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RESEARCH NOTES

Examining language switching in bilinguals: The role of preparation time*

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Much research on language control in bilinguals has relied on the interpretation of the costs of switching between two languages. Of the two types of costs that are linked to language control, switching costs are assumed to be transient in nature and modulated by trial-specific manipulations (e.g., by preparation time), while mixing costs are supposed to be more stable and less affected by trial-specific manipulations. The present study investigated the effect of preparation time on switching and mixing costs, revealing that both types of costs can be influenced by trial-specific manipulations.

Keywords: Bilingual language switching, preparation time, switching costs, mixing costs, picture naming

Introduction

One of the most astonishing skills of a fluent bilingual or trilingual person is the ability to switch between different languages. The costs associated with language switching have been the centre of many studies investigating multilinguals' lexical retrieval. Two kinds of costs are usually linked to language switching tasks, costs for language SWITCHING and for language MIXING. A common technique to measure LANGUAGE SWITCHING COSTS is to compare participants' performance in a task in which they have to switch from one language to another ("switch trial") to a task in which they stay in the same language ("repetition trial"). Performance in switch trials has been found to be slower and more error-prone than in repetition trials. The reaction time (RT) difference between repetition and switch trials is called "switching costs" (e.g., Roger & Monsell, 1995). The experimental technique may also include SINGLE language blocks (in which stimuli from two or more languages are tested in separate blocks) as opposed to MIXED language blocks (in which stimuli from more than one language are intermixed). For each language, MIXING COSTS are measured as the difference in performance between trials in the single-language block and repetition trials in the mixed language-block (e.g., Rubin & Meiran, 2005). While in the single-language block only one language is active, in the mixed-language block more than one language needs to be maintained active. These two types of costs reflect different cognitive control processes (e.g., Koch, Prinz & Allport, 2005). While switching costs are believed to reflect the effort involved in configuring an upcoming task or trial, a momentary process supported by a 'transient' control mechanism, mixing costs are supposed to reflect a prolonged or 'sustained' control process of maintaining multiple languages active in the mixed compared to the single language block (Braver, Reynolds & Donaldson, 2003). In this way, we can distinguish between trial-specific versus not-trial-specific costs of language control, the former involved in switching costs and the latter in mixing costs (Braver et al., 2003). Consequently, trial-level manipulations, e.g., through different preparation times, can be expected to affect switching costs, but less so or not at all mixing costs. The current study sheds new light on these processes by investigating potential effects of different preparation times in bilingual language switching.

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Several previous studies have found that switching costs are influenced by participant-level factors (e.g., language proficiency) as well by task-related factors (e.g., stimulus properties); see Bobb & Wodniecka (2013) for a review. The momentary nature of switching costs signalling transient control is confirmed by studies showing that when speakers are given a longer interval between the language cue and the stimulus ('cue-stimulus interval', CSI), switching costs decrease (e.g., Costa & Santesteban, 2004). This indicates that the earlier presentation of the cue can boost preparation for the upcoming trial (Meiran, 2000). Additionally, there is some evidence suggesting that inter-trial intervals (ITI) can also affect performance in task/language switching studies such that longer intervals between response and cue (RCI) were, for example, found to speed up reaction times (Koch & Allport, 2006; Philipp, Gade & Koch, 2007). This could be due to reduced passive interference from the previous trial, which may lead to smaller switching costs (Allport, Styles & Hsieh, 1994). In previous studies, the interval between trials (such as ITI or RCI) was either relatively short (e.g., 400 ms in Declerck, Koch & Philipp, 2012; 1150 ms in Costa & Santesteban, 2004) or left uncontrolled (i.e., variable from 1500 ms to 2300 ms in Verhoef, Roelofs & Chwilla, 2009; variable from 1000 ms to 1250 ms in Fink & Goldrick, 2015; 100 ms RCI in long CSI condition vs. 1000 ms RCI in short CSI condition in Philipp et al., 2007). From these studies, the potential effects of active preparation on transient control processes involved in language switching are hard to determine.

Moreover, while there is agreement on the beneficial effect of preparation time on switching costs, it is not clear whether or not preparation time also affects mixing costs. If mixing costs reflect a stable process of maintaining two or more languages active in the mixed-language block, we may expect that this process is not affected by any kind of task (viz. preparation time) manipulation. However, previous studies have yielded inconsistent findings regarding mixing costs in language switching. Some studies found mixing costs in both the L1 and the L2 (e.g., Prior & Gollan, 2011), others only in the L1 but not in the L2 (e.g., Christoffels, Firk & Schiller, 2007) and yet other studies obtained a "mixing benefit", i.e., faster responses (in the L2, but not the L1) for the mixed-language than the single-language block (e.g., Hernandez, Dapretto, Mazziotta & Bookheimer, 2001). Furthermore, inconsistencies across studies could also be due to the fact that different types of bilinguals have been tested in language switching studies (e.g., early bilinguals: Prior & Gollan, 2011; late bilinguals: Christoffels et al., 2007; L2-dominant bilinguals: Hernandez et al., 2001). Finally, different time manipulations have been used in previous studies (e.g., 200 ms CSI and fixed ITI for Hernandez et al., 2001; 0 ms CSI and variable ITI in Christoffels et al., 2007, and 250 ms CSI and fixed RCI in Prior & Gollan, 2011) so that the question remains of how task manipulations, specifically trial-level differences in preparation time, affect the sustained control processes involved in language switching tasks.

