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Speaking Two Languages for the Price of One: Bypassing Language Control Mechanisms via Accessibility-Driven Switches

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Abstract
How do bilinguals switch easily between languages in everyday conversation, even though studies have consistently found that switching slows responses? In previous work, researchers have not considered that although switches may happen for different reasons, only some switches—including those typically studied in laboratory experiments—might be costly. Using a repeated picture-naming task, we found that bilinguals can maintain and use two languages as efficiently as a single language, switching between them frequently without any cost, if they switch only when a word is more accessible in the other language. These results suggest that language switch costs arise during lexical selection, that top-down language control mechanisms can be suspended, and that language-mixing efficiency can be strategically increased with instruction. Thus, bilinguals might switch languages spontaneously because doing so is not always costly, and there appears to be greater flexibility and efficiency in the cognitive mechanisms that enable switching than previously assumed.

Keywords
language switching, voluntary, cost-free, bilingualism, lexical accessibility

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Bilinguals sometimes switch back and forth between languages when conversing with other bilinguals, though nothing obvious compels them to do so. Thus, switching languages must sometimes be relatively easy. However, studies have shown that switching takes longer than speaking just one language (Meuter & Allport, 1999), even for highly proficient bilinguals (Costa & Santesteban, 2004), when bilinguals can predict when they will have to switch (Festman, Rodriguez-Fornells, & Münte, 2010) or the exact word they will have to say (Declerck, Koch, & Philipp, 2015; Declerck, Philipp, & Koch, 2013), and when they can choose when (and whether) to switch (Gollan & Ferreira, 2009; Gollan, Kleinman, & Wierenga, 2014).

The reason for this apparently fundamental disconnect between bilingual behavior in situ and in the lab may lie partly in factors that motivate bilinguals to switch. Bilinguals might switch if the name of the concept they want to express is more accessible in the other language (e.g., a bilingual speaking English could switch to Spanish if *reloj* is more accessible than *clock*). Alternatively, they might switch for independent reasons, as when switching from Spanish to English to answer the telephone. We call accessibility-driven switches *bottom-up switches* and accessibility-independent switches *top-down switches*.

Nearly all language-switching studies have forced bilinguals to switch top-down by telling them which language to use on each trial, and bilinguals may adopt inefficient strategies even in studies with voluntary switching, mixing bottom-up and top-down switches (e.g., after naming several consecutive pictures in English, a bilingual might decide in advance to switch to Spanish on the next trial). However, in prior work, researchers have not

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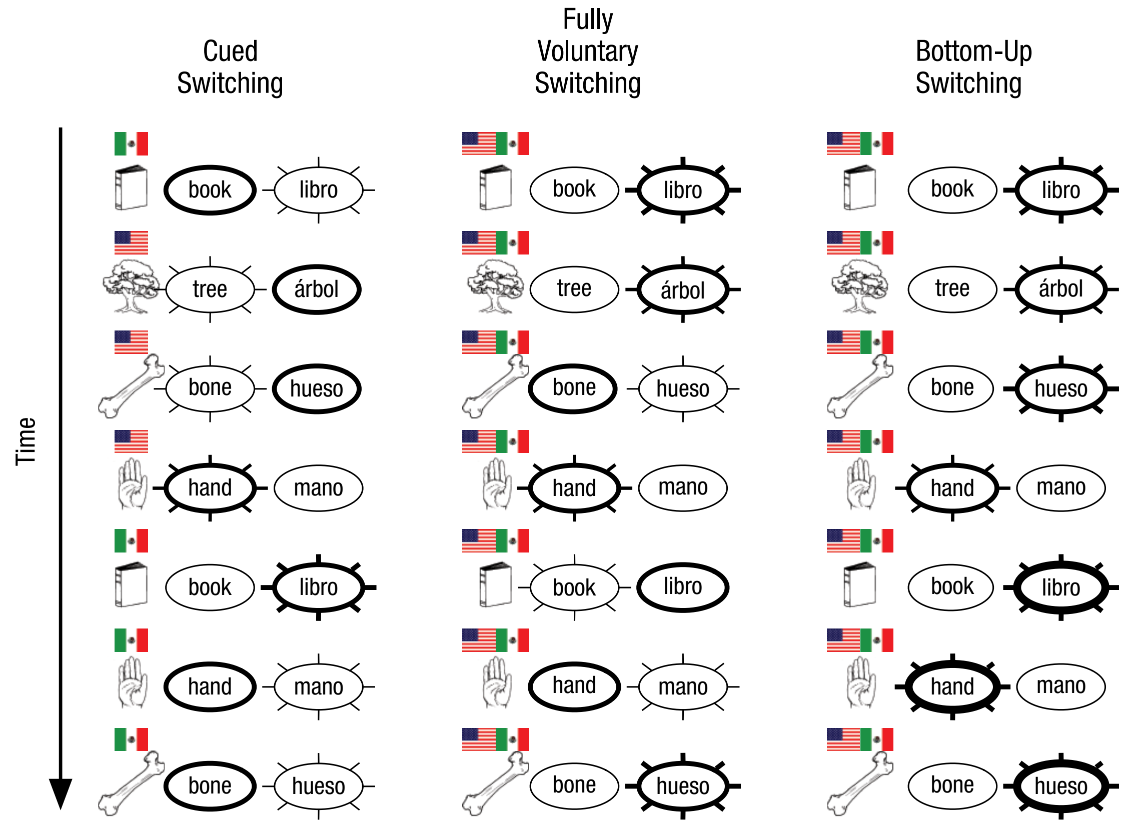

Fig. 1. Illustration of the experimental procedure and hypothesized effects of task instructions and participants' strategies on overall response efficiency. In Experiments 1a and 1b, Spanish-English bilinguals performed a picture-naming task in four conditions: In two single-language blocks (not shown here), there was no switching; participants named all pictures in English in one block and named all pictures in Spanish in the other. In another block (cued switching; left column), the language to be used varied across trials and was cued by the country flag that was shown with the picture; in a fourth block (bottom-up switching; right column), the appearance of both flags indicated that participants were free to use whichever language they chose the first time a picture appeared but should use the same language whenever it was presented on subsequent trials. For each picture, the figure shows the picture names in English and Spanish, with greater accessibility indicated by a thicker oval. Because accessibility varies idiosyncratically with language, participants were often forced in the cued-switching block to select a name (indicated by the radiating lines) that was less accessible than its translation. In Experiment 2, a block with fully voluntary switching (middle column) replaced the bottom-up-switching block; given these task instructions, bilinguals usually, but not always, select the name that is more accessible (Gollan, Kleinman, & Wierenga, 2014). We predicted that in bottom-up switching, lexical (i.e., word) accessibility would fully drive language selection and build with repetition, so that responses would become maximally accessible by the end of the block regardless of the language used on the previous trial.

considered that switch costs might be eliminated if bilinguals engage exclusively in bottom-up switching—switching languages only when doing so is easier than the alternative. We investigated this possibility using a quasivoluntary language-switching task in which bilinguals initially chose which language to use to name each picture, but were required to use that language every time that picture appeared subsequently. Though this instruction greatly restricted the bilinguals' freedom to choose when to switch, we predicted that it would reduce costs associated with switching, and that the role of bottom-up control processes in language selection would be increasingly revealed with repetition (see Fig. 1).

