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Modulation of Language Switching by Cue Timing: Implications for Models of Bilingual Language Control

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The current study examines the interplay between global and local processes in bilingual language control. We investigated language-switching performance of unbalanced Arabic-Hebrew bilinguals in cued picture naming, using 5 different cuing parameters. The language cue could precede the picture, follow it, or appear simultaneously with it. Naming latencies were reduced with precuing, demonstrating bilinguals' ability to globally modulate language activation, and more strongly reduced with postcuing, demonstrating bilinguals' ability to locally activate lemmas in both languages. Precuing reduced switching costs in reaction time (RT), and postcuing significantly reduced switching costs in accuracy, but not in RT. Switching costs were mostly symmetric for both languages, although participants were unbalanced bilinguals. These results support the notion that both global language selection and resolution of competition between activated lemmas are involved in bilingual language control. They further demonstrate that persisting language schema activation and local lemma selection and inhibition are equal across both languages of unbalanced bilinguals. Finally, results demonstrate that experimental manipulations of cuing parameters can have dissociable influences on overall RTs, and switch costs in latency and accuracy, suggesting that language-switching performance reflects complex interactions of bilingual profiles and task demands.

Keywords: picture naming, bilingualism, language control

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In everyday life, proficient bilinguals seem to be able to switch languages effortlessly, fluently, and accurately. This perception is somewhat misleading, however, since in controlled laboratory paradigms cued switching between two languages usually incurs costs in performance (e.g., Macizo, Bajo, & Paolieri, 2012; Meuter & Allport, 1999; Prior & Gollan, 2013; Thomas & Allport, 2000; but see also Kleinman & Gollan, 2016). Importantly, controlled language-switching paradigms have been instrumental in the development of theoretical models of bilingual language control (e.g., Green, 1998), and continue to provide empirical evidence used to evaluate and refine such models (e.g., Bobb & Wodniecka, 2013; Declerck, Koch, & Philipp, 2015; Fink & Goldrick, 2015). The current study contributes to this body of knowledge by investigating the effects of whole language (global) versus lemma specific (local) activation and inhibition in a language-switching paradigm.

One of the most intriguing abilities of bilinguals is their capacity to separate between two languages while talking, but also to switch from one language to another depending on the preferred language of their interlocutors. The cognitive mechanism that enables these abilities is referred to as *language control* (Abutalebi & Green, 2007). Current models of bilingual lexical selection suggest that the lexicons of the two languages are activated in parallel in the bilingual brain during language processing (Caramazza & Costa, 2000; Dijkstra & van Heuven, 2002; Kroll, Bobb, & Hoshino, 2014). If this is indeed the case, the question arises how bilinguals ensure that they are producing the desired messages in the proper target language for communicative purposes (Costa, Santesteban, & Ivanova, 2006). One suggested solution to this problem lies in inhibitory models and specifically the Inhibitory Control (IC) model proposed by Green (1998). According to the IC model, the selection of a target language is managed through inhibiting the lexical representations of the nontarget language (Green, 1998). The model specifies that language schemas can globally activate and inhibit lemmas in L1 and L2 according to the intended target language. Further, local inhibition of specific competing lemmas in the two languages is achieved once the conceptual information is specified (see also Misra, Guo, Bobb, & Kroll, 2012; Declerck, Koch et al., 2015). This type of local control is implemented in the IC model as lateral inhibitory connections between translation-equivalent lemmas in the two languages.

When a stimulus is presented for naming in a language-switching paradigm, two competing responses are activated for bilingual speakers—one in each language. Thus, to be able to produce a response, bilinguals need information about the target

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language in a given trial, in addition to the target stimulus to be named. By experimentally manipulating the time course of the availability of these two types of information in the current study, we can identify the interplay between global, language schema control and local, lemma-level control. By global control we mean activation and inhibition at the level of the language schema; and by local control, we mean the local lateral connections between translation-equivalent lemmas within the bilingual lexicon. We now address each of these in more detail.

Global Language Schema Control

Preparation Effects

One approach to investigating global control mechanisms in bilingual language production has been to examine the effects of preparation on language-switching performance. A comparison to the nonlinguistic task switching literature is instructive in this regard, where similar preparation effects have been investigated to identify mechanisms of active task preparation (Kiesel et al., 2010). Thus, in the cued task-switching paradigm, in each trial there is a task cue that appears before or with the stimulus, in an unpredictable manner (Sudevan & Taylor, 1987). Several studies have shown that augmenting the time between the cue and the stimulus leads to faster RTs overall, and in addition reduces switching costs—namely, the difference between trials in which the task is repeated and trials in which the task changes (Kiesel et al., 2010; Meiran, 1996; Monsell & Mizon, 2006; Prior, 2012; Rogers & Monsell, 1995). The analogy to language switching is that if bilinguals can benefit from a preparation interval in which the target language is specified before the stimulus to be named appears, this is evidence that global, language-schema information can be used to influence the relative activation levels of lexical items in the two languages. If this is true, we would predict that longer preparation intervals should lead both to overall reductions in RT and possibly also to smaller language-switching costs. Table 1 presents an overview of studies examining preparation effects in bilingual language-switching experiments.

To illustrate, in accordance with this rationale, Costa and Santesteban (2004; Experiment 5) report a picture-naming language-switching study with highly proficient Catalan-Spanish bilinguals, using unpredictable language cuing, with differing cue stimulus intervals (CSI; synchronous, short, and long). The results show that the short CSI lead to reduced RTs overall, as well as a reduction in switching costs for both languages. The longer CSI did not speed up RTs beyond that of the short CSI, but did further decrease switching costs. A recent study by Fink and Goldrick (2015) also compared short and long CSIs. Proficient bilinguals showed a decrease in overall RTs and in switch costs with longer preparation times. In a group of less proficient L2 learners, a simultaneous cuing condition was added as a baseline, and results showed reduction in RTs and in switch costs with preparation, but no difference between the long and short CSI conditions. Recently, Ma, Li, and Guo (2016) also demonstrated shorter RTs and reduced switching costs with longer CSIs in a group of unbalanced Chinese-English biliguals.

