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RESEARCH REPORT

Asymmetrical Switch Costs in Bilingual Language Production Induced by Reading Words

David Peeters
Max Planck Institute for Psycholinguistics,
Nijmegen, the Netherlands

Elin Runnqvist, Daisy Bertrand, and
Jonathan Grainger
Aix–Marseille University and Centre National de la Recherche
Scientifique, Marseille, France

We examined language-switching effects in French–English bilinguals using a paradigm where pictures are always named in the same language (either French or English) within a block of trials, and on each trial, the picture is preceded by a printed word from the same language or from the other language. Participants had to either make a language decision on the word or categorize it as an animal name or not. Picture-naming latencies in French (Language 1 [L1]) were slower when pictures were preceded by an English word than by a French word, independently of the task performed on the word. There were no language-switching effects when pictures were named in English (L2). This pattern replicates asymmetrical switch costs found with the cued picture-naming paradigm and shows that the asymmetrical pattern can be obtained (a) in the absence of artificial (nonlinguistic) language cues, (b) when the switch involves a shift from comprehension in 1 language to production in another, and (c) when the naming language is blocked (univalent response). We concluded that language switch costs in bilinguals cannot be reduced to effects driven by task control or response-selection mechanisms.

Keywords: language-switching, language production, bilingualism, picture naming

Switching languages is a rather frequent activity for many bilingual speakers. For example, a plausible beginning of the day for a bilingual person might involve reading the newspaper in Language A, chatting with a family member in Language B, then attending a work meeting held in Language A that gets interrupted by a phone call from a friend in Language B. The apparent ease and accuracy with which language switches are made suggest that bilinguals develop a high level of skill in executing and controlling such switches. However, research on bilingual language production and comprehension has shown that switches entail a processing cost (e.g., Grainger & Beauvillain, 1987; Macizo, Bajo, & Paolieri, 2012; Meuter & Allport, 1999; Thomas & Allport, 2000; von Studnitz & Green, 2002). Furthermore, the fact that in spoken language production, larger costs are observed when switching into the dominant language than vice versa (i.e., asymmetrical switch costs: Costa & Santesteban, 2004; Costa, Santesteban, & Ivanova, 2006; Hernandez & Kohnert, 1999; Meuter & Allport, 1999) suggests that the cost is not exclusively generated by a generic task-switching mechanism. It has thus been proposed that such switch costs might reflect properties of the architecture and dynamics underlying bilingual language processing, such as the residual activation of language nodes and the influence they have on the relative activation of words in each language (e.g., Grainger & Dijkstra, 1992; Grainger, Midgley, & Holcomb, 2010) or the adaptation of task control mechanisms to the specific job of controlling language use in bilinguals (Dijkstra & van Heuven, 2002; Green, 1998).

Nevertheless, it is still an issue as to whether language switch costs in general, and the asymmetrical pattern of such costs seen in studies of language production in particular, have anything to do with everyday out-of-the-laboratory language processing in bilinguals (Finkbeiner, Almeida, Janssen, & Caramazza, 2006; Gollan & Ferreira, 2009). Furthermore, bilinguals are often faced with switches between comprehension and production, yet language-switching studies conducted so far have focused on switches within a single modality (either comprehension or production), and most current models of language switching predict no costs when switching from comprehension to production. Thus, it is possible that even if switch costs are relevant for natural language production, their scope is rather limited.

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David Peeters, Max Planck Institute for Psycholinguistics, Nijmegen, the Netherlands; Elin Runnqvist, Daisy Bertrand, and Jonathan Grainger, Laboratoire de Psychologie Cognitive, Aix–Marseille University, Marseille, France, and Centre National de la Recherche Scientifique, Marseille, France.

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Correspondence concerning this article should be addressed to Jonathan Grainger, Laboratoire de Psychologie Cognitive, Aix-Marseille Université, 3 place Victor Hugo, 13331 Marseille, France. E-mail: jonathan.grainger@univ-amu.fr

In the present study, we introduce a paradigm designed (a) to provide a test of certain extralinguistic accounts of language switch costs, to be described later, and (b) to assess whether switch costs can be obtained across modalities (i.e., from comprehension to production). We focus on the phenomena that are at the heart of the debate surrounding mechanisms underlying language-switching effects—that is, language switch costs in spoken language production and the asymmetrical pattern associated with such costs. Contrary to comprehension studies, in studies of language switching in production, participants have to be told which language to use, and this is typically achieved by associating a language cue (a color, a flag, and so forth.) with the to-be-named stimulus (typically, a picture of an object) in the so-called "cued picture-naming" paradigm. It is therefore important to establish to what extent the observed switch costs and their associated asymmetry are not just an artifact of the rather unnatural circumstances under which the language switch is executed.