Switch costs are not the only phenomenon reflecting language control mechanisms in bilingual speech production (Green, 1998). For example, bilinguals' responses in a picture-naming task are slower on nonswitch trials within mixed-language blocks than in single-language blocks; these *mixing costs* reflect the need to actively maintain response readiness in both languages (Declerck & Philipp, 2015a). In addition, bilinguals sometimes name pictures faster in the nondominant language than in the dominant language, either only on switch trials (*asymmetric switch costs*; Meuter & Allport, 1999) or on both switch and nonswitch trials (*reverse dominance effects*; Christoffels, Firk, & Schiller, 2007; Costa & Santesteban, 2004; Gollan & Ferreira, 2009; Verhoef, Roelofs, & Chwilla, 2009; for a review, see Declerck & Philipp, 2015a). Both patterns suggest top-down control operating via activation (boosting) of the nondominant language, inhibition (active suppression) of the dominant language, or both. If bilinguals can follow instructions to engage in bottom-up selection without considering language membership, this could eliminate switch costs, mixing costs, and reverse dominance effects—that is, all top-down signatures of language control. Preliminary evidence from a small number of bilinguals who spontaneously chose to name each picture in just one language (but named some pictures in English and others in Spanish) in a voluntary block showed no switch costs (Gollan et al., 2014, Experiment 2). In the study reported here, we tested whether this approach works only for bilinguals who choose it spontaneously, or if it represents a universal, cost-free switching strategy that, once discovered, could be adopted by all.

Experiments 1a and 1b

We examined the effects of bottom-up switching in Experiment 1a and then conducted Experiment 1b to confirm unexpected effects of block order found in Experiment 1a. The two experiments differed only in the stimulus sets that were used.

Method

Participants. In Experiment 1a, participants were 120 Spanish-English bilingual students from the University of California, San Diego, who received course credit. A large sample was needed because approximately half of the bilinguals tested in previous studies of voluntary language switching did not contribute data to every condition and were thus excluded from analyses (Gollan & Ferreira, 2009; Gollan et al., 2014). The exact sample size was determined by running as many multiples of 24 individuals (a number chosen for counterbalancing purposes) as possible in two academic terms; analysis did not begin until data collection was complete. Of the 120 bilinguals, 87 (72.5%) were ultimately included in the analyses. (Exclusion criteria are discussed in more detail in the Analysis section.)

In Experiment 1b, participants were 122 Spanish-English bilingual students from the same population, who also received course credit. The sample size was intended to match that of Experiment 1a; however, scheduling participants in parallel with data collection led to the participation of 2 extra individuals. Of the 122 bilinguals in Experiment 1b, 84 (68.9%) were ultimately included in the analyses.

Across the two experiments, 174 of the bilinguals reported learning to speak Spanish before English at home (Experiment 1a: n = 92; Experiment 1b: n = 82), 10 reported learning to speak English before Spanish (Experiment 1a: n = 3; Experiment 1b: n = 7), and 56 reported learning to speak English and Spanish at the same age (Experiment 1a: n = 25; Experiment 1b: n = 31). (Two bilinguals in Experiment 1b did not provide this information for at least one language and thus are not included in this count.) The characteristics of the bilinguals who were included and excluded from the statistical analyses are summarized in Table 1. Across the experiments, the only examined dimension that showed a significant difference between included and excluded participants was age, and that was in Experiment 1a only: The excluded bilinguals in that experiment were slightly older than the included bilinguals. As this difference was small (1.4 years) and unexpected, and as bilinguals who were excluded for similar reasons from a previous voluntary-language-switching experiment (Gollan et al., 2014, Experiment 1) were slightly younger than included bilinguals (also by 1.4 years), we do not interpret the difference further.

A multilingual naming test (MINT; Gollan, Weissberger, Runnqvist, Montoya, & Cera, 2012) was administered to determine participants' language dominance. Those who scored higher in English than in Spanish or identically in the two languages were classified as English-dominant bilinguals (Experiment 1a: n = 110, 78 of whom were included in the analyses; Experiment 1b: n = 115, 81 of whom were included); others were classified as Spanish-dominant bilinguals (Experiment 1a: n = 10, 9 of whom were included; Experiment 1b: n = 5, 2 of whom were included). This classification agreed with self-reported dominance for most of the participants (Experiment 1a: n = 105; Experiment 1b: n = 110). Among the participants included in the analyses in Experiment 1a, the English-dominant bilinguals correctly named an average of 61 (SD = 3) of 68 pictures correctly in English and 46 (SD = 9) of 68 pictures correctly in Spanish; the Spanish-dominant bilinguals correctly named an average of 54 (SD = 6) and 59 (SD = 4) pictures in English and Spanish, respectively. Among the participants included in the analyses in Experiment 1b, the English-dominant bilinguals correctly named an average of 61 (SD = 3) and 45 (SD = 10) out of 68 MINT pictures in English and Spanish, respectively; the Spanish-dominant bilinguals correctly named an average of 53 (SD = 5) and 58 (SD = 5) pictures in English and Spanish, respectively.

Materials and procedure. Participants in both experiments completed the picture-naming task, a language-history questionnaire, and the MINT (Gollan et al., 2012).

Table 1. Comparison of the Included and Excluded Participants in Experiments 1a and 1b

	Experiment 1a					Experiment 1b				
	Included (n = 87)		Excluded (n = 33)			Included (n = 84)		Excluded (n = 38)		
Characteristic	*M*	*SD*	*M*	*SD*	Comparison	*M*	*SD*	*M*	*SD*	Comparison
Age (years)	20.0	1.9	21.4	3.7	$t(118) = -2.67$, $p = .009$	20.6	2.0	20.3	1.4	$t(120) = 0.71$, $p = .480$
Age of acquisition of English (years)[a]	3.9	2.7	4.0	3.0	$t(118) = -0.21$, $p = .836$	3.2	2.7	3.2	2.3	$t(119) = -0.10$, $p = .920$
Age of acquisition of Spanish (years)[a]	0.2	0.7	0.6	2.1	$t(118) = -1.27$, $p = .207$	0.4	1.0	0.6	1.2	$t(118) = -0.85$, $p = .397$
English MINT score[a,b]	60.2	3.9	60.2	3.9	$t(118) = 0.05$, $p = .964$	60.5	2.9	59.7	4.9	$t(118) = 1.07$, $p = .286$
Spanish MINT score[a,b]	47.5	9.2	44.9	10.9	$t(118) = 1.32$, $p = .190$	44.5	9.9	47.4	9.2	$t(118) = -1.46$, $p = .146$
English speaking ability[c]	6.6	0.7	6.3	1.0	$t(118) = 1.58$, $p = .117$	6.5	0.7	6.7	0.6	$t(120) = -1.12$, $p = .265$
English writing ability[c]	6.5	0.8	6.4	0.9	$t(118) = 0.45$, $p = .654$	6.4	0.8	6.6	0.6	$t(120) = -1.14$, $p = .257$
English listening ability[c]	6.7	0.5	6.5	0.8	$t(118) = 1.58$, $p = .117$	6.8	0.6	6.8	0.5	$t(120) = -0.60$, $p = .548$
English reading ability[c]	6.7	0.6	6.5	0.8	$t(118) = 1.21$, $p = .229$	6.6	0.6	6.7	0.5	$t(120) = -0.38$, $p = .706$
Spanish speaking ability[c]	6.0	1.1	5.6	1.6	$t(118) = 1.61$, $p = .111$	5.8	1.1	6.0	0.9	$t(120) = -0.97$, $p = .332$
Spanish writing ability[c]	5.4	1.2	5.5	1.1	$t(118) = -0.21$, $p = .830$	5.1	1.2	5.3	1.3	$t(120) = -0.65$, $p = .515$
Spanish listening ability[c]	6.5	0.9	6.3	1.0	$t(118) = 0.68$, $p = .501$	6.5	0.9	6.5	0.9	$t(120) = -0.38$, $p = .705$
Spanish reading ability[c]	6.0	1.1	5.8	1.0	$t(118) = 0.64$, $p = .524$	5.7	1.0	6.1	1.0	$t(120) = -1.64$, $p = .104$
Percentage English use currently	82.3	14.7	86.2	12.3	$t(118) = -1.37$, $p = .175$	83.6	12.9	81.7	15.5	$t(120) = 0.70$, $p = .484$
Percentage English use during childhood	58.5	17.6	52.9	20.4	$t(118) = 1.49$, $p = .138$	57.3	18.2	59.7	18.1	$t(120) = -0.66$, $p = .512$
Switching frequency currently[d]	3.6	1.5	4.0	1.6	$t(118) = -1.12$, $p = .266$	3.7	1.5	3.7	1.5	$t(120) = 0.18$, $p = .855$
Switching frequency in childhood[d]	3.4	1.5	3.7	1.5	$t(118) = -1.05$, $p = .295$	3.7	1.5	3.6	1.5	$t(120) = 0.50$, $p = .615$
Shipley vocabulary test[a,e]	28.7	3.3	28.0	3.0	$t(116) = 1.12$, $p = .264$	28.4	3.4	28.8	2.8	$t(106) = -0.64$, $p = .523$