Verhoef, Roelofs, and Chwilla (2009) also report that longer CSI in a language-switching experiment lead to faster RTs overall, as well as to a reduction in switch costs, but only for L1. A reduction of switch costs with longer preparation was also reported by Declerck, Philipp, and Koch (2013) in a memory-based language-switching paradigm, where both the concept to be named and the language to be used were predetermined and fully available to participants. Finally, a recent study by Mosca and Clahsen (2016) reported that with preparation overall RTs were reduced, and language switch costs were eliminated altogether.

However, preparation effects have not been uniform in all studies. Philipp, Gade, and Koch (2007) manipulated CSIs in a digit-naming language-switching paradigm. Longer preparation times lead to faster RTs overall, but did not lead to a reduction in switch costs. In a conceptually similar manipulation, Declerck, Koch et al. (2015) showed that when the target language was predictable, overall RTs were faster but switch costs were not reduced.

Thus, most studies show that language information can speed up overall RTs, across language repetition and language switch trials. These findings support the notion that such knowledge allows bilinguals to use language schemas to prepare for language production in a specific target language. However, results are still mixed as to whether bilinguals can use language information to inhibit activation in a recently used language in order to facilitate switching into the target language of the upcoming trials. Some studies above indeed show that providing bilinguals with language information leads to a reduction of language-switching costs (or even their elimination, in the case of Mosca & Clahsen, 2016). However, this result has not been consistent in all previous studies.

Further, the extant studies have used a relatively large range of cuing intervals, such that across different studies very similar magnitudes are considered long or short cuing intervals (for details see Table 1). With the exception of three studies (Costa & Santesteban, 2004; Ma et al., 2016; Philipp et al., 2007), different cuing intervals were also mixed randomly within the same experimental blocks, which might lead to strategic differences than when cuing intervals are manipulated across blocks or participants. Finally, the balance of activation and inhibition between language schemas is influenced not only by the preparation CSI interval, but also by the length of the interval between the response on a given trial and the onset of the next trial, as this latter period allows for passive dissipation of the active language schema (Kiesel et al., 2010; Ma et al., 2016). Once again, this interval has varied greatly across studies. To address these issues, in the current study CSI was manipulated within participants, but across different experimental blocks and the intertrial interval was held constant.

Switch Cost A/symmetry as a Marker of Global Control

Beyond preparation effects, the relative magnitude of the switch costs in the two languages of bilinguals has also been interpreted by some researchers as a marker of global language control. Again, the nonlinguistic task-switching literature is instructive here. Behavioral studies have shown that strongly activated items need stronger inhibition to prevent them from being produced. Thus, in task-switching paradigms the cost of switching from the more challenging to the easier task is often higher than the cost of switching from the easier to the more challenging task (Kiesel et al., 2010). For bilinguals, producing the dominant (usually L1) language is analogous to an easier task, and producing the L2 is more challenging (Lee & Williams, 2001). Due to such language

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Table 1
Preparation Effects in Language Switching

Paper	Languages and proficiency	Preparation manipulation	CTI	RCI	Preparation effect: RT/Accuracy	Preparation effect: Switch cost
(Costa & Santesteban, 2004; Experiment 5)	Spanish-Catalan, Highly proficient and balanced	Cue-target SOA, between subject	0, 500, 800 ms	variable	L1 slower than L2. Analysis not reported, visually preparation seems to reduce overall RTs	Longer preparation reduced switch costs, which were symmetric.
(Philipp, Gade, & Koch, 2007; Experiment 1)	German-English-French trilinguals, moderately proficient L2/L3 learners. Switching between two languages	Cue-target SOA, within subject, between blocks	100, 1,000 ms	1,000, 100 ms—to maintain constant response-stimulus interval of 1,100 ms	Longer preparation time reduced overall RT, more strongly in dominant language. Longer preparation also lead to increased error rate	Longer preparation increased switch cost.
(Verhoef, Roelofs, & Chwilla, 2009)	Dutch-English, moderately proficient L2 learners	Cue-target SOA, within subject, mixed in the same block	750, 1,500 ms	variable	L1 slower than L2. Longer preparation reduced overall RTs	Longer preparation reduced switch costs for L1 but not for L2. Larger switch cost asymmetry with short than with long SOA
(Fink & Goldrick, 2015)	Exp. 1: Other-English, moderately proficient	Cue-target SOA, within subject, mixed in the same block	Exp. 1: 500, 1,250 ms	Exp 1&2: 1000–1,250 ITI	Exp. 1: L1 and L2 equally fast. Longer preparation reduced overall RTs.	Exp. 1: Longer preparation reduced switch costs, which were symmetric.
	Exp. 2: English-Spanish, low proficiency L2 learners		Exp. 2: 0, 500, 1,250 ms		Exp. 2: L1 faster than L2. Longer preparation reduced overall RTs.	Exp. 2: Longer preparation reduced switch costs, which were asymmetric.
(Mosca & Clahsen, 2015)	German-English, moderately proficient	Cue-target SOA, within subject, single mixed block, but preparation duration chunked. 25% switch trials.	0, 800 ms	Trial length constant at 4,700 ms, RCI variable	L1 and L2 equally fast. Longer preparation reduced overall RTs.	Longer preparation eliminated switch costs, which were symmetric.
(Ma, Li, & Guo, 2016)	Chinese-English, moderately proficient	Cue-target SOA, within subject, between blocks	Exp1: 0, 500, 800 ms	ITI constant at 1,000 ms	L1 slower than L2. Longer preparation reduced overall RTs.	Longer preparation reduced switch costs, which were asymmetric.
(Declerck, Philipp, & Koch, 2013)	German-English, moderately proficient	Memory-based retrieval of language and concept sequences. Interval manipulated within subject, different blocks	Interval between response onset and signal for next response (RSI): short 1,100 ms, long 2,000 ms.		L1 slower than L2. Trend towards faster responses with longer preparation	Longer preparation reduced switch costs.

(*table continues*)

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Table 1 (*continued*)

Paper	Languages and proficiency	Preparation manipulation	CTI	RCI	Preparation effect	
					RT/Accuracy	Switch cost
(Declerck, Koch, & Philipp, 2015)	German-English, moderately proficient	Memory based vs. randomly cued language switching. Manipulated within participant, across blocks	Interval between response onset and signal for next response (RSI) held constant at 1,500 ms		L2 slower than L1. Predictable sequences faster than random sequences (even when only language was predictable).	When both language and concept were predictable switch costs were reduced. When only language was predictable SC were not reduced. When only concept was predictable SC reduced only in L1.