Precisely because of the unnatural cueing procedure used in studies of switch costs in language production, Gollan and Ferreira (2009) questioned the generalizability of the observation that switching language comes at a cost. These authors argued that the kind of switching that occurs in the laboratory differs from that in real life, in that language switches are imposed through artificial cues in the former context while in the latter they are often a result of the intention of the speaker. They conducted a series of voluntary or quasi-voluntary language-switch experiments in which subjects could decide themselves when to switch languages. In these conditions, they found either symmetrical switch costs or no switch costs at all. This suggests that cue-induced switch costs (and especially their asymmetry) might not reflect basic mechanisms involved in bilingual language production, but might rather reflect the specific way in which the switch is induced.

However, while it is true that, in real life, language switches are not forced upon speakers through artificial cues such as colors or flags, it is equally true that switches can be triggered by environmental cues such as the appearance of a particular person or overhearing speech in another language. Thus, it is possible that the switch-cost patterns observed in cued picture-naming paradigms, whatever their underlying cause, may still be relevant as a window into the basic mechanisms involved in bilingual language production. Nonetheless, the issue of the relatively unnatural switch cues typically used in such studies remains.

One major advantage of the paradigm introduced in the present study is that it dispenses with any explicit cueing.[1] During four blocks of 100 trials, printed words and pictures were alternated. Participants categorized words either according to language membership or as being members or not of a prespecified semantic category (animals), and they named the pictures. While in all blocks, words were presented in Language 1 (L1) and Language 2 (L2), pictures were only named in one language in a given block. Hence, production language was unambiguous (univalent), and introducing the language switch through the written modality, which intrinsically possesses a language cue, removes the need for any additional external cues.

This new procedure allowed us to test several different accounts of asymmetrical switch costs in language production in bilinguals. First, if previous switch costs reported in the literature (particularly asymmetrical switch costs) are a consequence of the artificial nonlinguistic cueing procedure that was used (as argued by Gollan & Ferreira, 2009), then here we should observe symmetrical and reduced switch costs, if any at all. Second, if it is the very fact of producing a word in a different language that is the source of switch costs in language production, then we should not observe any influence of language switching when there is no production associated with the switch-inducing trial. This is what one might expect on the basis of task-specific inhibitory accounts of language switching, such as the *task schema* account proposed by Green (1998). More precisely, according to this account, the task schema for producing in Language A inhibits the task schema for producing in Language B, and this in turn inhibits lexical representations in Language B. It does not follow, however, that a hypothetical task schema for understanding a word in Language A should inhibit the task schema for producing in Language B. Finally, the procedure adopted in the present study removed any role for response-selection artifacts (Finkbeiner et al., 2006), since all the critical responses on which switch costs were measured were univalent within a given block. That is, as noted earlier, only one language was used to name pictures per block, and therefore, according to Finkbeiner et al.'s response selection hypothesis, no asymmetrical switch-costs would be observed. More precisely, according to this hypothesis, it is the change (switch trials) or not (nonswitch trials) of response selection criteria, necessary for selecting the appropriate response for bivalent stimuli, that drives asymmetrical switch costs in bilingual language production.

In sum, several accounts of asymmetrical switch costs in language production predict that there should be no asymmetry and possibly no switch costs at all when the language switch involves silently reading a word in Language A followed by naming a picture in Language B, with picture-naming language held constant across a block of trials and the language of the word to be read varying across the block. On the other hand, an extension of the bilingual interactive–activation model (BIA-model; Grainger & Dijkstra, 1992; van Heuven, Dijkstra, & Grainger, 1998), proposed by Grainger et al. (2010), hypothesizes a unique mechanism for language-switching effects independently of stimulus and response modality. In this model, language nodes integrate bottom-up and top-down information about language membership, and they modulate the relative activity of lexical representations in each language. We therefore would expect to observe cross-modality language switch effects on the basis of this model. Furthermore, one might expect the asymmetric nature of these effects to be maintained given that language node activity conjointly influences lexical representations involved in both comprehension and production. The present study puts these different predictions to test.

Method

Participants

Twenty-six native speakers of French (seven men; 20–27 years old, mean age = 22.4 years) took part in the experiment. All participants were advanced students of English (i.e., at least in

[1] We acknowledge that the paradigm introduced by Finkbeiner et al. (2006) did not require cues for target picture naming, since target language was blocked, as in the present study. However, explicit cues were required to determine the language of the switch-inducing naming response in that study, and this explicit cueing could have influenced the nature of switching effects.

their third year) at Aix–Marseille University, France. Participants filled in a questionnaire to allow us to assess their self-rated French and English language skills (Table 1).