[a]Missing demographic data for some participants led to fewer degrees of freedom for one or both experiments. [b]On the Multilingual Naming Test (MINT; Gollan, Weissberger, Runnqvist, Montoya, & Cera, 2012), the maximum possible score for each language is 68 correctly named pictures. [c]Self-ratings were on a scale from 1 (*little to no knowledge*) to 7 (*like a native speaker*). [d]The anchors on the self-rating scale were as follows: 1 (*never*), 2 (*very infrequently*), 3 (*occasionally*), 4 (*2–3 times per conversation*), 5 (*several times per conversation*), and 6 (*constantly*). [e]On the Shipley vocabulary test (Zachary, 1992), participants identify each vocabulary word's closest synonym from among four multiple-choice options; the maximum possible score is 40.

In each experiment, the critical picture-naming stimuli were nine black-and-white line drawings of objects. This set size is similar to the set sizes used in many other language- and task-switching studies (e.g., Meuter & Allport, 1999), and we specifically chose a small set size so that participants would be able to remember which language they had used to name each picture.

In Experiment 1a, the pictures were selected, on the basis of previous data (Gollan et al., 2014, Experiment 1), so that bilinguals might prefer to name some of them in English (*bell-campana, bone-hueso, grapes-uvas, octopus-pulpo, pencil-lapiz*) and others in Spanish (*book-libro, hand-mano, money-dinero, tree-árbol*). In Experiment 1b, on the basis of the same previous data, we selected only pictures that bilinguals might prefer to name in Spanish. This change was made in an (unsuccessful) attempt to reduce the number of bilinguals who named every or nearly every picture in English and were thus excluded from analyses because of missing data. Four of the selected pictures had been used in Experiment 1a (*book-libro, hand-mano, money-dinero, tree-árbol*); five were new (*door-puerta, dress-vestido, horse-caballo, king-rey, star-estrella*).

The picture-naming task in both experiments consisted of a bottom-up-switching block, a cued-switching block, and English and Spanish single-language blocks (see Fig. 1). The order of the four blocks was fully counterbalanced to permit analysis of effects of block order. We compared switch costs in the bottom-up and cued-switching blocks and assessed the costs of language mixing by comparing performance in the single-language blocks and the bottom-up-switching block.

In each block, participants were first given oral and written instructions. In the bottom-up block, the key instructions were to

> [name] each picture in either English or Spanish based on whatever seems easier for you to do. When you see each picture for the first time, just choose whichever language seems easiest. However, once you decide which language is easier to use for a particular picture, please try to use that language to name that picture for the rest of this block.

(For complete instructions for this block, see the Supplemental Material available online.)

Instructions in each block were followed by 12 practice trials (using six noncritical pictures), to familiarize the participants with the task. After a break in which they were told that the practice had ended, 1 practice trial was followed immediately by 108 critical trials. Each of the nine critical pictures was repeated 12 times in each block; the pictures were presented in a pseudorandom order such that no picture was presented on consecutive trials. In the cued-switching block, each picture was presented 4 times in each language on nonswitch trials and 2 times in each language on switch trials, for a switch rate of 33%. Also in the cued-switching block, there were never more than five consecutive nonswitch trials or two consecutive switch trials.

Stimuli were presented using PsyScope X software (Build 57; Bonatti, n.d.; Cohen, MacWhinney, Flatt, & Provost, 1993) on an iMac 7 computer with a 20-in. color monitor. Each trial started with a fixation cross presented for 350 ms, followed by a 150-ms blank screen. A language cue then appeared on the screen, 7.7 cm above the center of the fixation cross. Depending on the condition, the cue was a United States flag, signifying that the picture was to be named in English; a Mexican flag, signifying that the picture was to be named in Spanish; or both flags presented side by side (in the bottom-up block only). After 250 ms, the target picture appeared in the center of the screen while the cue stayed on-screen. The cue and target remained until the participant responded, or for a maximum of 3,000 ms. An 850-ms intertrial interval preceded the next trial.

Analysis. Following our previous procedure (Gollan et al., 2014), we excluded 23 bilinguals from analyses in Experiment 1a and 29 bilinguals from analyses in Experiment 1b because they did not produce usable data in at least one of the four conditions of interest in the bottom-up block (i.e., stay, or nonswitch, trials in the dominant language; switch trials in the dominant language; stay trials in the nondominant language; and switch trials in the nondominant language): Either they never used their nondominant language (Experiment 1a: n = 5; Experiment 1b: n = 4), never used their dominant language (Experiment 1a: n = 3; Experiment 1b: n = 3), never used their nondominant language on consecutive trials (generally because they named only a single picture consistently in their nondominant language, and the same picture was never repeated on consecutive trials; Experiment 1a: n = 15; Experiment 1b: n = 21), or never used their dominant language on consecutive trials (Experiment 1a: n = 0; Experiment 1b: n = 1).

A smaller number of bilinguals with data in every condition (Experiment 1a: n = 8; Experiment 1b: n = 8) were excluded for failing to follow instructions in the bottom-up block (i.e., for being inconsistent as to which languages they used to name pictures). For each participant and picture, we computed a consistency score reflecting how often that person named that picture in the language he or she used to name it more often. For example, if someone named a picture in the bottom-up block 2 times in his or her dominant language and 10 times in his or her nondominant language, that person's consistency score for that picture would be 83% (10/(2 + 10)).

Participants were considered consistent if they both (a) were completely consistent for most of the pictures and (b) were mostly consistent for all of the pictures. To satisfy the first criterion, a participant needed to be 100% consistent for at least six of the nine pictures. To satisfy the second criterion, a participant needed to have a mean consistency score (averaged across all pictures) of at least 90%. All 16 bilinguals who were excluded for being inconsistent failed to satisfy the first criterion; 8 (Experiment 1a: $n = 5$; Experiment 1b: $n = 3$) also failed to satisfy the second criterion.