The goal of the present study is to investigate the effect of preparation time on both transient and sustained control, by measuring switching and mixing costs in a bilingual picture naming task. To minimize the effect of passive interference and principally focus on that of preparation time, we compared performances in trials with and without preparation time, while using a relatively long and fixed ITI. Following the above-mentioned distinction between trial-specific vs. non trial-specific costs (i.e., switching vs. mixing costs; see Bates et al., 2003), we expect to find an effect of a trial-specific manipulation (of preparation time), specifically reduced switching (but not mixing) costs in trials with preparation time compared to trials without preparation time.

Materials

Eighteen pictures were selected from the Colorized Snodgrass and Vanderwart object set (Rossion & Pourtois, 2004) to be named in English and/or German. Pictures had a size of 197×281 pixel and were presented at the centre of a 15-inch computer screen set to 1280×800 pixel resolution. Stimuli were seen from a distance of approximately 80 cm. DMDX (Forster & Forster, 2003) was used for stimulus presentation and CheckVocal (Protopapas, 2007) for recording and measuring speech-onset latencies. See Appendix A for detailed information on the items used.

Participants

Thirty participants (11 males, 19 females, mean age: 25.6, SD: 5.26) were recruited from the student population of the University of Potsdam and tested in German and English. Participants were all university educated, right-handed and had normal or corrected to normal vision. They all gave their consent before the experiment and were paid or given course credit for their participation. All participants acquired German from birth as their sole native language (L1) and English as second language (L2) at school for a minimum of 5 years with an average age of onset of 9.55 (SD: 1.58). See Appendix B for detailed information on participants.

Procedure

Participants were seated in front of a computer screen and instructed to name each picture displayed on the computer screen either in their L1 or their L2 as quickly and accurately as possible. The language to be used was indicated by the colour of the screen background (blue = L1, red = L2). A with-preparation trial consisted of (i) a language cue (for 500 ms on red or blue background), (ii) a blank screen for (300 ms), (iii) a picture (for 1500 ms), (iv) a blank screen (for 2400 ms). A no-preparation trial entailed (i) a fixation point (for 500 ms), (ii) a blank screen (for 300 ms), (iii) a picture together with a language cue (for 1500 ms), (iv) a blank screen (for 2400 ms). Thus, both no-preparation and with-preparation trials had a constant duration of 4700 ms and different cuing time, namely CSI = 0 ms and CSI = 800 ms respectively. Moreover, independently from subjects' response speed, pictures remained on the screen for a fixed duration of 1500 ms.

Each participant completed one experimental session, which included a single followed by a mixed-language block. In the SINGLE-LANGUAGE BLOCK, participants named stimuli in the L1 and the L2 separately. Participants named a set of 36 pictures in the L1 and a set of 36 pictures in the L2, in a counterbalanced order across participants. In each language-set, the first half of the items were with-preparation trials and the second half no-preparation trials; this was also counterbalanced across participants. The presentation of the stimuli was fully randomized and each picture was seen once in each of the four conditions (L1, L2, with-preparation, no-preparation). In addition to the variables 'Language' (L1 vs. L2) and 'Presentation Type' (with-preparation vs. no-preparation), the MIXED-LANGUAGE BLOCK also included the variable 'Trial Type' (no-switch vs. switch). In a no-switch trial, a given picture had to be named in the same language as the previous one and in a switch trial in a different language than the previous one. Trials were grouped such that 75% was no-switch and 25% switch trials, e.g., L1-L1-L1-L2 in which case three consecutive pictures had to be named in the L1 and one in the L2. There were 144 trials (108 no-switch and 36 switch trials) in the mixed-language block, presented half in the with-preparation and half in the no-preparation Presentation Type. The same 18 pictures as for the single-language block were used in the mixed-language block, nine for the L1 and nine for the L2, presented eight times each. Two presentation lists of pseudo-randomized trials were created of which each participant saw only one. One list had the with-preparation trials first, whereas the other started with the no-preparation trials, making cuing display predictable. Likewise, the order of the two languages (German, English) for naming pictures was also counterbalanced between the two lists. Within each list, pictures were never repeated within five trials. Furthermore, the same type of chunk pattern (e.g., L1-L1-L1-L2) did not appear more than twice in a row. Due to these precautions, participants were unable to anticipate the order of the background colour.