Design and Stimuli

Participants were presented with lists of to-be-named pictures intermixed with French (L1) and English (L2) words. Prior to receiving a list of pictures and printed words, participants were told in which language they were to name the picture (naming language: L1 or L2) and what task they had to perform on the word stimuli (task: language decision or semantic categorization). The combination of these two factors gave rise to four blocks of trials. In each block, 50 pictures were shown, once preceded by a French (L1) word and once preceded by an English (L2) word, defining the two levels of the switch factor. Naming language, task, and switch were within-participant factors in a $2 \times 2 \times 2$ factorial design. In the two semantic categorization blocks, participants had to press a button whenever they saw an animal name (in French or English). In one of these blocks, they named all pictures in French and in the other block they named all pictures in English. In the two language decision blocks, participants indicated whether the word was French or English. Again, in one block, they named all pictures in French and in the other block in English. In each block of the experiment, there were 50 switch trials (language of the word was different from the picture-naming language) and 50 nonswitch trials (language of the word was the same as the picture-naming language). There were always at least 25 trials between the first and the second presentation of the same picture. The order of presentation of the pictures and corresponding words was randomized for each participant. The order of the four blocks of the experiment was counterbalanced. In both semantic categorization blocks, 10 pictures were added that were preceded by 10 different animal names (half French and half English). All pictures were single-object color images, taken from Chauncey, Holcomb, and Grainger (2009).

We selected the 400 critical words using CELEX (Baayen, Piepenbrock, & van Rijn, 1993) for the English words and LEXIQUE Version 3.71 (New, Pallier, Ferrand, & Matos, 2001) for the French words, avoiding close cognates and cross-language homographs (see Appendix for a list of these words and the names of the pictures). All words were four to six letters long and were matched on word length and lemma frequency across the four conditions formed by the combination of naming language and task on the word stimuli (see Table 2). The two words (one English and one French) that preceded the same picture always had the same number of letters, and they were matched as closely as possible on lemma frequency. Picture names were matched across language (L1 French and L2 English) on length (number of phonemes) and number of phonological neighbors (all t tests: $p > .1$).

Table 1
Self Assessed Ratings for Language 1 (French) and Language 2 (English) Proficiency as Well as the Self-Reported Reading Frequency in Both Languages

Language	Reading	Speaking	Reading frequency	General comprehension
L1 (French)	6.88 (0.33)	6.88 (0.33)	6.58 (0.64)	6.92 (0.27)
L2 (English)	5.81 (0.94)	5.81 (0.85)	5.50 (1.24)	5.92 (0.89)

Note. Ratings made on a 7-point Likert scale. Standard deviations are the values within the parentheses. L1 = Language 1; L2 = Language 2.

Table 2
Average Lemma Frequency per Million Words and Average Number of Letters for the Word Stimuli Used in the Different Conditions

Task	Lemma frequency	Number of letters
Language decision		
L1 naming block		
L1 words	100	5.1
L2 words	101	5.1
L2 naming block		
L1 words	101	5.1
L2 words	100	5.1
Semantic categorization		
L1 naming block		
L1 words	97	5.1
L2 words	100	5.1
L2 naming block		
L1 words	99	5.1
L2 words	100	5.1

Note. Different conditions as a function of the task performed (language decision vs. semantic categorization) or the naming language of the block (Language 1 vs. Language 2). L1 = Language 1 (French); L2 = Language 2 (English).

Procedure

Words were presented in white font (Courier New size 18) on a black background. Pictures were presented centered on the screen in white on a black background. Throughout the experiment, every trial consisted of a fixation point (200 ms) followed by a blank (100 ms), a word stimulus (1,500 ms), a blank (500 ms), the to-be-named picture (4,000 ms), and a symbol indicating that participants could blink their eyes (1,500 ms).[2]

Participants received written instructions in the picture-naming language of each block before beginning each block. In the semantic categorization blocks, they were asked to read every letter string carefully and to press a button with their right index finger whenever the presented word was an animal name (either in French or English). In the language decision tasks, they were asked to press a right button with their right index finger for English words and a left button with their left index finger for French words. They were asked to make their decisions as quickly and as accurately as possible. In addition, they were asked to name every picture in the target language of that block as quickly and correctly as possible. Every block began with the same set of 10 practice trials with words and pictures as in the main experiment but involving stimuli that were not used in the main experiment. Furthermore, every block in the experiment was preceded by a training session in which participants first saw all pictures one after the other with the corresponding picture name presented above it (either in English or French, depending on the picture-

[2] Participants' electroencephalograms (EEGs) were recorded continuously throughout the experiment. These data will be reported elsewhere.

naming language of the following block), and then they saw the pictures without their corresponding names and were asked to name the picture (with no time pressure). Whenever they made a mistake in the training session, the experimenter told them the correct word to say.

Results

The main results of the present study concern performance in the picture-naming task as a function of the picture-naming language (naming language: L1 vs. L2), whether the language of the preceding word was the same as the picture-naming language or not (switch: switch trials vs. nonswitch trials), and the task performed on the preceding word (task: language decision vs. semantic categorization). We therefore first present an analysis of the picture-naming results before briefly summarizing the results obtained in the language decision and semantic categorization tasks performed on the word stimuli.[3]

Picture Naming

Incorrect responses, false starts, and hesitations were counted as errors. Participants correctly named 99.1% of the pictures. Reaction times (RTs) outside the range of 2.5 standard deviations from each participant's mean RT were removed from further analysis (2.2% of all data). The microphone failed to record RTs on 6.9% of the trials. Figure 1 gives an overview of the mean RTs per condition.