One additional bilingual was excluded from Experiment 1a for having a 746-ms switch *benefit* in the nondominant language in the bottom-up block (because there was only one usable nondominant stay trial, which had a very slow response time). This switch benefit was more than 9 standard deviations less than the mean nondominant-language switch cost in the bottom-up block among the bilinguals who were included in Experiment 1a analyses. Given that a major goal of this study was to determine if switch costs could be eliminated, excluding this bilingual was a conservative approach. Finally, 1 bilingual was excluded from Experiment 1a because of a failure to record a sound file, and 1 bilingual was excluded from Experiment 1b because of a technical error that resulted in missing data.

In Experiment 1a, the 87 bilinguals who were included in the analyses provided data for 37,584 critical trials, of which 95.9% (36,041) were analyzed. In Experiment 1b, the 84 bilinguals who were included in the analyses provided data for 36,288 critical trials, of which 97.4% (35,327) were analyzed. Trials were excluded when the response did not match the target or an acceptable alternative (Experiment 1a: 1,385 trials; Experiment 1b: 760 trials), when the voice key was not triggered at speech onset (Experiment 1a: 271 trials; Experiment 1b: 224 trials), when the language of the previous trial could not be determined (Experiment 1a: 1 trial; Experiment 1b: 1 trial), or when the participant responded faster than 250 ms (Experiment 1a: 49 trials; Experiment 1b: 30 trials) or did not respond within 3,000 ms (Experiment 1a: 163 trials; Experiment 1b: 80 trials). (Note that some trials violated multiple criteria.) When trial type (switch vs. stay) was undefined in the bottom-up-switching block (e.g., because the preceding trial was excluded for lack of a response), we identified the trial type according to the language used on the most recent trial on which the participant had given a response.

Picture-naming latencies were analyzed using mixed-effects models (Baayen, Davidson, & Bates, 2008) with maximal random effects (Barr, Levy, Scheepers, & Tily, 2013). All models contained random intercepts for participants and pictures, random slopes allowing every within-factor fixed effect to vary by participants and pictures (except as noted), and a full correlational structure. Statistical significance was assessed via nested model comparison. When a model did not converge, the random effect accounting for the lowest variance was removed, and the same random-effects structure was used in the model with which it was compared. To reduce collinearity, we contrast-coded predictors, which were all nominal variables with two levels, such that levels were separated by 1 and the average weighted value was 0. Subsequently, some predictors were linearly scaled to facilitate model convergence; all reported values are descaled.

The main analysis for each experiment had a 2 (trial type: stay vs. switch trial) × 2 (dominance: dominant vs. nondominant language) × 2 (instruction: cued switching vs. bottom-up switching) design. As effect sizes from fitted statistical models are more difficult to interpret than simple averages, we report by-participant effect sizes and confidence intervals (CIs), accompanied by significance tests based on the mixed-effects models just described. These statistics are shown in Table 2 for all analyses of naming latencies in Experiments 1a and 1b. In the Results section, we discuss only the by-participant effect sizes for all naming-latency analyses in Experiment 1a and key naming-latency analyses in Experiment 1b. All reported effects were statistically significant ($p < .05$) except as indicated.

Results

Overall analyses. Figure 2 shows the mean by-participant naming latencies for the bilinguals who were included in the analyses (Experiment 1a: $n = 87$; Experiment 1b: $n = 84$). Across the mixed-language blocks in Experiment 1a, these bilinguals named pictures 13 ms slower on switch trials than on stay trials, but switch costs were 44 ms larger in the cued-switching block than in the bottom-up block. Specifically, in the cued-switching block, latencies were 49 ms slower on switch than on stay trials, and switch costs were present in both languages (βs > 47 ms). Critically, in the bottom-up block, latencies were only 6 ms slower on switch than on stay trials, a difference that was not significant; switch costs were also not significant in either language (βs < 16 ms). This difference in the significance of switch costs emerged even though bilinguals switched *more* often in the bottom-up block ($M = 46.2\%$, 95% CI = [44.3%, 48.2%]) than in the cued block (33.3%), $t(86) = 13.45$, $p < .001$.

In addition, the bilinguals showed a *bottom-up advantage*, naming pictures 94 ms faster in the bottom-up block than in the cued block, and mixing costs, naming pictures 65 ms slower in the bottom-up block than in the single-language blocks. (Note that whereas mixing costs

Table 2. Structure and Results of Naming-Latency Analyses in Experiments 1a and 1b

		Experiment 1a (n = 87)				Experiment 1b (n = 84)			
Description of analysis and effect tested	Interpretation of effect	β (ms)	95% CI (ms)	$\chi^2(1)$	p	β (ms)	95% CI (ms)	$\chi^2(1)$	p
Overall analyses									
Cued and bottom-up blocks (Instruction Type × Dominance × Trial Type)									
Instruction type	Bottom-up advantage	−94	[−113, −75]	19.21	< .001	−66	[−86, −45]	19.74	< .001
Dominance	Dominance effect[a]	−11	[−22, 0]	3.19	.074	0	[−14, 13]	1.20	.274
Trial type	Switch cost	13	[4, 22]	19.42	< .001	18	[8, 28]	16.97	< .001
Instruction Type × Dominance	Difference in dominance effects by instruction	11	[−5, 28]	0.15	.702	−21	[−38, −4]	1.63	.201
Instruction Type × Trial Type	Difference in switch costs by instruction	−44	[−57, −31]	14.26	< .001	−43	[−58, −29]	11.56	< .001
Dominance × Trial Type	Dominance asymmetry	−20	[−40, 0]	0.02	.881	−27	[−47, −8]	0.00	1.000
Instruction Type × Dominance × Trial Type[c]	Difference in dominance asymmetries by instruction	14	[−22, 50]	0.38	.537	−27	[−64, 11]	0.35	.554
Cued block (Dominance × Trial Type)									
Trial type	Cued switch cost	49	[38, 61]	23.41	< .001	50	[37, 63]	18.32	< .001
Cued block: dominant language									
Trial type	Cued dominant-language switch cost	51	[37, 66]	18.26	< .001	49	[32, 66]	12.79	< .001
Cued block: nondominant language									
Trial type	Cued nondominant-language switch cost	47	[28, 67]	12.14	< .001	51	[34, 68]	13.41	< .001
Bottom-up block (Dominance × Trial Type)									
Trial type	Bottom-up switch cost[a]	6	[−4, 15]	2.31	.129	7	[−3, 17]	3.60	.058
Bottom-up block: dominant language									
Trial type	Bottom-up dominant-language switch cost[a]	6	[−6, 17]	0.49	.482	14	[1, 27]	3.59	.058
Bottom-up block: nondominant language									
Trial type	Bottom-up nondominant-language switch cost	16	[−2, 34]	1.98	.160	−10	[−35, 14]	0.20	.655
Single-language and bottom-up blocks (Instruction Type × Dominance)									
Instruction type	Bottom-up mixing cost[b,c]	65	[48, 82]	18.14	< .001	73	[56, 90]	22.15	< .001
Block-order analyses (including data from both first and second half of trials in each block)									
Bottom-up block (Block Order × Dominance × Trial Type)									
Block order[c]	RT difference between groups	−73	[−114, −31]	9.51	.002	−85	[−132, −38]	12.71	< .001
Block Order × Dominance[c]	Dominance-effect difference between groups	22	[−1, 46]	2.35	.125	12	[−19, 44]	0.89	.347
Block Order × Trial Type[c]	Switch-cost difference between groups[a]	−17	[−35, 1]	5.19	.023	−4	[−24, 16]	0.23	.631
Block Order × Dominance × Trial Type[c]	Dominance-asymmetry difference between groups	4	[−37, 46]	0.07	.791	39	[−26, 103]	0.80	.370
Single-language and bottom-up blocks (Block Order × Instruction Type × Dominance)									
Block Order × Instruction Type[c]	Mixing-cost difference between groups[b]	−58	[−90, −27]	9.96	.002	−54	[−87, −21]	9.41	.002