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dominance, higher switching costs (defined in terms of RTs and error rate) are sometimes reported when bilinguals switch from the weaker L2 to the dominant L1 than when switching from L1 to L2 (Meuter & Allport, 1999; Ma et al., 2016; Philipp et al., 2007). This asymmetry in switching costs is interpreted as a result of the fact that the stronger inhibition exerted on L1 (to allow speaking in L2) persists into the following switch trial (Macizo et al., 2012; Meuter & Allport, 1999). However, this asymmetry in language-switching costs has not been replicated in all studies of unbalanced bilinguals (e.g., Declerck, Koch, & Philipp, 2012). Several studies that investigated switching costs in balanced bilinguals showed symmetrical switching costs in both languages, while in the case of unbalanced bilinguals the asymmetry can be reduced after training (Costa & Santesteban, 2004; Meuter & Allport, 1999; Prior & Gollan, 2013).

Interestingly, Bobb and Wodniecka (2013) argue convincingly that the issue of symmetry or asymmetry in switch costs does not necessarily index global language inhibition, but rather can vary depending on specific task demands. Similarly, Declerck, Thoma, Koch, and Philipp (2015) have also demonstrated that switch costs symmetry, or lack thereof, does not necessarily provide a strong index for the degree to which bilinguals might rely on global language inhibition. Recently, Reynolds, Schlöffel, and Peressotti (2016) have also suggested that at least some portion of the asymmetry in switch costs in unbalanced bilinguals may arise from phonological competition within the language system, and not exclusively from inhibition at the level of the global language scheme.

In light of these conflicting views in the literature, in the current study we report the magnitude of the switch costs in L1 versus L2 across varying cuing conditions. Because our participants are unbalanced bilinguals, the view that interprets possible differences in relative switch cost magnitude as a signature of global inhibition would predict an asymmetry in switch costs—namely, larger switch costs when switching into the L1 (which requires stronger inhibition) than when switching into the L2. However, given the above criticisms of this view, and to anticipate our results, we view the current study as a promising opportunity to examine the relative magnitude of switch costs by allowing us to investigate these patterns for the same participants across different cuing conditions.

Persistence of Language-Schema Activation: A Novel Postcuing Manipulation

As detailed above, previous research mostly investigated the issue of global, language schema activation and control by examining preparation effects and switching costs when a language cue preceded the target in production tasks. In the study reported here, we wish to further explore this issue by asking whether we can find evidence for persisting activation of a recently used language even at the level of specific lemmas. According to the IC model, bilinguals can make use of activation and inhibition at the global level of the language schema. Thus, when a bilingual is presented with a specific target picture to be named it is possible that such persisting activation will cause the lemma in the recently used language to be more strongly activated than the competing lemma in the nontarget language. We investigate this possibility by presenting bilinguals with a cue to the target language only after the target picture. Thus, bilinguals could initiate lexical access to retrieve the appropriate lemmas in both languages. Then, either 300 or 900 ms later, they were presented with a cue indicating the target language, which would allow them to select one of the activated lemmas for production. We called these the "postcuing" conditions. Participants therefore have time to retrieve lemmas in both languages before being given a cue as to the relevant language on a given trial.

If indeed the previously instantiated language schema continues exerting its influence, leading to stronger activation of associated lemmas until a new language schema is invoked, we would expect language-switching costs in both the postcuing conditions, for both L1 and L2. Alternatively, and specifically in the context of a language-switching study, it is possible that once specific lemma activation and lexical selection are launched by a given target stimulus, the bilingual language system might be able to overcome such global, language schema recency effects, and activate both candidates to a comparable degree, thus effectively reducing, or even eliminating, switch costs. Therefore, the postcuing manipulation implemented in the current study has the potential of refining our understanding regarding the extent to which global, language-schema information might influence and bias the activation of specific lemmas within the bilingual lexicon.

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This postcuing paradigm has been used in two previous imaging studies comparing language switching with task switching (Abutalebi et al., 2008; Khateb et al., 2007), but its impact on behavioral measures of language-switching performance costs was not examined in these studies. A recent study by Declerck and colleagues (2015), which orthogonally manipulated concept and language predictability in a language-switching paradigm, provides some informative directions. The results showed that concept predictability (which is somewhat similar to language postcuing) allowed a reduction, but not elimination, in switch costs, but only in the L1. The effect of a postcuing manipulation was also examined recently by Ma and colleagues (2016) in a study comparing short and long SCIs in a language-switching digit-naming task. The results of this study also support the notion of persisting activation from a recently used language, even at the level of specific lemmas, as significant switching costs were found with postcuing. However, in this study longer SCIs did not lead to a reduction in switching cost. Further, in this study the postcuing conditions were not compared directly with a simultaneous cuing condition, thus limiting our ability to generate a full picture of this manipulation.

The current study thus provides three measures of global, language schema, control within a single group of moderately proficient bilingual participants. We investigate the impact of preceding language cues, the possible patterns of symmetry and the possibility of persisting activation at the lemma level by including poststimulus language cues.

If bilinguals are able to use information about the target language in the upcoming trial to modulate activation at the language-schema level, we would expect overall RTs to be faster with preparation across both language repetition and language-switching trials. If bilinguals are also able to use such information to further specifically inhibit the nontarget language, we would expect preparation to yield smaller switching costs as well. Such preparation effects in overall RT and switch costs would demonstrate the role of global control mechanisms in bilingual language control, in line with previous findings (see Table 1). Finally, we ask whether lemma-level activation is also sensitive to persisting global, language-schema, influences, to reach a fuller understanding of the scope of such global effects.

Local Control—Lateral Inhibition of Activated Lemmas

In addition to global control, the current study also investigated local control mechanisms, or the strength of inhibitory connections between specific translation-equivalent lemmas, in the context of a language-switching paradigm. There is robust evidence in the literature that translation equivalents from the nontarget language become activated during bilingual language processing (e.g., Thierry & Wu, 2007). Thus, both picture-naming and picture-word interference studies have documented the influence of nontarget translation equivalents on bilingual performance (Costa, Miozzo, & Caramazza, 1999; Colomé, 2001; Hoshino & Kroll, 2008). In these studies, however, the target language remains stable across trials and thus managing cross-language interference may also recruit global language control mechanisms. A recent relevant study by Van Assche, Duyck, and Gollan (2013) examined order effects in a verbal fluency task, and showed that production in the dominant L1 suffered following production in the L2, but only when the semantic category was repeated across languages, suggesting inhibition at the lemma level. The authors conclude that language control is realized via multiple levels of inhibitory control, which might be differentially recruited by different bilinguals.