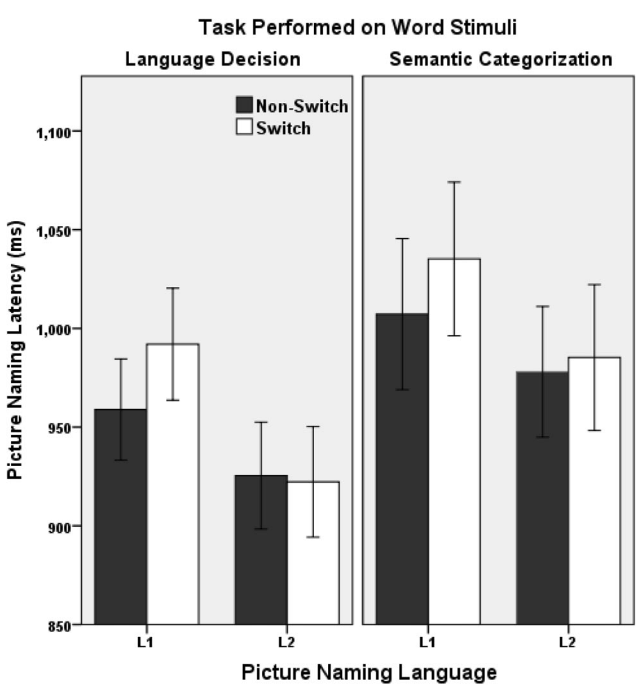

Figure 1. Mean picture-naming latencies as a function of naming language (L1 vs. L2), the task performed on the word stimuli in the same block (language decision vs. semantic categorization), and whether the word on the previous trial was from the same language as the naming language (nonswitch) or not (switch). Error bars are standard errors of the mean. L1 = Language 1 (French); L2 = Language 2 (English).

An analysis of variance (ANOVA) performed on the picture-naming RTs (time-locked from picture onset) revealed significant main effects of naming language, $F_1(1, 25) = 15.62$, mean square error (MSE) = 6,918, $p = .001$, $\eta_p^2 = .38$; $F_2(1, 392) = 34.56$, $MSE = 5{,}696$, $p = .001$, $\eta_p^2 = .08$, with naming RTs being slower in L1 than in L2, a main effect of switch, $F_1(1, 25) = 10.66$, $MSE = 1{,}297$, $p = .003$, $\eta_p^2 = .30$; $F_2(1,392) = 4.37$, $MSE = 5{,}696$, $p = .037$, $\eta_p^2 = .01$, with RTs being slower following a language switch, and a significant interaction between these two factors, $F_1(1, 25) = 8.36$, $MSE = 1{,}261$, $p = .008$, $\eta_p^2 = .25$; $F_2(1, 392) = 3.93$, $MSE = 5{,}696$, $p = .048$, $\eta_p^2 = .01$. Follow-up analyses showed that RTs were slower on switch than nonswitch trials in the L1 naming blocks, $F_1(1, 25) = 18.27$, $MSE = 1{,}327$, $p = .001$, $\eta_p^2 = .42$; $F_2(1, 198) = 7.71$, $MSE = 6{,}124$, $p = .006$, $\eta_p^2 = .04$, while the difference was not significant in the L2 naming blocks (both F_1 and $F_2 < 1$). Finally, there was a main effect of task, $F_1(1, 25) = 8.69$, $MSE = 16{,}032$, $p = .007$, $\eta_p^2 = .26$; $F_2(1, 392) = 46.78$, $MSE = 5{,}696$, $p = .001$, $\eta_p^2 = .11$, reflecting that picture-naming RTs were faster following a language decision than a semantic categorization.

Word Stimuli

Mean RTs and error rates in the semantic categorization and language decision tasks as a function of the language of the word (word language: L1 vs. L2) and the language of the naming task (naming language: L1 vs. L2) are shown in Table 3. The results of ANOVAs performed separately for each task are shown in Table 4. One key result in the language decision task is that language decisions on L1 words were significantly slower in the L1 naming block than in the L2 naming block.[4] Furthermore, there was a reversed dominance in the L1 naming block with slower RTs and significantly more errors to L1 words than to L2 words. In the semantic categorization task, fewer errors were made to L1 words than L2 words, and fewer errors were made in the L1 naming block than the L2 naming block (these effects were only significant in the by-participant analyses probably due to the small number of items per condition).

Discussion

In the present study, we investigated language-switching effects in bilingual language production in a situation where no artificial nonlinguistic language cues were required and in which the

[3] Note that the results concerning the word stimuli should be interpreted with caution since different words were tested in the different conditions, although they were matched on length and frequency.