(continued)

Table 2. *(continued)*

Description of analysis and effect tested	Interpretation of effect	Experiment 1a (n = 87) β (ms)	95% CI (ms)	$\chi^2(1)$	p	Experiment 1b (n = 84) β (ms)	95% CI (ms)	$\chi^2(1)$	p
Cued and bottom-up blocks (Instruction Type × Block Half)									
Instruction Type × Block Half	Bottom-up-advantage difference between block halves	−109	[−131, −86]	22.15	< .001	−100	[−123, −77]	28.63	< .001
Block-half analyses (second half only)									
Bottom-up block (Block Order × Dominance × Trial Type)									
Block Order × Dominance	Dominance-effect difference between groups[a]	34	[6, 61]	4.12	.042	23	[−8, 55]	2.76	.096
Block Order × Trial Type	Switch-cost difference between groups[a]	−13	[−35, 9]	5.56	.018	−13	[−36, 10]	2.52	.113
Single-language and bottom-up blocks (Block Order × Instruction Type × Dominance)									
Block Order × Instruction Type	Mixing-cost difference between groups[b]	−72	[−103, −41]	11.38	< .001	−49	[−80, −19]	11.22	< .001
Cued-first bilinguals (second half only)									
Bottom-up block (Dominance × Trial Type)									
Dominance	Dominance effect	−37	[−59, −15]	5.60	.018	−38	[−63, −12]	5.64	.018
Trial type	Switch cost	23	[8, 39]	8.23	.004	23	[4, 41]	11.05	< .001
Single-language and bottom-up blocks (Instruction Type × Dominance)									
Instruction type	Mixing cost[b]	73	[50, 95]	16.68	< .001	60	[40, 80]	15.54	< .001
Bottom-up-first bilinguals (second half only)									
Bottom-up block (Dominance × Trial Type)									
Dominance	Dominance effect	−3	[−19, 14]	0.43	.513	−15	[−31, 2]	1.15	.283
Trial type	Switch cost[a]	10	[−6, 27]	0.65	.420	9	[−2, 21]	3.88	.049
Single-language and bottom-up blocks (Instruction Type × Dominance)									
Instruction type	Mixing cost[b]	0	[−22, 23]	0.00	1.000	11	[−13, 35]	0.42	.519

Note: The estimates and confidence intervals (CIs) for each effect are based on by-participant means. The χ^2 and p values for each effect are based on comparison of a mixed-effects model with the fixed factors shown and an identical model without the tested factor. For the block-order and block-half analyses, the groups referred to are the cued-first bilinguals and the bottom-up-first bilinguals (see the text). Positive values of β indicate slower response time (RT) for the bottom-up block (vs. either the cued block or the single-language blocks, as indicated), the nondominant language (vs. the dominant language), switch trials (vs. stay trials), bottom-up-first bilinguals (vs. cued-first bilinguals), or second half of the block (vs. first half).

[a]Every effect was categorized for each experiment as statistically significant ($p < .05$), marginally significant ($.05 < p < .10$), or nonsignificant ($p > .10$). These effects differed in statistical significance between Experiment 1a and Experiment 1b. [b]Because of our interest in why bilinguals spontaneously switch languages (a question about the overall efficiency of choosing to mix languages), we calculated mixing costs as the difference between latencies in the bottom-up switching block—including both nonswitch trials and switch trials—and latencies in both single-language blocks. [c]Because of convergence issues, the random slope that accounted for the least variance was removed from these analyses for Experiment 1a: Trial type did not vary by picture in the overall three-way interaction analysis, trial type did not vary by participant in the four block-order analyses of the bottom-up block, and block order did not vary by picture in the block-order analysis of mixing costs.

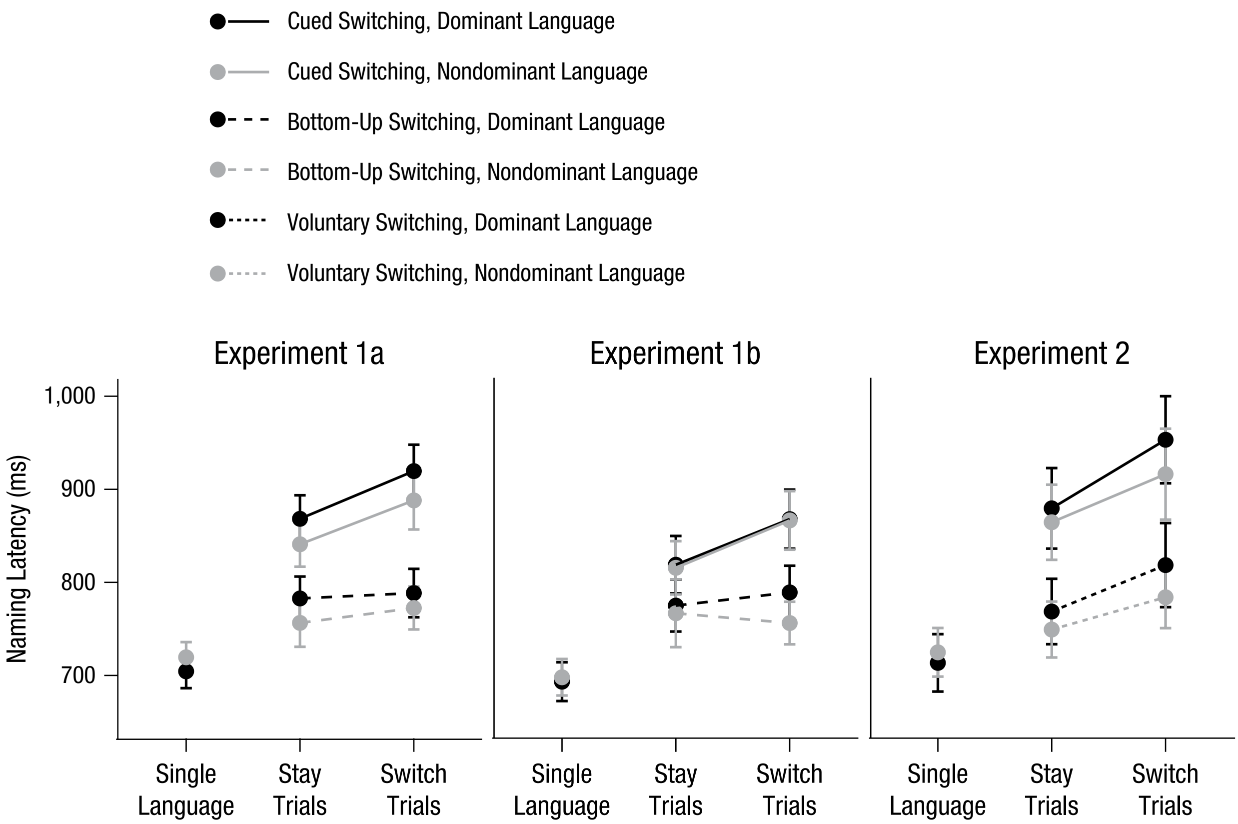

Fig. 2. Mean by-participant naming latencies from the bilinguals included in the analyses for Experiments 1a, 1b, and 2. Results are shown separately as a function of instruction type (single language and cued switching in all three experiments, bottom-up switching in Experiments 1a and 1b only, voluntary switching in Experiment 2 only), dominance (dominant language, nondominant language), and trial type (stay, switch). Error bars show 95% confidence intervals. The stimulus set in Experiments 1a and 2 contained a mix of pictures intended to be English and Spanish biased; the stimulus set in Experiment 1b contained only pictures intended to be Spanish biased.

are traditionally defined as the difference between nonswitch trials in a mixed-language block and trials in single-language blocks, we compared all trials, including switch trials, in a mixed-language block with trials in single-language blocks. This atypical definition means that our mixing costs represent overall differences in blockwide efficiency—the total cost in maintaining and using two languages rather than one.) Participants also exhibited marginally significant reverse dominance effects, naming pictures 11 ms faster in the nondominant language than in the dominant language. No other effects were significant: Dominance effects did not differ between mixed blocks, a dominance asymmetry was not observed, and dominance asymmetries did not differ between mixed blocks.