Prior to the experiment, participants were familiarized with the procedures using six practice trials for the single-language block and eight for the mixed one.

Data coding and analysis

The dependent variables were participants' accuracy and picture-naming response times (RT), the latter measured from the display of the target picture until speech onset. Data from four participants and two items (*Kürbis* 'pumpkin' in the single-language block, and *Uhr* 'watch' in the mixed one) were excluded from any further analysis due to low accuracy rates of less than 70%. For the remaining 26 participants, RTs and accuracy scores were calculated. Prior to the RT analysis, trials with incorrect responses, hesitations and cases in which the microphone was mis-triggered (e.g., through coughs or stuttering) were excluded (5.4% of the data). Trials with RTs faster than 350 ms as well as those slower than 2,000 ms (0.26% of the data), were treated as extreme values and also removed from the RT analysis. Due to these exclusions, the total amounts of removed data were 4.7% and 5% of the L1 responses, 6.5% and 5.5% of the L2 responses, the former in the single and the latter in the mixed language block.

To analyse the data statistically, mixed-effects linear regression models were fitted to the RT data and generalized linear models with a binomial link function (Cnaan, Laird & Slasor, 1997; Guo & Zhao, 2000) to the accuracy data. See Appendix C for detailed information on data analysis.

Results

Table 1 shows mean RTs and accuracy scores for the different experimental conditions. Tables 2 and 3 present the results of the statistical analyses.

Consider first the accuracy data from Table 1 and the corresponding statistical results in Table 2. In the single-language block, accuracy rates were significantly higher for the L1 than the L2 and for the 'no-preparation' Presentation Type than for the 'with-preparation' one; see the main effects of Language and Presentation Type in Table 2. There were no further main effects or interactions. In the mixed-language block, accuracy rates were similar across conditions without any reliable main effects or interactions.

Consider next the RT data. In the single-language block naming latencies in the L1 were significantly faster than in the L2 (741 ms vs. 790 ms), while there were no differences between the two levels of Presentation Type, with and without preparation time (769 ms vs. 764 ms); see Table 1. This contrast was confirmed by a main effect of Language, but not of Presentation Type in the single-language block; see Table 3a. These results show that in the single-language task, the Presentation Type manipulation did not affect naming latencies. This was different in the mixed-language block. While there was no reliable main effect of Language, with similar naming latencies for L1 and the L2, there were significant effects

Table 1. *Correct mean RTs (standard deviations in brackets) and accuracy rates (in percent), for L1 vs. L2, with-preparation vs. no-preparation trials, switch vs. no-switch trials, and single vs. mixed-language blocks. Switching costs for L1 and L2 (calculated as the difference between no-switch and switch trials) as well as mixing costs for L1 and L2 (calculated as the difference between single and mixed language block) are reported in italics.*

	No-preparation			With-preparation		
	L1	L2	Trial Type Mean	L1	L2	Trial Type Mean
Single-language block						
	735 ms	791 ms	764 ms	746 ms	790 ms	769 ms
	(229)	(200)	(216)	(212)	(208)	(210)
Accuracy	96.6%	93.4%	95%	94.2%	93.7	93.8%
	(25)	(33)	(29)	(33)	(32)	(32)
Mixed-language block						
No-switch	791 ms	729 ms	760 ms	731 ms	727 ms	729 ms
	(193)	(156)	(178)	(198)	(190)	(194)
Accuracy	95.9%	95.7%	95.8%	94.8%	94.8%	94.8%
	(33)	(34)	(33)	(37)	(34)	(35)
Switch	877 ms	834 ms	855 ms	754 ms	716 ms	734 ms
	(215)	(217)	(217)	(244)	(166)	(207)
Accuracy	95.4%	92.1%	93.9%	93.7%	94.7%	94.2%
	(35)	(39)	(37)	(39)	(36)	(37)
Switching Costs	*86 ms*	*105 ms*		*23 ms*	*−11 ms*	
Mixing Costs	*56 ms*	*−62 ms*		*−15 ms*	*−63 ms*	
LanguageMean	831 ms	779 ms	804 ms	741 ms	721 ms	731 ms
	(208)	(195)	(203)	(221)	(178)	(200)
Accuracy	95.7%	94%		94.2%	94.8%	
	(34)	(37)		(38)	(35)	

Table 2. *Estimated coefficients standard errors (SE) and z values from the best-fit generalized linear mixed-effects models for the accuracy data. Asterisks (*) indicate: p < .05 (*), p < .01 (**), p<. 001(***) and p < .0001 (****).*