[4] When order of naming language was introduced as a factor, there was a significant three-way interaction between naming language, word language, and order in the RT analysis, $F(1, 24) = 6.91$, $p = .015$. Only participants who performed L2 picture naming before L1 picture naming ($n = 13$) showed the pattern reported here. The RT pattern in the language decision data in this group was (a) L1 picture naming L1 words: 790 ms vs. L2 words: 753 ms; (b) L2 picture naming L1 words: 737 ms vs. L2 words: 788 ms. Effects of naming language, word language, and the interaction were not significant in the remaining group of participants. The RT pattern in this group was (a) L1 picture naming L1 words: 826 ms vs. L2: words: 836 ms; (b) L2 picture naming L1 words: 802 ms vs. L2 words: 819 ms. Please see the first row in Table 3 for comparison. There were no interactions with the order factor in any of the other analyses.

Table 3
Mean Reaction Times and Error Rates for the Word Stimuli in the Language Decision and Semantic Categorization Tasks

Task	L1 picture naming		L2 picture naming	
	L1 words	L2 words	L1 words	L2 words
Language decision				
Reaction times (ms)	808 (26.1)	794 (29.0)	769 (26.6)	804 (25.9)
Error rate (%)	5.4 (1.1)	2.3 (0.5)	4.3 (1.3)	3.9 (0.8)
Semantic categorization				
Reaction times (ms)	867 (35.6)	908 (30.0)	861 (46.2)	914 (34.9)
Error rate (%)	6.0 (2.8)	9.8 (3.2)	11.5 (4.0)	21.7 (5.6)

Note. Words appeared in a picture-naming block in Language 1 (L1, French) or Language 2 (L2, English). Standard errors of the mean are values within parentheses. Note that variance is higher in the semantic categorization task due to the smaller number of observations per condition and participant.

language switch took place across modalities (i.e., from comprehension to production). To this end, we conducted a language-switching experiment using a new paradigm in which the to-be-used language for production was blocked, and language switches were induced by varying the language of immediately preceding printed word stimuli. We reasoned that if switch costs and their asymmetrical pattern, found previously in the literature, were exclusively due to the type of cueing that had been used, we should observe reduced and more symmetrical switch costs. Furthermore, if switch costs were triggered by the inhibition of a particular task schema (e.g., "speak in L1"; Green, 1998), then the cross-modal induction of language switches used here should prevent switch costs from occurring. Finally, given that naming language was blocked in our paradigm, the response selection hypothesis (Finkbeiner et al., 2006) predicted no switch costs. On the contrary, we found robust asymmetrical switch costs, which were only significant when switching into the dominant language (L1), thus reproducing the asymmetrical pattern found with similar bilingual populations in studies using the standard cued picture-naming or digit-naming paradigm (Costa & Santesteban, 2004; Costa et al., 2006; Hernandez & Kohnert, 1999; Meuter & Allport, 1999). Asymmetrical switch costs seen in prior work are therefore unlikely to be driven by the particular language-cueing procedure that was used. Our findings therefore help reinstate switch costs as a key phenomenon related to language processing in bilinguals and suggest that switch costs cannot be dismissed as uniquely reflecting extralinguistic task-control or response selection mechanisms.

Green (1998) was the first to propose an explanation for switch costs in bilingual language processing as primarily reflecting the operation of a task-control mechanism used to determine which language should be associated with a given task on a given trial. In this account, switch costs arise via mutually inhibitory interactions between language-specific task schemas. When an individual is expecting to process a word in Language A, the task schema associated with that language is activated and consequently inhibits the task schema associated with Language B. Inhibition of a task schema results in inhibition of all lexical representations in the associated language, hence causing an increased difficulty in processing lexical information in Language B following processing of Language A, compared with a nonswitch context. Thus, in an experiment where picture stimuli are to be named in Language A, the task schema "Name a picture in Language A" will be activated, and this will inhibit the task schema "Name a picture in Language B," and subsequently all lexical representations in Language B. According to Green (1998), more inhibition is required to remove interference from L1 when speaking in L2; hence, L1 picture/digit naming suffers more from a language switch than does L2 picture/digit naming (i.e., asymmetrical switch costs).

The problem for the task schema account of switch costs in language production is that in the present study, switch costs were generated in the absence of any production related to the switch-generating stimuli (i.e., the word stimuli). Assuming that there is no need to suppress a language-specific production task schema when understanding a word independently of the language in which it is written, one would not expect to observe switch costs in this situation. Directly related to this issue is the finding that switch costs are observed in the generalized lexical decision task introduced by Grainger and Beauvillain (1987). Since, in this paradigm, the task is the same for words in both languages: "Press the right button when the stimulus is a word, either English or French, and the left button when it is not." There is no change in task schemas associated with a switch in language, yet switch costs are observed (e.g., Grainger & Beauvillain, 1987; Thomas & Allport, 2000). It may well be that task-control mechanisms play a role in language switching in certain contexts (e.g., language-specific lexical decision). What our results suggest is that this is not the whole story.

