (see Appendix C for all the categories and the percentage of each type of errors).

For the analysis of response latencies, we re-measured speech onset manually in Praat (Boersma & Weenink, 2016) and discarded naming-latency outliers based on individual participants' performance, within each language and each trial type (switch vs. repeat). Correctly responded trials with a naming latency deviating more than three standard deviations from the condition mean were defined as outliers. The twelve other types of errors together with naming-latency outliers are hereafter referred as *other errors* in the error analysis.

The current analyses mainly focused on switch trials. In the error analysis, we excluded trials that could not be classified as either switch or repeat (trials at the beginning of each block and trials following language selection errors or other interlingual errors; see Appendix C for details). In the naming latency analysis, we excluded all error trials and post-error trials. We analyzed error rates and naming latency using repeated-measured ANOVAs across participants (F_1) as well as items (F_2), with the factors language (switch to Dutch vs. switch to English) and run length (short vs. long). Significant interactions in ANOVAs were followed by separate paired-sample *t*-tests.

To provide a more complete picture especially concerning the classic notion of switch costs (i.e. the difference between performances in switch vs. repeat trials), we also compared repeat trials with switch trials. To make the analysis of repeat trials more comparable to the critical switch trials (only non-cognate items), we excluded all cognate items on repeat trials for this analysis.

Results

Analysis of switch trials

Error rates

Speakers made different types of speech errors on 17.7% of all trials, including responses in the nontarget language (e.g. say "boom" instead of "tree"; language selection errors) on 10.0% of the trials. On critical switch trials, language selection errors reached an average rate of 23.9% and other errors reached 10.9% (Figure 1). This allowed us to conduct a powerful statistical analysis on error rates.

Language selection error rate. In general, speakers made more language selection errors when they had to switch to their L1, Dutch, than when switching to their L2, English ($F_1(1, 23) = 17.54$, $p < .001$, $\eta_p^2 = .43$; $F_2(1, 39) = 43.36$, $p < .001$, $\eta_p^2 = .53$). Moreover, speakers made more language selection errors after a short run of repeat trials than after a long run ($F_1(1, 23) = 19.91$, $p < .001$, $\eta_p^2 = .46$; $F_2(1, 39) = 23.28$, $p < .001$, $\eta_p^2 = .37$). Crucially, though, the factors of language and run length showed a significant interaction ($F_1(1, 23) = 11.05$, $p = .003$, $\eta_p^2 = .33$; $F_2(1, 39) = 8.53$, $p = .006$, $\eta_p^2 = .18$). When switching from the L2 to the L1, speakers made more language selection errors after a short run than a long run ($t_1(23) = 5.13$, $p < .001$, Cohen's $d = .80$; $t_2(39) = 5.72$, $p < .001$, Cohen's $d = 1.23$). In contrast, when switching from the L1 to the L2, the manipulation of run length did not affect error rates ($t_1(23) = 1.54$, $p = .14$, Cohen's $d = .25$; $t_2(39) = 1.01$, $p = .32$, Cohen's $d = .24$).