	Accuracy		
	Estimate	SE	z-value
Single-language block			
Intercepts	36.16	9.097	3.97***
Language (L1 vs. L2)	8.313	2.942	2.82**
Presentation Type (no-preparation vs. with-preparation)	6.893	2.788	2.47*
Formula: Accuracy ∼ Presentation Type + Language + (1 / subject) + (1/ item)			
Mixed-language block			
Intercepts	15.103	2.439	6.19****
Language (L1 vs. L2)	−1.828	1.303	−1.40
Trial Type (no-switch vs. switch)	0.775	0.755	1.02
Presentation Type (no-preparation vs. with-preparation)	0.266	0.730	0.36
Formula: Accuracy ∼ Presentation Type + Language + Trial Type + (1+Language/subject) + (1/item)			

of Trial Type, with shorter RTs for no-switch than for switch trials (744 ms vs. 794 ms) and of Presentation Type, with shorter RTs for the with-preparation than for the no-preparation trials (731 ms vs. 804 ms). Most importantly, however, there was a significant interaction of Presentation Type and Trial Type in the mixed-language block ($p < .05$). To further examine this interaction, we split the data by Presentation Type; see Table 3c and Table 3d. While in the no-preparation trials, switch trials yielded significantly longer RTs than no-switch trials (760 ms vs. 855 ms,

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Table 3. *Estimated coefficients, standard errors (SE) and t values from the best-fit linear mixed effects models run on inversed-transformed RTs. Asterisks (*) indicate: p < .05 (*), p < .01 (**), p<. 001(***) and p < .0001 (****).*

	Reaction Times		
	Estimate	SE	t-value
(a) Single-language block - Overall model			
(Intercept)	1.387	0.033	41.44****
Language (L1 vs. L2)	0.053	0.022	2.42*
Presentation Type (no-preparation vs. with-preparation)	0.011	0.027	0.41
*Formula: RT~ Language*Presentation Type + (1 + Presentation Type/ subject) + (1/ item)*			
(b) Mixed-language block - Overall model			
(Intercept)	−1.379	0.028	−49.59****
Language (L1 vs. L2)	0.019	0.017	1.15
Trial Type (no-switch vs. switch)	−0.030	0.014	−2.11*
Presentation Type (no-preparation vs. with-preparation)	0.074	0.013	5.11****
Presentation Type*Trial Type	−0.036	0.013	−2.67*
*Formula: RT~ Language + Presentation Type*Trial Type + (1 + Language*Trial Type/ subject) + (1/ item)*			
(c) No-preparation			
(Intercept)	−1.302	0.029	−43.79****
Trial Type: switch vs. no-switch	− 0.069	0.017	−4.00****
Formula: RT~ Trial Type + (1 + Trial Type/ subject) + (1/ item)			
(d) With-preparation			
(Intercept)	−1.443	0.033	−42.95****
Trial Type: switch vs. no-switch	−0.006	0.023	0.26
Formula: RT~ Trial Type + (1 / subject) + (1/ item)			
(e) Mixing costs – Overall model			
(Intercept)	1.392	0.033	41.75****
Language (L1 vs. L2)	−0.037	0.043	−0.86
Presentation Type (no-preparation vs. with-preparation	0.002	0.043	0.07
Block Type (single vs. mixed)	0.051	0.012	4.15****
Language*Presentation Type	−0.058	0.077	−0.75
Language*Block Type	0.174	0.024	7.08****
Presentation Type*Block Type	0.135	0–024	5.53****
Language*Presentation Type* Block Type	−0.120	0.048	−2.49*
*Formula: RT ~ Language * Procedure* Block + (1 + Procedure + Language / subject) + (1/ item)*			
(f) Mixing costs – No preparation			
(Intercept)	738.66	16.77	44.04****
Language (L1 vs. L2)	−0.69	25.38	−0.03
Block (single vs. mixed)	12.13	9.64	1.26
Language*Block	−136.7	19.07	−7.17****
*Formula: RT ~ Language*Block Type + (1 + Language / subject) + (1/ item)*			
(g) Mixing costs – With preparation			
(Intercept)	747.66	24.81	30.13****
Language (L1 vs. L2)	43.62	39.65	1.10
Block (single vs. mixed)	−63.79	18.86	−3.38**
Language*Block	−54.43	19.32	−2.81*
*Formula: RT ~ Language*Block + (1 + Block / subject) + (1/ item)*			