Given that the key finding was a null result (i.e., bilinguals who followed instructions in the bottom-up block exhibited no significant switch costs), we used Bayesian statistics to compare the relative probabilities of obtaining bottom-up switch costs with the observed by-participant mean (5.6 ms) and standard error (4.6 ms) under different statistical models. Assuming a normal distribution of effect sizes, our data constitute "positive" evidence (Bayes factor ≥ 3; Kass & Raftery, 1995, p. 777) that bottom-up switch costs were nonexistent ($\mu = 0$) relative to models with switch costs greater than 15 ms, and "very strong" evidence (Bayes factor ≥ 148; Kass & Raftery, 1995, p. 777) relative to models with switch costs greater than 22 ms. Similar results were obtained in Experiment 1b, in which bottom-up switch costs were 7 ms, which was only marginally significant (and even then, only in mixed-effects models; it was not significant in F_1 analyses). Those data constituted positive evidence for nonexistent switch costs relative to models with switch costs greater than 18 ms, and very strong evidence relative to models with switch costs greater than 25 ms—a range that includes most language switch costs reported in the literature (cf. Christoffels et al., 2007; Costa & Santesteban, 2004; Meuter & Allport, 1999).

Block-order analyses. To better understand the mechanisms of bottom-up switching, we considered whether its effects changed as a function of task order. Following prior research, we initially planned to divide the participants according to whether they completed the nondominant single-language block before or after the bottom-up-switching block (cf. Gollan & Ferreira, 2009; Guo, Liu, Misra, & Kroll, 2011; Misra, Guo, Bobb, & Kroll, 2012; Van Assche, Duyck, & Gollan, 2013). However, post hoc analyses of the data in Experiment 1a indicated that the order of the two mixed-language blocks had greater effects, so we divided participants instead according to whether they completed the cued-switching block before the bottom-up-switching block (*cued-first* bilinguals; Experiment 1a: n = 45; Experiment 1b: n = 47) or vice versa (*bottom-up-first* bilinguals; Experiment 1a: n = 42; Experiment 1b: n = 37). (As noted earlier, this unexpected effect of block order was the motivation for Experiment 1b.) Furthermore, as we had planned in advance to investigate whether the benefits of accessibility-driven switching change over time—either increasing (as shown in Fig. 1) or decreasing throughout the block—we present the results separately in Figure 3 for each group and block half.

In the bottom-up block of Experiment 1a, bottom-up-first bilinguals named pictures 73 ms faster than cued-first bilinguals. In addition, their switch costs were 17 ms smaller; switch costs were non-significant for bottom-up-first bilinguals, β = −3 ms, 95% CI = [−14 ms, 8 ms], $\chi^2(1) < 1$, but significant for cued-first bilinguals, β = 14 ms, 95% CI = [−1 ms, 28 ms], $\chi^2(1) = 4.97$, p = .026. Mixing costs were 58 ms smaller for bottom-up-first bilinguals than for cued-first bilinguals (35 ms vs. 94 ms). Finally, bottom-up-first bilinguals also switched 4.2% less often in the bottom-up block (44.1%) than cued-first bilinguals did (48.3%), 95% CI for the difference = [0.5%, 7.9%], $t(85)$ = 2.23, p = .028. Thus, bottom-up-first bilinguals' greater switching efficiency cannot be attributed to higher switching frequency (Gollan & Ferreira, 2009; Mayr, Diedrichsen, Ivry, & Keele, 2006). Neither dominance effects nor dominance asymmetries differed significantly between the groups.

Experiment 1b also showed several robust effects of block order on naming latencies in the bottom-up block. Relative to cued-first bilinguals, bottom-up-first bilinguals named pictures 85 ms faster and showed mixing costs that were 54 ms smaller, though switch costs did not differ between the groups.

Second-half analyses. In Experiment 1a, the advantage for the bottom-up block (relative to the cued block) was 109 ms greater in the second half of the block (148 ms) than in the first half (39 ms). This suggests that stimulus-response associations strengthened as the bilinguals continued to name each picture in just one language (see Fig. 1), increasing the difference in activation between each target and its translation and thereby making selection easier. Thus, differences between groups in the extent to which they engaged in bottom-up switching should also have increased over time. Accordingly, we repeated the block-order analyses, narrowing our focus to the second half of each block. In Experiment 1a, all three signatures of top-down control were significantly smaller in the bottom-up block for bottom-up-first bilinguals than for cued-first bilinguals. Specifically, cued-first bilinguals showed reverse dominance effects, switch costs, and mixing costs in the bottom-up block, naming pictures in that block 37 ms faster in their nondominant language than in their dominant language and 23 ms slower on switch trials than on stay trials, and naming pictures 73 ms slower in the bottom-up block than in the single-language blocks (including both switch and nonswitch trials). In contrast, bottom-up-first bilinguals demonstrated no reverse dominance effects, no bottom-up switch costs, and no mixing costs, naming pictures 3 ms faster in their nondominant language than in their dominant language, 10 ms slower on switch trials than on stay trials, and just as fast in the bottom-up block (again including both switch and nonswitch trials) as in the single-language blocks (difference = 0 ms).

In Experiment 1b, effects of block order on naming latency in the second half of the bottom-up block were more robust for reverse dominance effects and mixing costs than for switch costs. As in Experiment 1a, cued-first bilinguals showed all three signatures of top-down control. Bottom-up-first bilinguals showed nonsignificant reverse dominance effects (15 ms) that were marginally smaller than those of cued-first bilinguals (38 ms), and a significant 9-ms switch cost (only in mixed-effects models; this cost was not significant in F_1 analyses) that was statistically equivalent to the switch cost of cued-first bilinguals (23 ms). Crucially, however, this switch cost did not affect bottom-up-bilinguals' overall efficiency in maintaining and using two languages instead of one, as they again showed nonsignificant mixing costs (11 ms) that were smaller than those of cued-first bilinguals (60 ms).

Experiment 2

Given that Experiments 1a and 1b demonstrated a clear benefit for being consistent, in both increased overall efficiency and reduced (even eliminated) switch costs, one might wonder why most bilinguals do not adopt such a strategy in fully voluntary language-switching tasks. Before addressing this question, however, we needed to consider the possibility that we did not find bottom-up switch costs even though previous studies found significant voluntary switch costs (Gollan & Ferreira, 2009; Gollan et al., 2014) because of methodological differences between experiments in the stimuli used, the number of times stimuli were repeated, and counterbalancing procedures. We did this in Experiment 2.