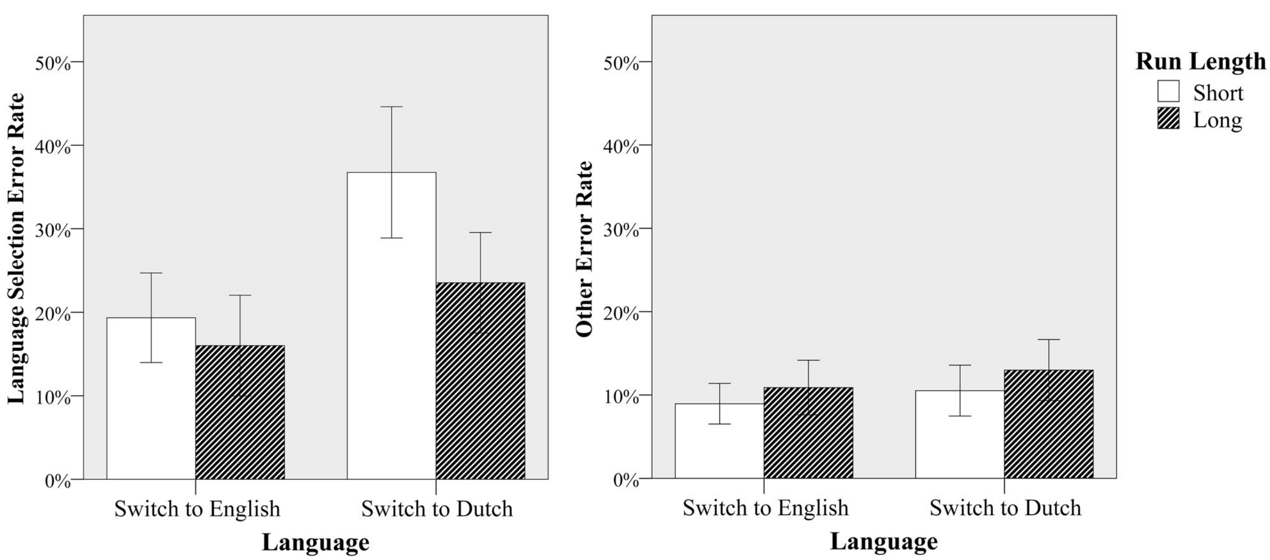

Figure 1. Language selection error rates (left panel) and other error rates (right panel) on critical switch trials, grouped by language (switch to English vs. switch to Dutch) and run length (short vs. long). Error bars indicate 95% CI.

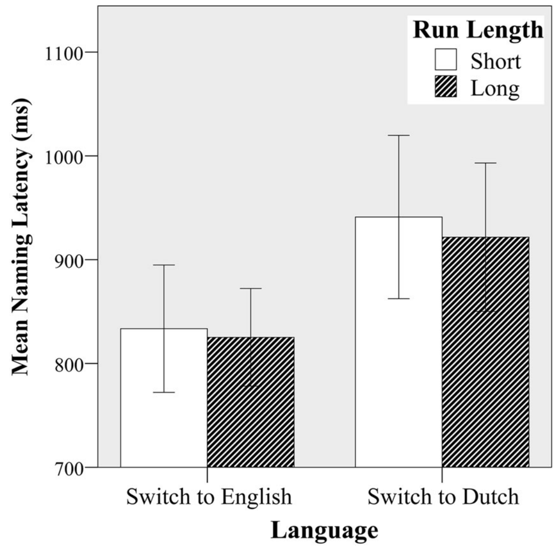

Figure 2. Mean naming latency of correct responses on critical switch trials, grouped by language (switch to English vs. switch to Dutch) and run length (short vs. long). Error bars indicate 95% CI.

Other error rate. There were no statistically significant effects of language or run length on other speech errors (all *ps* > .092; see Figure 1, right panel).

Naming latencies

Figure 2 shows the naming latency data on critical switch trials. In general, speakers were faster when switching from the L1 to the L2 than vice versa ($F_1(1, 23) = 21.78$, $p < .001$, $\eta_p^2 = .49$; $F_2(1, 39) = 23.43$, $p < .001$, $\eta_p^2 = .38$). However, whether they had to switch after a short or long run did not affect their naming latencies (both $F < 1$). There was no interaction between language and run length (both $F < 1$).

Analysis of repeat trials

Table 2 gives a summary of error rates and naming latencies on switch and repeat trials. Note that the data in the table are collapsed across run length, whereas Figures 1 and 2 show error rates and RTs on switch trials as a function of run length.

Error rates

On repeat trials, speakers also made more language selection errors when naming in the L1 than in the L2 ($F_1(1, 23) = 41.35$, $p < .001$, $\eta_p^2 = .64$; $F_2(1, 36) = 42.90$, $p < .001$, $\eta_p^2 = .54$). In contrast, speakers only made slightly more other errors when naming in the L1 than in the L2 ($F_1(1, 23) = 9.05$, $p = .006$, $\eta_p^2 = .28$; $F_2(1, 33) = 3.60$, $p = .07$, $\eta_p^2 = .09$).

To assess the effect of language repetition (presumably leading to language priming) throughout a run of same-language trials, we coded each trial in a run for its ordinal position (1 to 6). Trials with the ordinal position 1 were always on a switch, apart from the first trial of a block. Therefore, we excluded position 1 and compared error rates across the ordinal positions from two to six. Results showed that speakers made slightly more language selection errors at early positions than at later positions (position 2: 10.0%; position 3: 7.1%; position 4: 6.4%, position 5: 6.3%; position 6: 4.5%; $F_1(4, 20) = 4.59$, $p = .009$. $\eta_p^2 = .48$; $F_2(1, 33) = 1.92$, $p = .13$, $\eta_p^2 = .19$). In contrast, there was no difference in the rate of other errors across different ordinal positions ($F_1(4, 20) = 1.43$, $p = .26$, $\eta_p^2 = .22$; $F_2(1, 33) = 1.26$, $p = .31$, $\eta_p^2 = .11$).

Compared to (critical) switch trials, speakers made fewer language selection errors on repeat trials (see Table 2; $F_1(1, 23) = 84.39$, $p < .001$, $\eta_p^2 = .79$; $F_2(1, 39) = 428.00$, $p < .001$, $\eta_p^2 = .92$). There was a trend towards larger switch costs (i.e. switch vs. repeat) in terms of errors when switching from the L2 to the L1 (19.4%) than vice versa (14.5%; $F_1(1, 23) = 3.76$, $p = .07$, $\eta_p^2 = .14$; $F_2(1, 39) = 7.69$, $p = .008$, $\eta_p^2 = .17$).