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Table 3. *Continued.*

	Reaction Times		
	Estimate	SE	t-value
(h) Mixing costs – No preparation L1			
(Intercept)	738.48	22.18	33.29****
Block (single vs. mixed)	82.41	15.15	5.44****
Formula: RT ~ Block + (1 | subject) + (1| item)			
(i) Mixing costs - No preparation L2			
(Intercept)	737.26	19.17	38.45****
Block (single vs. mixed)	−60.29	11.82	−5.10****
Formula: RT ~ Block + (1 | subject) + (1| item)			
(l) Mixing costs – With preparation L1			
(Intercept)	729.55	25.10	29.07****
Block (single vs. mixed)	−37.44	23.25	−1.61
Formula: RT ~ Block + (1+ Block | subject) + (1| item)			
(m) Mixing costs – With preparation L2			
(Intercept)	766.49	34.50	22.22****
Block (single vs. mixed)	−91.76	13.87	−6.61****
Formula: RT ~ Block + (1 | subject) + (1| item)			

$p < .05$) in both the L1 and the L2, there was no reliable (switch vs. no-switch) contrast for the with-preparation trials (729 ms vs. 734 ms, $p = .79$), either in the L1 or in the L2. These results indicate that language-switching costs disappeared when participants were given time to prepare for the switch. Moreover, the best-fit models of both Presentation types required the exclusion of the Language and Trial Type interaction, indicating that in the no-preparation as well as in the with-preparation trials switching costs were symmetrical. Similarly, the lack of the three-way interaction for Language, Trial Type and Preparation Type in the model indicates all trials had comparable benefit from preparation time.

Finally, we measured mixing costs, i.e., the difference between single-language trials and no-switch trials in the mixed-language block. Table 3 (e) reveals a main effect of Block Type ($p < .001$), with surprisingly faster RTs for the mixed-language than the single-language block (744 ms vs. 768 ms). We also found a significant interaction of Language and Block Type ($p < .0001$), with facilitation for the L2 compared to the L1 (−63 ms vs. 21 ms), as well as a significant interaction of Preparation Type and Block Type ($p < .0001$), revealing a facilitatory effect for the with-preparation trials (−42 ms) but not for the no-preparation trials (−6 ms). The three-way interaction of Language, Block Type and Presentation Type was also significant ($p < .05$). To examine this interaction, we split the data by Presentation Type. Results of both the no-preparation trials (Table 3f) and the with-preparation trials (Table 3g) showed a significant interaction of Language and Block Type ($p < .0001$ and $p < .01$ respectively). In the no-preparation trials (see Table 3h and Table 3i), we found that responses in the L1 were slower in the mixed than in the single-language block (55 ms mixing costs; $p<.0001$), whereas responses in the L2 were faster in the mixed than in the single-language block (62 ms facilitatory effect; $p < .0001$). In the with-preparation trials (see Table 3l and Table 3m), there was no significant effect of Block Type for the L1 (−16 ms, $p = .10$), whereas L2 responses were faster in the mixed compared to the single-language block (63 ms facilitatory effect; $p < .0001$).

Discussion

Investigating the role of preparation time in a bilingual picture naming task, we found symmetrical switching costs when highly proficient bilinguals had no time to prepare for the task, and no switching costs when participants were given 800 ms preparation time. Whilst symmetrical switching costs for highly proficient bilinguals have been consistently reported (e.g., Costa, Santesteban & Ivanova, 2006), complete dissipation of language switching costs is a novel finding. Table 4 presents a comparison of our findings with results from previous studies. As shown in Table 4, earlier studies have used similar or even longer preparation times, but shorter inter-stimulus or response-stimulus intervals.

Table 4. *Overview of cued language switching studies. For each study information on the timing events are given: Cue-Stimulus Interval (CSI), Response-Cue Interval (RCI), Response-Stimulus Interval (RSI) and Inter-Trial Interval (ITI).*

Study	Preparation	CSI	RCI	RSI	ITI	Switch costs
Costa & Santesteban (2004)	Absent	0 ms	1150 ms	1150 ms	_	Symmetric
	Short	500 ms		1650 ms		Symmetric
	Long	800 ms		1950 ms		Symmetric
Philipp et al. (2007)	Short	100 ms	1000 ms	1100 ms	_	Asymmetric
	Long	1000 ms	100 ms	1100 ms	_	Asymmetric
Verhoef et al. (2009)	Short	750 ms	Variable	Variable	1500 ms/ 2300 ms	Asymmetric
	Long	1500 ms				Symmetric
Declerck et al. (2012)	–	1000 ms	400 ms	1400 ms	_	Symmetric
Fink & Goldrick (2015)						
Exp. 1	Short	750 ms	Variable	Variable	1000 ms/1250 ms	Symmetric
	Long	1500 ms				Symmetric
Exp. 2	Absent	0 ms	Variable	Variable	1000 ms/ 1250 ms	Asymmetric
	Short	750 ms				Asymmetric
	Long	1500 ms				Asymmetric
This study	Absent	0 ms	Variable	Variable	2400 ms	Symmetric
	Present	800 ms				Absent