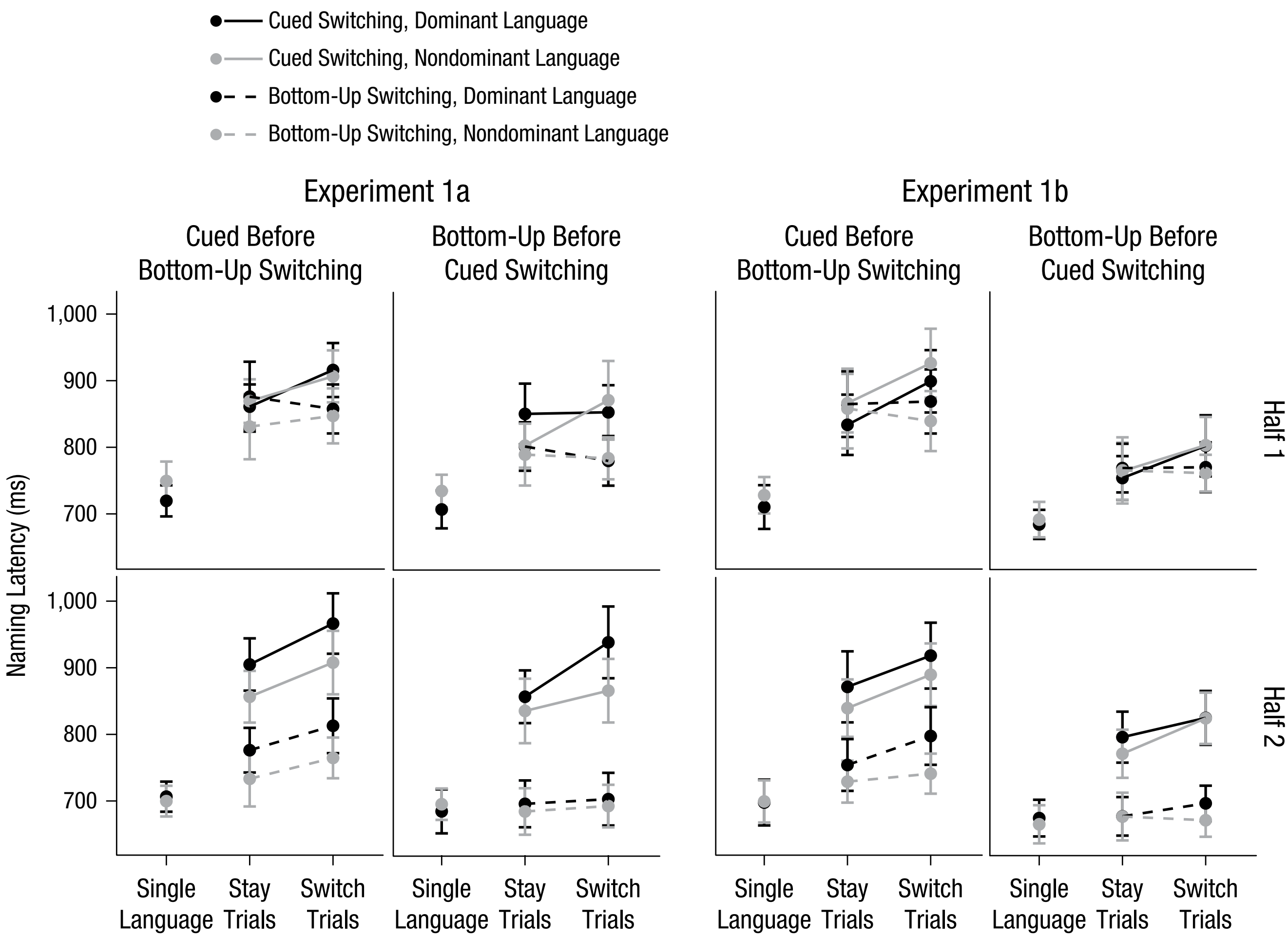

Fig. 3. Mean by-participant naming latencies from the bilinguals included in the analyses in Experiments 1a and 1b as a function of block order (cued switching before bottom-up switching, bottom-up switching before cued switching), block half (first, second), instruction type (single language, cued switching, bottom-up switching), dominance (dominant language, nondominant language), and trial type (stay, switch). Error bars show 95% confidence intervals.

Method

Participants. Forty-eight bilinguals from the same population as in Experiments 1a and 1b participated for course credit. This sample size (which again needed to be a multiple of 24 for counterbalancing purposes, and was determined prior to data collection) was smaller than in Experiments 1a and 1b because prior research led us to expect that voluntary switch costs would be much larger, and thus easier to detect, than the nonsignificant bottom-up switch costs observed in those experiments.

Materials and procedure. All experimental details were identical to those of Experiment 1a except that the bottom-up-switching block was replaced with a fully voluntary switching block in which participants were told to "use whichever language comes to mind first" on each trial, with no instructions regarding consistency.

Results

The 46 bilinguals who used both languages on both stay and switch trials in the voluntary block provided data for 19,872 critical trials, of which 94.3% (18,742) were analyzed. (Exclusion criteria were identical to those used in Experiments 1a and 1b except that participants were not excluded for being inconsistent.) By-participant means are shown for these bilinguals in Figure 2. The lack of instructions regarding consistency caused the bilinguals to switch languages less often (M = 36.5%, 95% CI = [32.4%, 40.6%]) than in Experiments 1a and 1b and to name most pictures in both languages at least some of the time: Their mean consistency score was 71.0% (95% CI = [68.1%, 73.9%]; minimum possible score = 50%), and only 1 participant met both consistency criteria used in Experiments 1a and 1b. As predicted, these bilinguals showed a significant 48-ms voluntary switch cost, 95%

CI = [32 ms, 63 ms], $\chi^2(1) = 13.95$, $p < .001$, which was apparent in each language individually—dominant: β = 50 ms, 95% CI = [27 ms, 73 ms], $\chi^2(1) = 9.13$, $p = .003$; nondominant: β = 35 ms, 95% CI = [19 ms, 50 ms], $\chi^2(1) = 11.32$, $p < .001$. A comparison across experiments showed that the 48-ms voluntary switch cost in Experiment 2 was significantly greater than the 6-ms bottom-up switch cost in Experiment 1a, β = 42 ms, 95% CI = [26 ms, 59 ms], $\chi^2(1) = 6.54$, $p = .011$. Analysis of the second half of the voluntary block revealed that the bilinguals in Experiment 2 again showed a significant switch cost, of 38 ms, 95% CI = [17 ms, 58 ms], $\chi^2(1) = 6.02$, $p = .014$, as well as a significant 53-ms mixing cost, 95% CI = [28 ms, 78 ms], $\chi^2(1) = 16.04$, $p < .001$, and a significant 29-ms reverse dominance effect, 95% CI = [−59 ms, 2 ms], $\chi^2(1) = 5.06$, $p = .024$.

General Discussion

The present experiments were designed to determine whether bilinguals can switch languages "for free" by switching only when the target name is more accessible in the other language. In Experiments 1a and 1b, bilinguals switched with little or no cost, and those who had not already named the same items in a cued language-switching task switched for free. Consistency in the language used to name each picture was integral to these results: The minority of bilinguals who (contrary to instructions) were inconsistent in the bottom-up block (n = 16, across both experiments) showed bottom-up switch costs (48 ms) while switching less often than the consistent bilinguals (38% vs. 46%). Thus, relying on lexical accessibility as the criterion for switching languages is a universal, cost-free switching strategy that all bilinguals can adopt.