In contrast, for other errors, there was only a small trend in the item analysis towards higher rates at switch trials (10.9% across languages) than at repeat trials (9.8%; $F_1(1, 23) = 1.99$, $p = .17$, $\eta_p^2 = .08$; $F_2(1, 39) = 4.40$, $p = .04$, $\eta_p^2 = .10$). There is no difference in switch costs between switching directions in terms of other errors ($F_1(1, 23) = .72$, $p = .40$, $\eta_p^2 = .03$; $F_2(1, 39) = 2.66$, $p = .11$, $\eta_p^2 = .06$).

In summary, speakers made more language selection errors when naming in the L1 than in the L2 on repeat trials. Compared to switch trials, they made fewer language selection errors on repeat trials. Switch costs

Table 2. Summary of error rates and naming latencies on switch and repeat trials.

		Error rates					
		Language selection errors		Other errors		Naming latencies	
		Mean (%)	*95% CI*	*Mean (%)*	*95% CI*	*Mean (ms)*	*95% CI*
Switch	to L1	30.1	23.7–36.6	11.8	8.7–14.8	931	860–1003
	to L2	17.7	12.4–22.9	9.9	7.8–12.0	829	778–880
Repeat	in L1	10.9	7.7–14.0	11.6	8.8–14.3	793	725–860
	in L2	2.9	1.6–4.2	8.5	6.5–10.6	748	708–788

Note. 95% *CI* = 95% Confidence Interval.

were larger when switching from the L2 to the L1 than vice versa. No such effects were not found in other errors.

Naming latencies

On repeat trials, naming in the L2 was slightly faster than in the L1 (see Table 2; $F_1(1, 23) = 3.56$, $p = .07$, $\eta^2_p = .13$; $F_2(1, 36) = 12.22$,, $p = .001$, $\eta^2_p = .25$). However, no difference was found in naming latencies across different ordinal positions ($F_1(4, 20) = 1.78$, $p = .26$, $\eta^2_p = .26$; $F_2(4, 33) = 2.11$, $p = .10$, $\eta^2_p = .20$), nor did position interact with language ($F_1(4, 20) = .15$, $p = .96$, $\eta^2_p = .03$; $F_2(4, 33) = .61$, $p = .66$, $\eta^2_p = .07$).

Speakers were slower at switch than at repeat trials (see Table 2; $F_1(1, 23) = 160.25$, $p < .001$, $\eta^2_p = .87$; $F_2(1, 39) = 191.13$, $p < .001$, $\eta^2_p = .83$). Switch costs were larger when switching from the L2 to the L1 (137 ms) than vice versa (82 ms; $F_1(1, 23) = 14.11$, $p = .001$, $\eta^2_p = .38$; $F_2(1, 39) = 6.86$, $p = .01$, $\eta^2_p = .15$).

Discussion

In the present study, we investigated how language priming and level of control interact in cued language switching and how they contribute to language selection errors. When speaking in the weaker L2, more top-down control is demanded, including inhibiting the dominant L1 and enhancing the weaker L2 (Allport & Wylie, 1999). At the same time, the weaker L2 is also more primed from bottom-up activation (cf. Yeung & Monsell, 2003). Consequently, when speakers have to switch back to the dominant L1, it should be more difficult to overcome the residual control and/or the residual priming. As expected, our data showed that bilingual speakers tend to make more language selection errors and become slower when switching from their weaker L2 to their dominant L1 than vice versa. Switching was more costly from the L2 to the L1 than vice versa, as the differences between switch and repeat trials in language selection errors and naming latencies were larger in switching from L2 to L1 than in the other direction, replicating the switch cost asymmetry found previously in naming latencies (e.g. Gollan, Kleinman, et al., 2014; Meuter & Allport, 1999). Our results on the repeat trials suggest that the effect of control and/or priming is "global", as bilingual speakers also tend to make more language selection errors and become slower when repeatedly naming in the L1 than in the L2 in a switching task (see also Christoffels et al., 2007; Costa & Santesteban, 2004; Verhoef et al., 2009 for similar results on naming latencies).

Although to our knowledge, no direct findings on language selection errors are available from previous cued language switching studies, researchers did report more speech errors (a combination of language selection errors and other errors) on L1 trials than on L2 trials in cued language switching (Declerck et al., 2012; Verhoef et al., 2009). Using a read-aloud task, Gollan and colleagues (Gollan & Goldrick, 2016; Gollan, Schotter, et al., 2014) also observed more language selection errors when bilinguals were speaking in their dominant language than in the weaker language. One thing to note is that the language selection errors we investigated in our study mainly concerned the errors on a switch (thus a failure to switch), whereas a failure to stay in the same language occurs more often in real life (*intrusion errors*; Poulisse, 1999). Future studies may address the issue of language switching and control by looking into the latter case of language selection errors.