With respect to participants' accuracy of responses in the mixed-language condition, we found no effect of preparation time, language (L1 or L2) or trial type (switch vs. no-switch). This finding is in line with previous language-switching studies (e.g., Schwieter & Sunderman, 2008). As regards the response-time data in the mixed-language condition, we found a trend for L1 naming latencies to be slower than for the L2. Slower naming latencies for the L1 than for the weaker language (either L2 or L3) have been labelled a 'paradoxical language effect' (Christoffels et al., 2007; Verhoef, Roelofs & Chwilla, 2010). This effect has been attributed to the additional cost involved in globally inhibiting the L1 in a mixed-language context, to facilitate naming in the weaker language (Costa & Santesteban, 2004; Verhoef et al., 2009). However, because of methodological differences between studies (e.g., type of bilinguals, type of task and material used), the sources of the paradoxical language effect in language switching are still not fully understood.

Furthermore, we also found a preparation-time benefit in L1 no-switch trials, in line with Fink and Goldrick's (2015) findings and contra Verhoef et al.'s (2009) hypothesis that L1 repetition trials do not benefit from longer CSI. Moreover, we found mixing costs only in the L1 (for the no-preparation trials), whereas there was a mixing benefit in the L2, for both no-preparation and with-preparation trials. We suggest that these results reflect an adjustment of naming strategies depending on task-demands, in order to successfully perform the tasks. Specifically, whilst in with-preparation trials the language cue is encoded first followed by the picture to be named, in the no-preparation trials both stimuli have to be processed simultaneously, making no-preparation trials more demanding than with-preparation trials. In case of bilingual language switching, the most challenging condition, the 'worst case' in Los' (1996) terms, is naming in the L2. Consequently, the speaker might devote more attention to the weaker L2 and less attention to the stronger L1, particularly in tasks that require more attentional resources. This strategy may yield a mixing BENEFIT in the L2 and a mixing COST in the L1 for the more demanding no-preparation trials. In the less demanding with-preparation trials, however, there are no mixing costs in the L1, but still a benefit in the L2. Mixing benefits rather than mixing costs for the L2 have previously been obtained by Hernandez et al. (2001). Similar to Hernandez et al.'s (2001) study, RCI and RSI in the present study have a variable duration. We suppose that, compared to studies with fixed RCI and RSI (e.g., Prior & Gollan, 2011), unpredictable RCI and RSI might enhance the level of task uncertainty, and thus of task demand, boosting facilitation of what is unconsciously perceived as the most difficult situation, i.e., naming in the L2.

Overall, these results suggest that mixing costs are not a mere reflection of the global costs of maintaining two or more languages active, but that they rather reflect unconscious adjustments to the task. Consequently,

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mixing costs are also flexible in nature and can be modulated by trial-specific manipulations, such as preparation time.

To conclude, our study reveals that both transient and sustained control processes are affected by preparation time. With regard to transient control, our results show that the cognitive system is able to fully prepare for the upcoming trial, challenging the view that it is impossible to completely eliminate switching costs (e.g., Rogers & Monsell, 1995). We suggest that this is due to the relative long ITI used in the present study, which together with a preparation time of 800 ms allows for the completion of the previous task and as a result for the system to prepare for the new one. This supports the hypothesis that advanced preparation can be fulfilled before the stimulus is presented (e.g., Monsell, 2003, but see Mayr & Kliegl, 2003). However, we acknowledge that the question of how preparation and inter-trial times affect bilingual language switching costs requires further study. In particular, the degree of overlap between passive decay and active preparation involved in modulating switching costs needs to be precisely determined. Moreover, the fact that in the present study the response-stimulus intervals were variable may have affected naming latencies and needs to be controlled for in future studies. With reference to sustained control, we found that it was also affected by a trial-specific manipulations. This undermines the idea that mixing costs are a mere reflection of the global costs of maintaining two tasks active in memory. Instead, mixing costs (like switching costs) reflect strategies speakers rely on during language switching tasks (for a review see Festman & Schwieter, 2015). We suggest that mixing costs are involuntary adjustments to a given task and are therefore affected by task-specific manipulations. Further investigation is needed to clarify not only how these strategies work but also how they are influenced by participant-level factors, specifically by bilinguals' language proficiency.