In the current study, we probe the manner in which a specific lemma is produced under conditions where both translation equivalents are activated by the concept, but target language remains unpredictable from trial to trial. As described above, larger switch costs into the dominant language have previously been ascribed, at the global control level, to the need to more strongly inhibit the L1 language schema to allow for production of L2. The postcuing condition can reveal whether such asymmetry may also be present in lemma-level inhibitory connections between translation equivalents within the bilingual lexicon. Namely, once both translation equivalents are activated, are the lemma-level connections symmetrical, or might it be easier for bilinguals to inhibit an L2 lemma in order to produce an L1 translation equivalent? If such local inhibitory links are symmetric, we would predict similar switch costs into both languages, whereas if L2 lemmas exert stronger inhibition on their L1 translation equivalents, we would expect to see asymmetrical switch costs in the postcuing manipulation. Thus, the postcuing manipulation will allow us to examine how the dynamics of activation and inhibition across L1 and L2 play out at the local level of two specific activated lemmas, rather than at the global language schema level, and thus promote our understanding of a less investigated aspect of bilingual language control.

Language Dominance

The final issue examined in the current study is that of the overall balance between the two languages of bilinguals. The current design will allow us to document how language dominance effects will play out when the language information is delayed. Specifically, in traditional picture naming experiments, bilinguals name pictures more quickly in the dominant L1 than in a less proficient L2, a finding that has been explained by the fact that concept-to-lemma links are stronger for L1 than for L2 (Kroll & Stewart, 1994; and more recently Kroll, Van Hell, Tokowicz, & Green, 2010), and which we expect to replicate in the single-language naming blocks in the current study. In comparison to the single-language blocks, the postcuing conditions in essence are similar to a delayed response signal, and allow for some response preparation. We therefore predict that for both L1 and L2 a longer stimulus-cue interval (SCI) would lead to faster RTs overall. The bilinguals in the current study were unbalanced in their language proficiency, such that concept-to-lemma activation should be less automatic and efficient in Hebrew (L2) than in Arabic (L1). The delay in target language information will allow us to examine the time course of lexical retrieval in the two languages, by examining language dominance with a delayed language cue. Thus, it may be the case that the target-cue interval will give bilinguals enough time to activate the lexical candidates in the weaker L2 to the same degree as that of lexical candidates in the dominant L1, thus eliminating such dominance effects in the longer postcuing condition, or perhaps in both postcuing conditions.

To summarize, the present study examines the dynamics of language activation and inhibition at the global level of language schemas, as well as at the local level of specific translation-

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equivalent lemmas. The novel postcuing manipulation will contribute to our characterization of global language control, by investigating the persistence of language schema activation after lemma selection, and to our understanding of local control by investigating whether lateral connections between translation-equivalent lemmas are symmetrical. The participants are adult unbalanced bilingual speakers of Arabic and Hebrew, who completed a picture-naming language-switching paradigm under five conditions: simultaneous cuing, short and long precuing, and short and long postcuing.

Method

Participants

Forty-seven proficient Arabic-Hebrew young bilingual university students (23 males, between the ages 18–27), were recruited from the University of Haifa and the Israel Institute of Technology, Haifa, and paid for their participation in the experiment. In both these academic institutions the instruction language is Hebrew; therefore, participants were partially immersed in their L2 at the time of testing. All participants had normal or corrected-to-normal vision. All but two were right-handed according to the Edinburgh handedness Inventory (Oldfield, 1971), with a mean laterality index $M = 0.65$, $SD = \pm 0.25$. All participants spoke Arabic as their first language (L1), Hebrew as a second language (L2), and English as a third language (L3). Through a demographic questionnaire, the participants gave information about the age of acquisition of the languages they spoke. Participants were schooled in Israel in Arabic-speaking schools, and started studying Hebrew formally as their L2 in the second grade. Six of the participants reported that they had been exposed to Hebrew in the environment before the onset of formal schooling (see Table 2).

Language Proficiency

Prior to the experiment, participants completed a questionnaire assessing their exposure and use of Arabic and Hebrew, and their self-rated proficiency (Wartenburger et al., 2003); for full participant characteristics see Table 2.

In an additional questionnaire participants responded to statements regarding their linguistic abilities (understanding oral and written language, conversation, etc.) by choosing one of three options: a) *this is still an objective for me;* b) *I can accomplish this if I make an effort*; c) *I can do this easily*; corresponding respectively to a score of 1 to 3. This questionnaire contained 11 items with a maximum score of 33. On average, participants evaluated their level of proficiency in Hebrew as relatively high ($M = 28$, $SD = 2.8$).

Table 2
Participant Characteristics, Mean (SD)

Participant characteristics	Mean (*SD*)
Age	22.2 (2.04)
Age of onset Hebrew instruction	7.6 (2.02)
Arabic (L1) daily exposure (hours)	8.8 (6.1)
Arabic (L1) self-rated proficiency[*]	3.9 (.28)
Hebrew (L2) daily exposure (hours)	5 (3.7)
Hebrew (L2) self-rated proficiency[*]	3.6 (.59)

[*] Participants rated their oral comprehension, reading comprehension, oral and written expression on a scale from 1–4 (1 indicating *low proficiency* and 4 indicating *very high proficiency*).

Materials and Procedure

Stimuli. The stimuli were images of concrete objects selected from the sets published by Snodgrass and Vanderwart (1980) and by Cycowicz, Friedman, Rothstein, and Snodgrass (1997). Forty Arabic-Hebrew bilinguals (who did not participate in the later study) each named 250 images in Arabic. Based on this pilot data, we selected 210 images that yielded single-word naming responses with naming agreement above 90% in Arabic. Images were then divided into seven lists of 30 items each, with particular attention paid to match images across lists in terms of the semantic categories used (tools, clothes, animals, etc.) and in terms of visual image complexity.