Finkbeiner et al. (2006) proposed an alternative account of language-switch costs, which they referred to as the response-selection hypothesis. According to this account, the bivalent nature of target stimuli (i.e., a given target can be named differently in two languages) is a necessary condition for obtaining switch costs, since it is only in these conditions that both responses are automatically prepared for output, and response selection criteria are used to select the appropriate response. Switch costs arise because response-selection criteria change on switch trials, and it takes additional time to establish the appropriate criteria in these conditions. Furthermore, switch costs are greater when switching into L1 because the L1 naming response becomes available more rapidly than the L2 naming response, and on certain trials, this can lead to premature rejection of the L1 response prior to establishment of response criteria. Does the response selection hypothesis correctly predict performance in the present study? The short answer is no. The fact that we obtained switch costs in a paradigm where the objects in pictures were always named in the same language in a given block (i.e., univalent responses) directly contradicts the predictions of the response-selection hypothesis. Once again, this does not imply that response criteria play no role at all in language-switching phenomena; it is just that, like task schemas, they are unlikely to be the whole story.

Indeed, there is abundant evidence that adjustments in response criteria play a key role in determining overall RT and accuracy in any task requiring a speeded response (see, for example, Dufau, Grainger, & Ziegler, 2012, for a recent account of such effects in the lexical decision task). Particularly relevant for the present work is a study showing how apparently asymmetrical task-switch costs can emerge as the result of a symmetric task-switch cost combined with an influence of processing difficulty on the switch-inducing trial (Schneider & Anderson, 2010). Given an easy task and a difficult task, a symmetric task-switch cost, and a cost associated

Table 4
Results of Analyses of Variance of Reaction Times and Error Rates in Responses to Word Stimuli

Effect	F	MSE	η_p^2
Language decision reaction times			
Naming language	$F_1 < 1$	*ns*	*ns*
	$F_2(1, 195) = 4.98^*$	3,279	.03
Word language	$F_1(1, 25) = 1.20$	*ns*	*ns*
	$F_2(1, 195) = 1.42$	*ns*	*ns*
Naming Language × Word Language	$F_1(1, 25) = 8.14^{**}$	1,832	.25
	$F_2(1, 195) = 7.42^{**}$	3,279	.04
Naming Language: L1 Words	$F_1(1, 25) = 5.64^*$	3,452	.18
	$F_2(1, 97) = 13.43^{***}$	3,012	.12
Naming Language: L2 Words	$F_1 < 1$	*ns*	*ns*
	$F_2 < 1$	*ns*	*ns*
Word Language in L1 Naming	$F_1(1, 25) = 1.83$	*ns*	*ns*
	$F_2(1, 97) = 1.09$	*ns*	*ns*
Word Language in L2 Naming	$F_1(1, 25) = 5.47^*$	2,780	.18
	$F_2(1, 97) = 8.33^{**}$	3,031	.08
Language decision error rate			
Naming language	$F_1 < 1$	*ns*	*ns*
	$F_2 < 1$	*ns*	*ns*
Word language	$F_1(1, 25) = 3.53$	*ns*	*ns*
	$F_2(1, 195) = 7.24^{**}$	.002	.04
Naming Language × Word Language	$F_1(1, 25) = 6.61^*$	.001	.21
	$F_2(1, 195) = 4.41^*$	.002	.02
Naming language: L1 words	$F_1 < 1$	*ns*	*ns*
	$F_2(1, 97) = 1.14$	*ns*	*ns*
Naming language: L2 words	$F_1(1, 25) = 4.70^*$	.001	.16
	$F_2(1, 97) = 4.12^*$	.002	.04
Word language in L1 naming	$F_1(1, 25) = 9.22^{**}$	.001	.27
	$F_2(1, 97) = 10.19^{**}$	.002	.10
Word language in L2 naming	$F_1 < 1$	*ns*	*ns*
	$F_2 < 1$	*ns*	*ns*
Semantic categorization reaction times			
Naming language	$F_1 < 1$	*ns*	*ns*
	$F_2(1,16) = 1.19$	*ns*	*ns*
Word language	$F_1(1,25) = 2.70$	*ns*	*ns*
	$F_2(1,16) = 5.85^*$	3,163	.27
Naming Language × Word Language	$F_1 < 1$	*ns*	*ns*
	$F_2 < 1$	*ns*	*ns*
Semantic categorization error rate			
Naming language	$F_1(1, 25) = 5.87^*$	337	.19
	$F_2(1, 16) = 3.91$	*ns*	*ns*
Word language	$F_1(1, 25) = 5.11^*$	248	.17
	$F_2(1, 16) = 2.90$	*ns*	*ns*
Naming Language × Word Language	$F_1(1, 25) = 1.30$	*ns*	*ns*
	$F_2 < 1$	*ns*	*ns*

Note. MSE = mean square error; *ns* = not significant.
$^* p < .05$. $^{**} p < .01$. $^{***} p < .001$.