Appendix A: Materials (L1 German, L2 English):

Eighteen pictures were selected from the Colorized Snodgrass and Vanderwart object set (Rossion & Pourtois, 2004) to be named in English and/or German. Items were matched according to conceptual complexity, word length (letters), lemma frequency, cognateness and semantic category using the International picture naming project (IPNP) database (Bates, D'Amico, Jacobsen, Szekely, Andonova, Devescovi, Herron, Lu, Pechmann, Pleh, Wicha, Federmeier, Gerdjikova, Gutierrez, Hung, Hsu, Iyer, Kohnert, Mehotcheva, Orozco-Figueroa, Tzeng & Tzeng, 2003). One-way ANOVAs revealed that there were no statistical differences for the test words in the two languages, neither with respect to lemma frequency (English: 3.19 (SD: 1.49) vs. German: 2.88 (SD: 1.75), $p = .36$) nor for word length (English: 5.3 (SD: 1.5) vs. German: 5.8 (SD: 2.5), $p = .53$). All the chosen pictures were classified as conceptually simple (conceptual complexity variable = 1); for details see Bates et al. (2003). Moreover, pictures denoting cognates or homophones in English and German were not selected. Finally, to avoid cumulative semantic interference effects (Howard et al., 2006), we selected pictures belonging to different semantic categories.

List of the items used:

Baum, tree; Besen, broom; Blatt, leaf; Gürtel, belt; Glocke, bell; Kette, necklace; Kleid, dress; Kürbis, pumpkin; Löffel, spoon; Pfeil, arrow; Pilz, mushroom; Rad, wheel; Schmetterling, butterfly; Stuhl, chair; Tür, door; Uhr, watch; Weintraube, grapes; Zwiebel, onion

Appendix B: Participants

All participants were native speakers of German (L1), late learners of English (L2). Their L2 proficiency level was assessed at the beginning of each experimental session using the grammar part of the paper-based Oxford Placement Test (Allan, 2004), which yielded a mean score of 75.4% (SD: 5.1) indicating that according to the Common European Framework of Reference for Languages (CEFR, Council of Europe, 2001a) they were proficient L2 users (C1 level). Six participants knew one additional language, ten reported knowledge of two additional languages, and five spoke three additional languages. French was reported to be among these languages from 21 participants, Spanish from six, Russian and Dutch from four respectively, and finally Italian, Swedish, Norwegian, Indonesian, Korean and Chinese from 1 participant each. As for their current usage of English, most participants employ it for watching TV or listening to the radio ($n = 28$), reading books ($n = 29$), for work ($n = 27$), talking to partners or family members ($n = 8$), or communicating with friends ($n = 21$).

Appendix C: Data analysis

All models were implemented with the lme4 package (Bates, Maechler, Bolker & Walker, 2014) and performed with the R software package (R Development Core Team, 2013). Models included the factors Language (L1 vs. L2), Presentation Type (with-preparation vs. no-preparation), and Trial Type (switch vs. no-switch) and Block Type (single vs. mixed). We fitted the data with crossed random factors for participants and items. Deviation contrasts were used for all fixed effects (0.5 and −0.5), so that estimates for factors reflected main effects and interactions. Intercept adjustments were included for all random factors. Slope adjustments (for the factors Language and/or Presentation Type, Language and Trial Type) were tested for inclusion through model comparisons of nested models (using AIC as a measure of model quality; e.g., Burnham & Anderson, 2004). Since our data were positively skewed, we used the Box-Cox function of the MASS package in R (Venables & Ripley, 2002) to estimate a transformation that would satisfy the assumption of normality of residuals (Kliegl, Masson & Richter, 2010). The results recommended performing an inverse transformation; all RTs were transformed accordingly prior to any further analysis (Baayen & Milin, 2010).

References

Allan, D. (2004). *Oxford Placement Test 1*. Oxford: Oxford University Press.

Allport, A., Styles, E. A., & Hsieh, S. (1994). Shifting intentional set: Exploring the dynamic control of tasks. In C. Umilta & M. Moscovitch (Eds.), *Conscious and nonconscious information processing: Attention and performance XV* (pp. 421–452). Cambridge, MA: MIT Press.

Baayen, R. H., & Milin, P. (2010). Analyzing reaction times. *International Journal of Psychological Research, 3,* 12–28.

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2014). lme4: Linear mixed-effects models using S4 classes. [http://CRAN. R-project.org/package=lme4]. R package version 1.1–7.

Bates, E., D'Amico, S., Jacobsen, T., Szekely, A., Andonova, E., Devescovi, A., Herron, D., Lu, C. C., Pechmann, T., Pleh, C., Wicha, N., Federmeier, K., Gerdjikova, I., Gutierrez, G., Hung, D., Hsu, J., Iyer, G., Kohnert, K., Mehotcheva, T., Orozco-Figueroa, A., Tzeng, A., & Tzeng, O. (2003). Timed picture naming in seven languages. *Psychonomic Bulletin & Review, 10,* 344–380.

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.

Braver, T. S., Reynolds, J. R., & Donaldson, D. I. (2003). Neural mechanisms of transient and sustained cognitive control during task switching. *Neuron, 39,* 713–726.

Burnham, K. P., & Anderson, D. R. (2004). Multimodel inference: understanding AIC and BIC in model selection. *Sociological Methods & Results, 33,* 261–304.