Procedure. Participants first completed two single-language naming blocks, one in Hebrew and one in Arabic, to practice the task. In the single-language naming blocks, each picture was presented once. The single-language naming blocks were followed by five blocks of mixed-language naming, with different cuing parameters, in counterbalanced order across participants. One stimulus list of 30 images was assigned to each mixed naming block.

In the mixed language blocks participants were presented with images to name either in L1 or in L2 as a function of a cue word signaling the language of response (the Arabic word for "Arabic" <عربي> for naming in Arabic, and the Hebrew word for "Hebrew" <עברית> for naming in Hebrew). Five different lists of 30 images were presented for naming in the mixed language blocks. In each list, each item was presented four times: a) Repetition Arabic, b) Repetition Hebrew, c) Switch Arabic, and d) Switch Hebrew. Thus, each mixed language block had a total of 120 trials, with a maximum of four consecutive trials of the same kind. The lists were rotated across the different language mixing blocks. Finally, two different random presentation orders were created for each list. These manipulations aimed at avoiding not only possible list effects but also order effects within the lists.

The mixed language blocks differed in timing of language cue and picture target presentation: a) language cue appeared 900 ms before the target (long CSI, hereafter: pre-900); b) language cue appeared 300 ms before the target (short CSI, hereafter: pre-300); c) language cue and target appeared simultaneously (hereafter: Simultaneous); d) language cue appeared 300 ms after target (short SCI, hereafter: post-300); e) language cue appeared 900 ms after the target (long SCI, hereafter: post-900) (see Figure 1). In all mixed-language blocks each trial started with a 1,000 ms fixation. The length of the time window available for response was modified across the mixed-language blocks, to ensure that the time elapsed between when a response was possible for trial n and when a response was possible for trial $n + 1$ was held constant at 4,000 ms (see Figure 1 and Table 3). Each block lasted about 8 min, for a total duration of about 60 min including breaks, training list, and the single-language naming blocks.

During the experiment, participants were seated in a comfortable chair in a quiet room. They were asked in each trial to give an overt oral response as quickly as possible after the appearance of

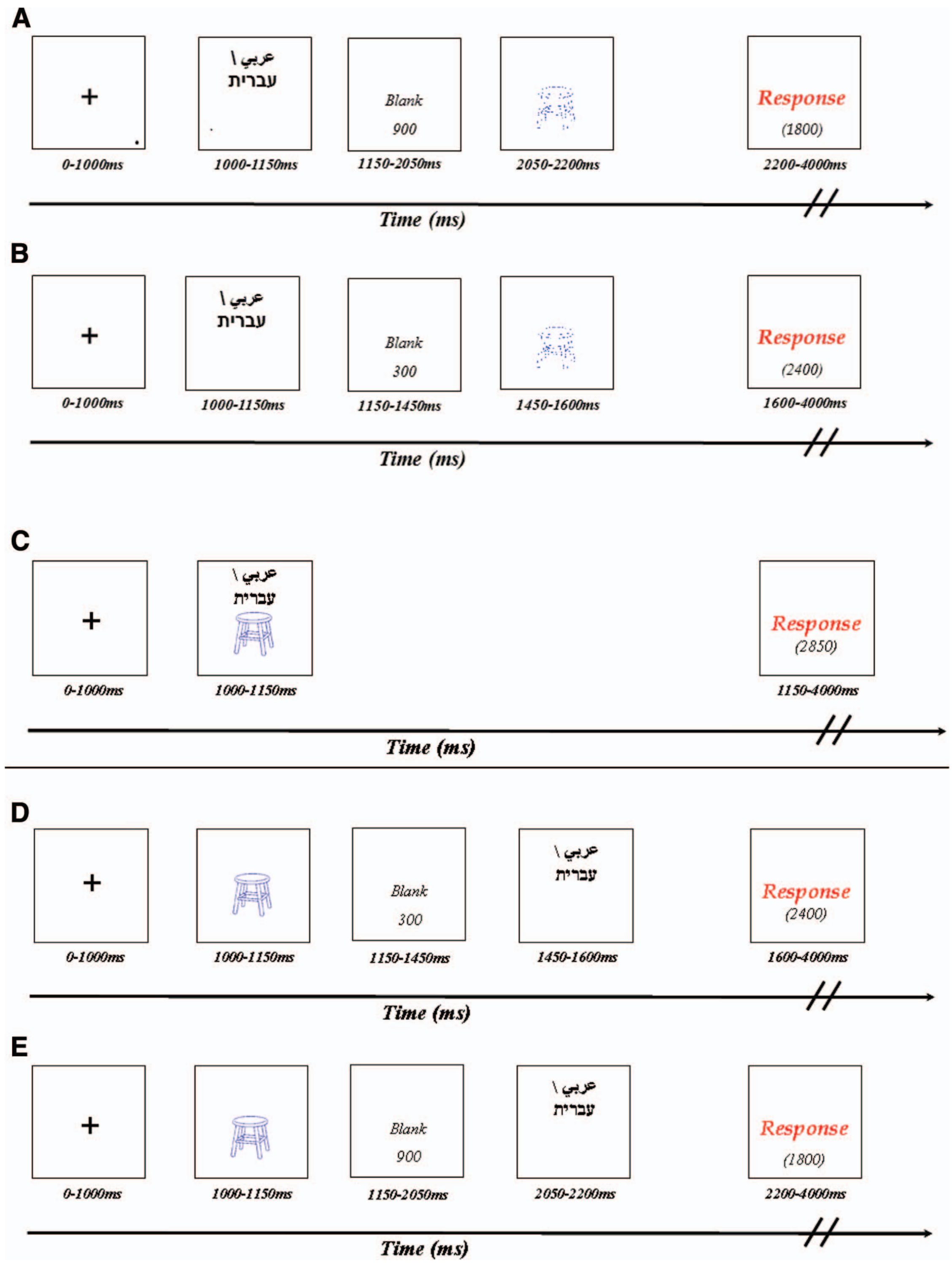

Figure 1. Schematic representation of the paradigm and sequence of events. (A) Precuing 900 ms; (B) Precuing 300 ms; (C) Cue and picture are present simultaneously; (D) Postcuing 300 ms; (E) Postcuing, 900 ms. See the online article for the color version of this figure.