with the processing difficulty of the immediately preceding trial (sequential difficulty cost), then switching into the easy task would combine both costs, whereas switching into the difficult task would combine a task-switch cost with a sequential processing advantage. Could this be the cause of the asymmetric language-switch costs found in the present study? According to this account, the fact that RTs and errors were actually numerically greater to L1 words than to L2 words in the L1 picture-naming block of the language decision task should have led to reduced switch effects in this condition. This was not the case, and therefore it would appear that sequential processing difficulty was having little impact on language switch effects within a given block of trials. On the other hand, sequential processing difficulty might provide an explanation for why picture-naming latencies were overall slower following semantic categorization than language decision, since RTs and errors were greater in the semantic categorization task. Finally, the role of changes in decision criteria as a factor driving language-switch costs in the lexical decision task had already been entertained and rejected by Grainger and Beauvillain (1987). Indeed, in this and other studies of language-switch costs in language comprehension, although L1 words are associated with easier processing than L2 words, switch costs tend, if anything. to be greater from L1 to L2 than from L2 to L1. We therefore reiterate that although modifications in response criteria may well affect performance in language-switching experiments, they cannot provide a complete account of the switch patterns that have been observed.

As noted in the introduction, the extension of the BIA model proposed by Grainger et al. (2010) hypothesized a unique mechanism for language-switching effects independently of stimulus and response modality, therefore correctly predicting the presence of cross-modality language-switching effects. Future modeling work within the framework of this model might help provide a complete account of the present findings, including the pattern of results observed with the word stimuli. One key distinction that we expect will provide important insights into language control in bilinguals is the distinction between endogenous and exogenous control. Endogenous control refers to the kind of control mechanism implemented by task schemas in Green's (1998) model, as well as the kind of sustained inhibition hypothesized by accounts of reversed language dominance, to be discussed later. Exogenous control, on the other hand, is uniquely stimulus driven, with the presence of language-specific cues in the environment (whatever their nature) triggering modulation of activity in other-language representations. In the BIA model, both of these control mechanisms are subserved by language nodes, which provide a simple mechanism for integrating information about a given language identity whatever the source of the information (Grainger et al., 2010). Exogenous control subserves switch costs in language comprehension because word stimuli automatically activate the corresponding language node, which then inhibits activity in the other language. Endogenous control subserves switch costs in language production because the intention to produce in Language A activates the appropriate language node, which in turn inhibits activity in the other language. The fact that in the BIA model, language nodes subserve both exogenous and endogenous control holds promise for future applications of this framework in explaining the switch costs found across modalities in the present study.[5]

Finally, another key finding of the present study is that picture naming in L1 was slower than picture naming in L2, even on the nonswitch trials. This reversed language dominance has been reported in a number of language-switching studies (e.g., Gollan & Ferreira, 2009), although typically such a pattern is accompanied by symmetrical switch costs. It has been proposed that asymmetrical switch costs and reversed language dominance reflect two different inhibitory language control strategies, namely, trial-by-trial based inhibition versus sustained inhibition of the dominant language (e.g., Gollan & Ferreira, 2009; Kroll, Bobb, Misra, & Guo, 2008). In a nutshell, the reasoning is that more balanced bilinguals would inhibit their slightly stronger language throughout the whole task in order to achieve an equal accessibility of both languages. In contrast, more unbalanced bilinguals would apply a strong inhibition only while speaking in the nondominant language, entailing a relatively larger cost when changing to the dominant language. Very tentatively, we would suggest that the fact that we observed reversed language dominance in relatively unbalanced bilinguals can be accounted for if we assume that the context of picture naming in L1 incited our bilingual participants to mildly inhibit their L1 throughout the L1 picture-naming block (i.e., sustained inhibition) in order to improve processing of the L2 words that appeared within that block. The fact that language-decision RTs to L1 words were significantly slower in the L1 naming block than the L2 naming block provides some support for this explanation.[6]

To conclude, we have shown asymmetrical language-switching effects in a picture-naming paradigm, where the naming language was blocked and language switches induced by printed word stimuli intermixed with the picture stimuli. Asymmetrical switch costs can therefore be obtained in the absence of artificial nonlinguistic cues, such as in the standard cued picture-naming paradigm. The asymmetrical pattern was obtained when the switch was from comprehension of a word in Language A to production of a word in Language B, hence falsifying the task schema account of switch costs (Dijkstra & van Heuven, 2002; Green, 1998). Furthermore, the asymmetrical pattern was obtained in conditions where the picture-naming language was blocked, hence falsifying the response selection hypothesis of Finkbeiner et al. (2006) and suggesting a much broader scope of switch costs than previously considered in the literature. The present results also illustrate how important it is to bridge the gap between comprehension research on the one hand and production research on the other in order to increase the understanding of language processing in general and bilingual language processing in particular.