Christoffels, I. K., Firk, C., & Schiller, N. (2007). Bilingual language control: An event-related brain potential study. *Brain Research, 1147,* 192–208.

Cnaan, A., Laird, N. M., & Slasor, P. (1997). Using the general linear mixed model to analyse unbalanced repeated measures and longitudinal data. *Statistics in Medicine, 16,* 2349–2380.

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,* 491–511.

Costa, A., Santesteban, M., & Ivanova, I. (2006). How do highly proficient bilinguals control their lexicalization process? Inhibitory and language-specific selection mechanisms are both functional. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32,* 1057–1074.

Council of Europe (2001a). Common European Framework of Reference for Languages: Learning, Teaching, Assessment. Cambridge: Cambridge University Press.

Declerck, M., Koch, I., & Philipp, A. M. (2012). Digits vs. Pictures: The influence of stimulus type on language switching. *Bilingualism: Language and Cognition, 15,* 896–904.

Festman, J., & Schwieter, J. W. (2015). Behavioural measures of language control: Production and comprehension. In *The Cambridge Handbook of bilingual language processing*, ed. By John W. Schwieter. Cambridge: Cambridge University Press, 527–547.

Fink, A., & Goldrick, M. (2015). Pervasive benefits of preparation in language switching. *Psychonomic Bulletin and Review*.

Forster, K. I., & Forster, J. C. (2003). DMDX: A windows display program with millisecond accuracy. *Behavior Research Methods, Instruments, & Computers, 35,* 116–124.

Guo, G., & Zhao, H. (2000). Multilevel modeling for binary data. *Annual Review of Sociology, 26,* 441–462.

Hernandez, A. E., Dapretto, M., Mazziotta, J., & Bookheimer, S. (2001). Language switching and language representation in Spanish-English bilinguals: an fMRI study. *Neuroimage, 14,* 510–520.

Howard, D., Nickels, L., Coltheart, M., & Cole-Virtue, J. (2006). Cumulative semantic inhibition in picture naming: experimental and computational studies. *Cognition, 100,* 464–482.

Kliegl, R., Masson, M. E. J., & Richter, E. M. (2010). A linear mixed model analysis of masked repetition priming. *Visual Cognition, 18,* 655–681.

Koch, I., & Allport, A. (2006). Cue-based preparation and stimulus-based priming of tasks in task switching. *Memory & Cognition, 34,* 433–444.

Koch, I., Prinz, W., & Allport, A. (2005). Involuntary retrieval in alphabet-arithmetic tasks: Task-mixing and task-switching costs. *Psychological Research, 69,* 252–261.

Los, S. A. (1996). On the origin of mixing costs: Exploring information processing in pure and mixed blocks of trials. *Acta Psychologica, 94,* 145–188.

Mayr, U., & Kliegl, R. (2003). Differential effects of cue changes and task changes on task-set selection costs. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29,* 362–372.

Meiran, N. (2000). Modeling cognitive control in task-switching. *Psychological Research, 63,* 234–249.

Monsell, S. (2003). Task switching. *Trends in Cognitive Sciences, 7,* 134–140

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.

Prior, A., & Gollan, T. H. (2011). Good language-switchers are good task-switchers: Evidence from Spanish-English and Mandarin-English bilinguals. *The Journal of the International Neuropsychological Society, 17,* 682–691.

Protopapas, A. (2007). CheckVocal: A program to facilitate checking the accuracy and response time of vocal responses from DMDX. *Behavior Research Methods, 39,* 859–862.

R Development Core Team. (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing. [http://www.R-project.org].

Rogers, R. D., & Monsell, S. (1995). Costs of a predictable switch between simple cognitive tasks. *Journal of Experimental Psychology: General, 124,* 207–231.

Rossion, B., & Pourtois, G. (2004). Revisiting Snodgrass and Vanderwart's object set: The role of surface detail in basic-level object recognition. *Perception, 33,* 217–236.

Rubin, O., & Meiran, N. (2005). On the origins of the task mixing cost in the cuing task-switching paradigm. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31,* 1477–1491.

Schwieter, J. W., & Sunderman, G. (2008). Language switching in bilingual speech production. *The Mental Lexicon, 3,* 214–238.

Venables, W. N., & Ripley, B. D. (2002). Modern Applied Statistics with S. Springer, New York, fourth edition. [http://www.stats.ox.ac.uk/pub/MASS4]. ISBN 0–387–95457–0.

Verhoef, K., Roelofs, A., & Chwilla, D. (2009). Role of inhibition in language switching: Evidence from event related brain potentials in overt picture naming. *Cognition, 110,* 84–99.

Verhoef, K., Roelofs, A., & Chwilla, D. (2010). Electrophysiological evidence for endogenous control in switching attention between languages in overt picture naming. *Journal of Cognitive Neuroscience, 22,* 1832–1843.