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Table 3
Timing of Events in the Experimental Blocks

Condition	Fixation duration	First event	First–second interval	Second event	ITI
Pre-900	1,000	Cue: 150	900	Target: 150	1,800
Pre-300	1,000	Cue: 150	300	Target: 150	2,400
Simultaneous	1,000	Cue + Target: 150	—	—	2,850
Post-300	1,000	Target: 150	300	Cue: 150	2,400
Post-900	1,000	Target: 150	900	Cue: 150	1,800

the target image in precuing contexts, or after the appearance of the language cue in the postcuing ones, or rapidly after the joint appearance of the image and the cue word in the simultaneous cuing context. Voice onset was recorded by a voice-key microphone connected to a response box monitored by E-Prime. Oral responses were also recorded for later offline accuracy coding.

In order to allow for easy comparisons between the mixed language naming blocks, mean RTs were always computed from the moment at which the response was possible. Specifically, in precuing and simultaneous blocks RTs were computed relative to the target onset (i.e., when both the language information and the target stimulus were available), whereas in postcuing blocks RTs were computed relative to the language cue onset (i.e., again here when both the language information and the target stimulus were available). Accuracy was determined for each subject as the percent of correct responses in each condition and block.

Results

Data from three participants were lost due to technical equipment failures. Thus, the final number of participants entering the analyses was 44.[1] For each participant, naming latencies in each language in each condition were calculated for correct trials only. Participants failed to respond on 7.8% of the trials, which were coded as errors, as were wrong names given in the intended language and responses in the nonintended language. In addition, 5.8% of the data were lost due to incorrect voice-key triggering. Finally, RTs shorter than 250 ms or longer than 2,950 ms were excluded from analysis (1.5% of the data). This timing window was selected as it represented the shortest time window available for response, namely in the pre-900 and post-900 cuing conditions. Across participants all averaged RTs are based on a minimum of 15 trials per condition, with an average of 23 trials per condition

The mean RT (in ms) and accuracy were computed for each participant separately for repeat and switch trials, in each language and each mixed language block (i.e., pre-900, pre-300, simultaneous, post-300 and post-900) (see Figure 2). The means over participants are presented in Table 4. Switch costs in RT and accuracy are presented in Figure 3. We investigated the effects of precuing and of postcuing on performance separately, comparing each type of cuing to the simultaneous cuing condition. Thus, data are analyzed in two nonorthogonal contrasts, because both pre- and postcuing were compared to the simultaneous cuing condition.

Single Language Naming

Voice-key data from the single language blocks of two participants were lost as a result of technical failure. Confirming that participants were unbalanced bilinguals, they were significantly faster and more accurate when naming pictures in L1 than in L2, $t(41) = 5.83$, $p < .001$ for RTs and $t(43 = 9.28$, $p < .001$ for accuracy).

Precuing: Preparation Effects as a Signature of Global Control

Response time. We conducted a 3-way repeated measures ANOVA, with language (L1, L2), trial type (repeat, switch) and cuing condition (pre-900, pre-300 and simultaneous) as within subject variables.

The main effect of cuing was significant ($F(2, 84) = 93.2$, $p < .001$, $\eta^2 = .69$), longer precuing led to shorter RTs. Planned comparisons showed that RTs in both the precuing conditions were significantly faster than in the simultaneous cuing condition ($F(1, 43) = 124.4$, $p < .001$, $\eta^2 = .74$, $F(1, 42) = 115.4$, $p < .001$, $\eta^2 = .73$, for the pre-300 and pre-900 conditions, respectively). This pattern shows preparation effects, and supports the influence of global control on language selection. The main effect of trial type was also significant ($F(1, 42) = 68.5$, $p < .001$, $\eta^2 = .62$), RTs to language repetition trial were faster than to trials in which the response language changed. However, the main effect of response language was not significant ($F(1, 42) = 1.4$ $p = .24$.

The main effect of cuing condition was qualified by a significant two-way interaction with response language ($F(2, 84) = 3.5$, $p = .034$, $\eta^2 = .08$). To follow up on this interaction, we analyzed separately the impact of each cuing condition on L1 and L2. When comparing the pre300 condition with the simultaneous condition, the two-way interaction between cuing and language was not significant ($F(1, 43) = 2.6$, $p = .11$, $\eta^2 = .06$) demonstrating that both languages benefitted equally from the short preparation interval. However, when comparing the pre-900 with the pre-300 condition, there was a significant interaction between cuing and language ($F(1, 42) = 8$, $p = .007$, $\eta^2 = .16$), because responses in L2 were faster in the longer than in the shorter cuing condition (by 34ms), but RTs in L1 were equally fast across both precuing conditions. Thus, the longer preparation duration benefitted only the less dominant L2.

The two-way interaction between trial type and language ($F(1, 42) = 3.1$, $p = .085$, $\eta^2 = .07$) was marginally significant, because switching costs tended to be larger when switching into Arabic (the L1, $M = 70$ ms) than when switching into Hebrew (the L2, $M = 43$ ms), across simultaneous and precuing conditions. Fur-

[1] In addition, one participant had no usable data in the pre-900 cuing condition, but was included in all analyses not including this condition.