[5] For an alternative account of language-switch costs involving target strengthening and speaker general conflict resolution rather than inhibitory bilingual language control, see Runnqvist, FitzPatrick, Strijkers, & Costa, 2012; Runnqvist, Strijkers, Alario, & Costa, 2012; Runnqvist, Strijkers, & Costa, in press).

[6] Furthermore, the fact that this particular pattern disappeared when participants first received the L1 picture-naming block can be explained by participants continuing to apply the L1 suppression during the following L2 naming block.

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(*Appendix follows*)

Appendix

Word Stimuli and Picture Names That Were Used in the Experiment

Picture Naming

L1 picture names. aube, bague, banc, bois, bouteille, cadeau, carton, ceinture, cerveau, charbon, chaussettes, cheveux, colonne, coude, couteau, cuillère, doigt, église, fantôme, foule, fromage, gants, jumeaux, livre, manteau, menton, montre, nuages, oeil, oeuf, os, panier, pantalon, pelle, pied, pierre, plage, poêle, poing, pomme, porte, queue, repas, rideau, sapin, soleil, terre, verre, viande, vin

L2 picture names. apple, basket, beach, belt, bench, bone, book, bottle, box, brain, cheese, chin, church, clouds, coal, coat, crowd, curtain, dawn, door, earth, eggs, elbow, eye, finger, fist, foot, ghost, gift, glass, gloves, hair, knife, meal, meat, pan, pillar, ring, rock, shovel, socks, spoon, sun, tail, tree, trousers, twins, watch, wine, wood

Language Decision

L1 naming block.

L1 words. abri, avion, besoin, bordel, brin, caisse, chou, cible, cuisse, éclat, espoir, étape, faim, fierté, frère, garçon, guerre, haine, hameau, jambon, jeudi, lundi, lutte, manège, mère, métier, moine, moulin, navire, onde, panne, plat, pluie, pognon, proie, puce, racine, saut, sein, soeur, soif, soin, souci, tête, tiroir, tort, trêve, ventre, vérité, volet

L2 words. bishop, bread, bridge, dairy, daisy, dirt, dream, faith, father, fellow, fourth, friend, fuel, globe, growth, hand, health, height, iron, killer, lack, life, lily, loan, nest, orbit, rental, rescue, sack, sand, shame, ship, soap, soul, steel, stone, story, street, stride, strike, taste, thigh, threat, topic, towel, waiter, weight, wheel, while, wonder

L2 naming block.

L1 words. aile, béton, blague, bourg, cahier, colère, croix, dureté, écran, fait, farine, femme, feutre, fille, folie, folle, fossé, fuite, gilet, hiver, invité, jambe, jeton, larme, lien, lueur, mardi, miel, outil, palier, paroi, pauvre, peigne, phare, poil, pont, poumon, quai, réseau, rêve, réveil, sapin, siècle, soir, sueur, toit, tueur, tuyau, verrou, ville

L2 words. ankle, answer, blade, bottom, bush, child, claim, cliff, cough, death, flesh, gold, grant, hammer, hatred, heath, hell, home, house, hurry, inside, lawyer, level, luck, miller, moon, owner, porch, praise, prey, pulse, rain, room, runner, screen, shift, shop, shower, skirt, slope, stake, thrust, travel, truth, waste, wheat, whole, wicket, wisdom, youth

Semantic Categorization

L1 naming block.

L1 words. année, août, appui, bateau, billet, bonbon, bonté, chemin, chêne, copain, côté, cuir, cuivre, dette, deuil, dieu, égard, ennui, espèce, fleuve, flic, foyer, gare, goût, jouet, lavabo, légume, lèvre, maison, marée, marié, midi, miette, noce, orage, patte, paysan, perte, peur, pudeur, rivage, seuil, soie, taille, toile, tricot, trou, valeur, vélo, virage

L2 words. amount, area, beard, birth, body, candle, copper, devil, estate, fabric, fence, fight, focus, gossip, handle, help, hint, hope, kettle, leaf, least, left, length, meadow, mood, mother, pitch, player, print, right, sake, scarf, sheet, silver, skin, smile, smoke, stance, summer, throat, tongue, trend, trip, twin, waist, water, weapon, work, writer, yield

L2 naming block

L1 words. amitié, anneau, balai, barbe, berger, beurre, boue, bougie, boulot, bout, brume, bulle, cire, ciseau, corvée, côte, cour, dédain, équipe, évêque, flèche, foin, foudre, frein, gâteau, gosse, haut, humeur, jour, jupe, lune, manche, marais, milieu, môme, monde, noix, paille, peau, pente, piste, poupée, rappel, recul, rive, saleté, santé, tard, tout, voie

L2 words. back, bulb, bundle, burden, burial, castle, cell, cellar, chest, climax, creek, denial, diet, dock, drawer, drum, editor, fear, flight, gate, glance, guest, heat, heaven, horn, lemon, movie, needle, outfit, pride, queen, rent, reward, ridge, rubber, rule, seed, shadow, spot, start, stool, survey, thread, wealth, week, wife, window, winner, world, year

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