In addition, we observed an effect of run length on error rates. That is, bilinguals were more likely to make language selection errors when they had to switch to the target language after few trials in the nontarget language, rather than after many trials. Although not much evidence is available on this manipulation in language switching, Monsell, Sumner, and Waters (2003) did report similar findings in task switching: When participants unpredictably switched between high/low and odd/even judgments of a digit, their reaction times and error rates decreased as the length of the previous run increased. Interestingly, in our study, the effect of run length was no longer obtained when the participants had to switch to the nondominant L2 (i.e. English). We discuss this finding later in terms of language priming and level of control.

The switch cost asymmetry (e.g. Gollan, Kleinman, et al., 2014; Meuter & Allport, 1999) and reversed dominance effect (Christoffels et al., 2007; Costa & Santesteban, 2004; Verhoef et al., 2009) were both replicated in our results of naming latencies. However, unlike the robust findings in error rates, there was no effect of run length on naming latency. Given that our participants had to make fast responses at the cost of making more errors, the trials where they experienced most difficulty (due to the factors of language and/or run length) presumably gave rise to an error rather than a slow response. In other words, by giving a strict deadline to naming latencies, we equalised the naming latencies and cut off the slow responses which were most likely to carry the effects. Since the effect of run length was not as strong as that of language, we are not surprised that its evidence in naming latencies was absent. The same reasoning also applies to the other null results in naming latencies (e.g. naming latencies across ordinal positions in repeat trials).

We wanted to examine the contribution of bottom-up language priming and top-down cognitive control to the tendency to make language selection errors. This was done by manipulating the factor run length. As we proposed in the introduction, our finding supports the control account (Allport & Wylie, 1999; Green, 1998; Meuter & Allport, 1999). After a long run of repeat trials, the state of the weaker L2 is better established in unbalanced bilingual speakers, which is also supported by the evidence of decreasing error rates with higher ordinal positions in repeat trials. As a consequence, the need to inhibit the stronger L1 or to enhance the weaker L2 becomes smaller. Thus, at the switch, it costs less to overcome the residual inhibition of the L1 or the residual enhancement of the L2, as represented by fewer language selection errors when switching from the L2 to the L1. On the other hand, a short run of L2 calls for more inhibition of the dominant L1 or more enhancement of the L2, and results in more L1 selection errors at the switch. However, in the other switching direction, when repeatedly using the dominant L1, the nontarget L2 does not compete much for selection (Verhoef et al., 2009) and the priming effect on the stronger L1 is also smaller (Yeung & Monsell, 2003). Therefore, the activation state of the L1 remains about the same after either a long or short run of L1 repetitions. Consequently, the rate of language selection errors when switching from the L1 to the L2 does not vary with different lengths of run.

In contrast, a pure (bottom-up) language priming account cannot explain the current data. The state of the weaker L2 would be more established (i.e. the L2 should be primed more) after a longer run, making the L2 subsequently a stronger competitor for the L1 when a switch has to be made. Therefore, an account assigning a dominant role to language priming would predict more L1 selection errors when switching after a long L2 run than a short L2 run, which was clearly not the case in our data. Thus, language selection errors as they occur in the cued language switching paradigm seem to be a consequence of top-down mechanisms of cognitive control, rather than of mere bottom-up activation due to language priming.

An alternative explanation of the run length effect states that in an unpredictable task switching situation, speakers' subjective expectation of a switch may increase with the position in a run ("gambler's fallacy"; Kahneman & Tversky, 1972) and may therefore be more prepared after a long run and make less errors (Monsell et al., 2003). However, this should have equally been the case for switching from the L1 to the L2 and vice versa. Therefore, it cannot explain why the run length effect no longer existed when switching from the L1 to the L2. Moreover, a previous study on the predictability of language trial sequence has revealed no difference in switch costs between language switching with and without a predictable sequence (Declerck, Koch, & Philipp, 2015). Based on this, the expectation account seems unlikely to be the correct explanation.

In summary, as a successful attempt to examine language selection errors from the perspective of language switching, the current study observed findings in line with the switch cost asymmetry and reversed dominance effect in a cued language switching task. Concerning the relative contribution of language priming and control to the language selection errors in language switching, our data support the view that language selection errors occur because of a carry-over of cognitive control rather than because of language priming. Moreover, by employing time pressure to induce speech errors in cued language switching, our paradigm also provides new possibilities for future explorations in bilingual error analysis and error monitoring studies.

Acknowledgements

The authors would like to thank Jana Klaus, Manuel Augustin, Martijn Bentum, Wouter Cames van Batenburg for helpful comments during the preparation of this manuscript.

Disclosure statement

No potential conflict of interest was reported by the authors.

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