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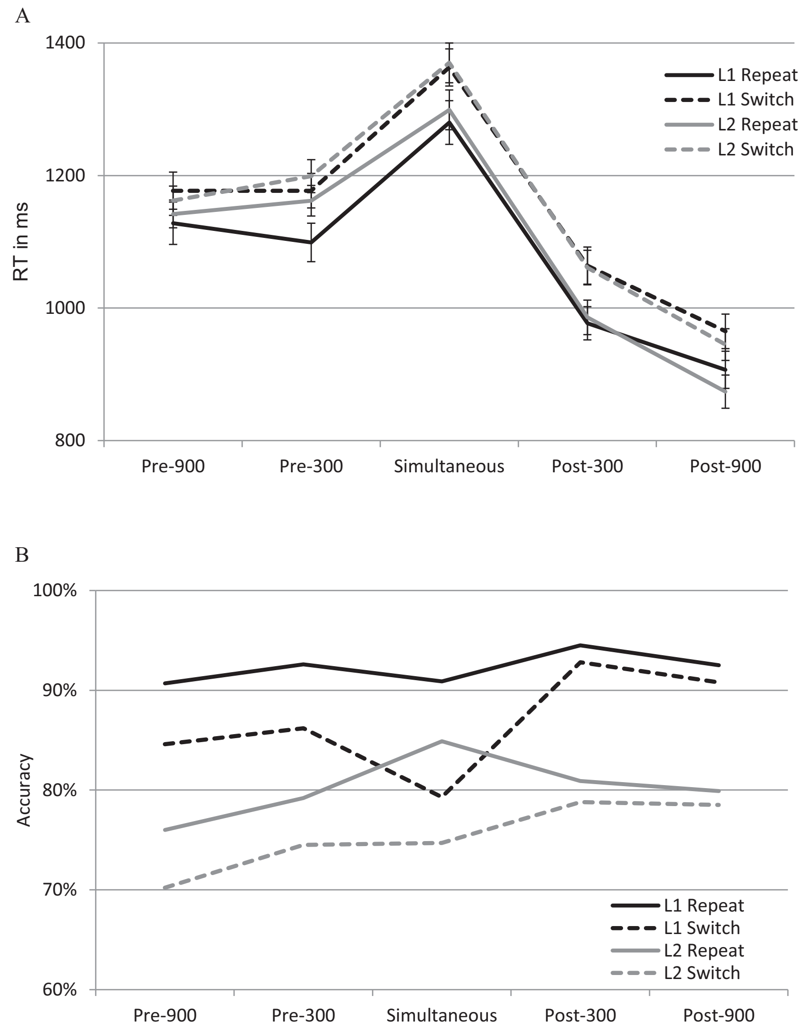

Figure 2. Performance on repeat and switch trials across cuing conditions, by language. Panel A: RTs. Panel B: Accuracy.

ther, the two way interaction between trial type and cuing condition was also marginally significant ($F(2, 84) = 2.6$, $p = .08$, $\eta^2 = .06$). Because of our specific interest in the effect of preparation, we followed up this interaction, even though it did not reach conventional significance levels, with planned comparisons comparing each of the precuing conditions with the simultaneous cuing condition. When examining the pre-300 condition, the two-way interaction between trial type and cuing condition was not significant, $F(1, 43) = 1.5$, $p = .24$, namely the short precuing condition did not lead to a reduction in switch costs. In contrast, when comparing the pre-900 condition with the simultaneous condition, the two-way interaction between trial type and cuing condition was significant ($F(1, 43) = 5.9$, $p = .019$, $\eta^2 = .12$). Thus, the longer precuing condition did lead to smaller switching costs, across both

Table 4
RTs (SD) for Repeat and Switch Trials by Language and Cuing Condition

	Pre-900	Pre-300	Simultaneous	Post-300	Post-900
Arabic (L1)					
Repeat	1,128 (176)	1,099 (189)	1,280 (222)	977 (168)	907 (187)
Switch	1,177 (185)	1,177 (170)	1,363 (187)	1,064 (188)	965 (170)
Hebrew (L2)					
Repeat	1,142 (141)	1,162 (147)	1,299 (198)	986 (171)	874 (168)
Switch	1,162 (147)	1,199 (167)	1,370 (198)	1,061 (174)	945 (159)

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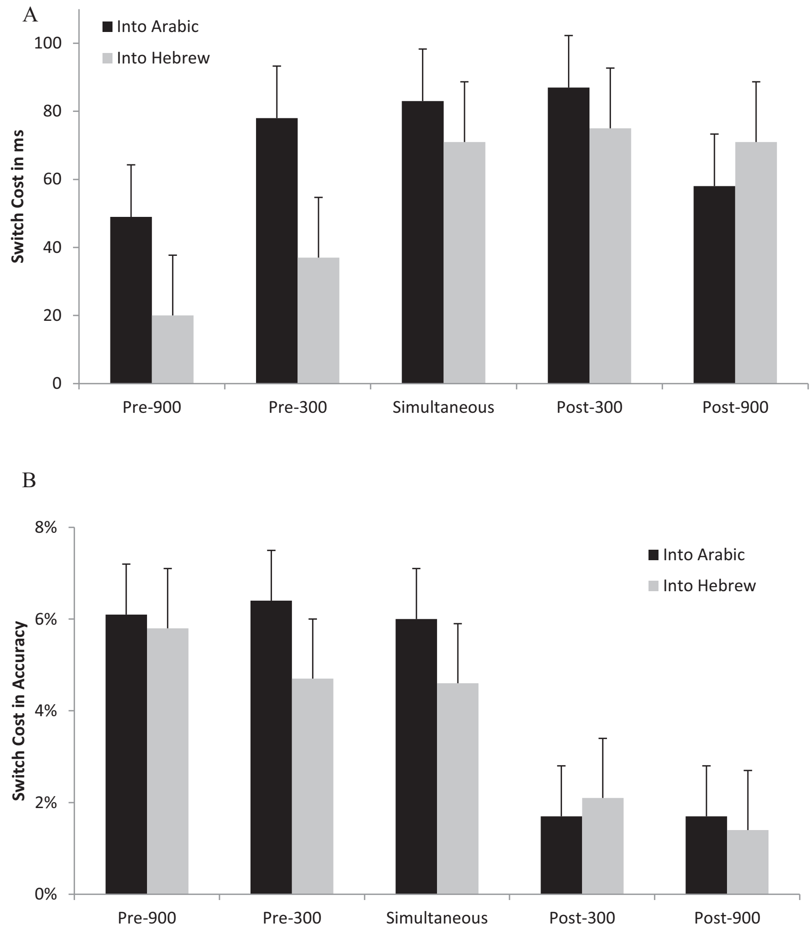

Figure 3. Switch costs across cuing conditions, by language. Panel A: Switch costs in RT. Panel B: Switch costs in Accuracy

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response languages. This pattern of results provides additional partial support to global control—with sufficient preparation time, participants were able to reduce language-switching costs, putatively by adjusting activation levels.

The three way interaction was not significant ($F < 1$).