However, as Experiment 2 showed, bilinguals do not automatically adopt this strategy on their own: Given full freedom to switch, participants mixed top-down and bottom-up switches, inconsistently mapping pictures to languages and paying a switch cost. Inconsistency may lead to smaller differences in accessibility between translation equivalents and thus a reduced incentive to engage in bottom-up switching. Alternatively, efficiency of switching may not be an automatic goal, or bilinguals may be imperfect at assessing the relative difficulty of naming in each language. Either way, language switching can be substantially more efficient than fully voluntary switching paradigms suggest.

Perhaps even more striking than the elimination of switch costs, though, was the effect of block order on bottom-up switching efficiency. Relative to cued-first bilinguals, bottom-up-first bilinguals named pictures in the bottom-up block much faster; by the second half of that block, they even named pictures as quickly as in the single-language blocks (despite our conservative definition of mixing costs, which incorporated both switch and nonswitch responses in the mixed block). In doing so, the bottom-up-first bilinguals actively maintained and used two languages, switching frequently between them, as efficiently as they used a single language. They also named pictures in the bottom-up block as quickly in their dominant language as in their nondominant language, and (in Experiment 1a) as quickly when switching languages as when staying in the same language, thereby showing no signs of top-down language control.

These feats were made possible by aligning language control with lexical accessibility: As stimulus-response associations built up during the bottom-up block, lexical selection became easier. This may have led the bottom-up-first bilinguals to effectively treat the pictures as univalent stimuli (i.e., affording one name), which sometimes eliminates switch costs (Dreisbach, Goschke, & Haider, 2006, 2007; Finkbeiner, Almeida, Janssen, & Caramazza, 2006; but see, e.g., Filippi, Karaminis, & Thomas, 2014; Rogers & Monsell, 1995; Ruthruff, Remington, & Johnston, 2001). Subsequently, the bilinguals were able to select more accessible names and switch between languages without needing to decide which language to use, without checking that the selected names matched the intended language, and without exercising any form of top-down control (e.g., inhibition of the dominant language or activation of the nondominant language) or needing to rely on inhibition between lexical representations (Green, 1998) to guide selection. Furthermore, the near-total absence of language switch costs in a paradigm that afforded no advance preparation (participants did not know which language they would have to use in the bottom-up block until each picture appeared, so the cue-stimulus interval was effectively 0 ms) suggests that these costs are entirely, or at least largely, incurred at a lexical rather than a postlexical level: Motoric switch costs would still have been observed given that participants were overtly switching between languages.

Why did the order in which the bilinguals completed the two mixed-language blocks affect their use of top-down language control mechanisms? We speculate that the cued-first bilinguals may have entered a "top-down mode" in the cued block and then stayed in that mode in the subsequent bottom-up block even though this strategy was relatively inefficient. Such effects might resemble "language mode" changes, in which the relative activation of a bilingual's languages depends on the audience (Grosjean, 2001). In both cases, alternation between modes might not always be conscious or under volitional control. Another possibility is that bottom-up mixing costs and switch costs were greater for the cued-first bilinguals than for the bottom-up-first bilinguals because they had previously named each picture in both languages and thus had varied rather than consistent mappings (cf. Koch, Prinz, & Allport, 2005; Waszak, Hommel, & Allport, 2003, 2004, 2005), but our manipulation eliminated mixing and switch costs altogether, revealing greater efficiency than previously reported.

Although there have been isolated reports of cost-free switching in the literature, methodological instantiations of switching in those studies limit comparison with language switching in natural conversation (and switching in naturally occurring circumstances more generally). Studies of language production have demonstrated cost-free language switches under several different situations: when bilinguals memorized and then repeatedly produced mixed-language sentences with long (1,500 ms) and obligatory intervals between all words (Declerck & Philipp, 2015b), when the intervals between successive stimuli were long (3,200 ms) and thus afforded ample preparation time (Mosca & Clahsen, 2015), when the task that showed cost-free switches was only ever performed in one language (Finkbeiner et al., 2006), and when experimental demands led switching to become the default behavior (Gollan & Ferreira, 2009, Experiment 2). In studies of language comprehension, bilinguals have exhibited cost-free switching when reading written words silently and when reading them aloud (Gullifer, Kroll, & Dussias, 2013; Guzzardo Tamargo, 2012; Ibáñez, Macizo, & Bajo, 2010).

In nonlinguistic tasks, apparently cost-free switches have been found for similar reasons—because participants are encouraged or required to prepare in advance (Lien, Ruthruff, Remington, & Johnston, 2005; Verbruggen, Liefooghe, Vandierendonck, & Demanet, 2007) or to switch very often (Mayr et al., 2006)—as well as for other reasons that are not relevant to language switching. These include the presence of "hyper-compatible" relationships between the stimuli and responses (Hunt & Klein, 2002; Meiran, 2000), which is inapplicable to language switching because concept-to-word mappings are arbitrary (de Saussure, 1916/1972); experimental demands that required the preparation but not the execution of responses (Schuch & Koch, 2003), which are inapplicable because language switches are overtly produced; and participants' lack of awareness of task rules (Dreisbach et al., 2006, 2007), which is inapplicable because bilinguals obviously know which language they are speaking. In addition, cost-free task switches and even cost-free task mixing have been observed when the stimulus on a given trial is compatible with only a single task (e.g., Allport, Styles, & Hsieh, 1994), a condition that is inapplicable to bilingual language production because bilinguals can express most (if not all) concepts in both languages. Thus, it is not clear how the strategies people used to switch for free in these situations could be generalized to everyday language use.

Our study adds to this literature in three ways. First, we showed that bilinguals can effortlessly alternate between languages, selecting words as easily as from a single language, even when those switches are explicitly marked by language-specific accents and phoneme sets. Furthermore, unlike previous studies, our study demonstrates that this cost-free mixing and switching is possible without advance preparation, as participants could not know which language to use in the bottom-up block until each picture appeared. This finding is broadly important as an existence proof that bilinguals can switch for free on the basis of accessibility—a factor that may motivate many spontaneous switches in natural settings.

Second, our data validate the distinction between top-down and bottom-up switches. The fact that not all switches require top-down control further implies that the general efficiency of a switching mechanism may be affected both by the frequency with which a bilingual switches languages (Prior & Gollan, 2011) and by the frequency of switch types (bottom-up vs. top-down; see also Gollan et al., 2014). Thus, bilinguals might exhibit more efficient switching than monolinguals if they regularly engage in top-down switching, but not if they switch languages primarily for bottom-up reasons.

Finally, our study provides a paradigm for isolating bottom-up switches, thereby enabling study of the circumstances under which switching and mixing can be maximally efficient. If bottom-up switches occur in all domains regardless of expertise, this paradigm could become more broadly useful in research on task switching, ultimately explaining why people choose to shift between tasks in other circumstances (e.g., between reading a journal article and checking Facebook), as switches may sometimes be cost free provided that they are not cued.

Action Editor

Matthew A. Goldrick served as action editor for this article.

Author Contributions

T. H. Gollan developed the study concept. D. Kleinman performed the data analysis. All other responsibilities—study design, interpretation, and manuscript writing—were shared by the authors, both of whom approved the final version of this manuscript for submission.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Supplemental Material

Additional supporting information can be found at http://pss.sagepub.com/content/by/supplemental-data

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