To summarize, the RT findings demonstrate significant preparation effects in overall RTs for both languages. For the L2, the longer preparation condition was also beneficial beyond the shorter preparation condition. The long, but not the short, precuing condition also led to a reduction in switch costs across both languages. This pattern supports the influence of global language schema preparation and control on bilingual language production. Finally, although switch costs were numerically larger when switching into L1 than when switching into L2, across all three cuing conditions, this difference was only marginally significant, such that switch costs may be considered mostly symmetrical. In this aspect, the current results do not support the notion of a switch cost asymmetry as a hallmark of global control in unbalanced bilinguals.

Accuracy. We again conducted a three-way repeated measures ANOVA on accuracy rates, with language (L1, L2), trial type (repeat, switch) and cuing condition (pre-900, pre-300, and simultaneous) as within-subject variables.

The main effect of response language was significant ($F(1, 42) = 70.14$, $p < .001$, $\eta^2 = .63$), overall participants were more accurate when naming pictures in the L1 than in the L2. The main effect of trial type was also significant ($F(1, 42) = 78.1$, $p < .001$, $\eta^2 = .65$), participants were more accurate on language repetition trials than on language switch trials.

The main effect of cuing was significant ($F(2, 84) = 4.5$, $p = .014$, $\eta^2 = .10$). Planned comparisons revealed that accuracy in the pre-300 condition did not differ significantly from accuracy in the simultaneous cuing condition ($F < 1$). However, accuracy was lower in the pre-900 condition than in the simultaneous condition ($F(1, 42) = 5.8$, $p = .021$, $\eta^2 = .12$). An examination of the means in Table 5 suggests that whereas accuracy rates for L1 naming remained relatively constant across all cuing conditions, accuracy rates for L2 naming were lower in the pre-900 than in the simultaneous cuing condition.

All two-way interactions and the three-way interaction were not significant (All $p > .19$).

Thus, the only effect of cuing on accuracy was elevated error rates in the pre-900 cuing condition, for L2 naming. This creates a pattern of a speed–accuracy trade-off—as RTs were significantly faster in this condition as well. Precuing did not influence switch costs in accuracy. These issues will be taken up in the discussion.

Table 5
Accuracy Rates (SD) for Repeat and Switch Trials by Language and Cuing Condition

	Pre-900	Pre-300	Simultaneous	Post-300	Post-900
Arabic (L1)					
Repeat	90.7 (7)	92.6 (5)	90.9 (8)	94.5 (5)	92.5 (6)
Switch	84.6 (10)	86.2 (8)	84.9 (10)	92.8 (6)	90.8 (7)
Hebrew (L2)					
Repeat	76.0 (13)	79.2 (13)	79.3 (11)	80.9 (5)	79.9 (12)
Switch	70.2 (15)	74.5 (14)	74.7 (14)	78.8 (12)	78.5 (12)

Postcuing: Persisting Language Schema Activation and Local Inhibition

Response time. We again conducted a three-way repeated measures ANOVA, with language (L1, L2), trial type (repeat, switch) and cuing condition (simultaneous, post-300, post-900) as within-subject variables.

The main effect of cuing was significant ($F(2, 86) = 304.2$ $p <$ .001, $\eta^2 = .88$), longer postcuing led to shorter RTs. Planned comparisons showed that RTs in both the postcuing conditions were significantly faster than in the simultaneous cuing condition ($F(1, 43) = 265.4$, $p < .001$, $\eta^2 = .86$, $F(1, 43) = 510.5$, $p < .001$, $\eta^2 = .92$, for the post-300 and post-900 conditions, respectively). The main effect of trial type was also significant ($F(1, 43) = 75.4$, $p < .001$, $\eta^2 = .64$), RTs to language repetition trials were faster than to trials in which the response language changed, indicating significant language-switching costs. Finally, the main effect of response language was not significant ($F < 1$). All two- and three-way interactions were not significant (all $p > .16$).

Thus, postcuing allowed participants to respond faster in both languages, but did not lead to a reduction in the magnitude of switching costs, which remained stable. This finding of robust switching costs demonstrates persisting global language schema activation, even after specific lexical items have been selected following the presentation of the target to-be-named. Importantly, switching costs were symmetrical into L1 and L2 in both postcuing conditions. This finding suggests that lateral inhibitory links are of equal strength between L1 and L2 lemmas—namely, when two translation-equivalent lemmas are activated, bilinguals can inhibit the nontarget language lemma equally well regardless of its language membership.

Accuracy. We conducted a three-way repeated measures ANOVA on accuracy rates, with language (L1, L2), trial type (repeat, switch) and cuing condition (simultaneous, post-300 and post-900) as within subject variables.

The main effect of cuing was significant ($F(2, 86) = 15.8$, $p <$ .001, $\eta^2 = .27$). Planned comparisons showed that accuracy rates in both the postcuing conditions were significantly higher than in the simultaneous cuing condition ($F(1, 43) = 25.$, $p < .001$, $\eta^2 =$ .37, $F(1, 43) = 14.2$, $p < .001$, $\eta^2 = .25$, for the post-300 and post-900 conditions, respectively). Further, accuracy rates in the post900 condition were marginally higher than in the post-300 condition ($F(1, 43) = 3.7$, $p = .06$, $\eta^2 = .08$). The main effect of response language was significant ($F(1, 43) = 90.7$, $p<.001$, $\eta^2 =$ .68), overall participants were more accurate when naming pictures in the L1 than in the L2. The main effect of trial type was also significant ($F(1, 43) = 44.5$, $p < .001$, $\eta^2 = .51$), participants were more accurate on language-repetition trials than on language-switch trials, indicating a language-switching cost in accuracy. This final finding again supports the notion of persistent activation at the level of language schemas, even after lemma selection.

Finally, the two-way interaction between cuing condition and trial type was significant, ($F(2, 86) = 9.8$, $p < .001$, $\eta^2 = .19$); switch costs in accuracy were smaller in the postcuing conditions than in the simultaneous cuing condition. We used planned comparisons to investigate this reduction in switch costs separately for each of the postcuing conditions—the two-way interaction between cuing condition and trial type remained significant in an analysis comparing the post-300 condition with the simultaneous condition ($F(1, 43) = 11.9$, $p = .001$, $\eta^2 = .22$) and in an analysis comparing the post-900 condition with the simultaneous cuing condition ($F(1, 43) = 14.3$, $p < .001$, $\eta^2 = .25$). Thus, in both postcuing conditions switch costs in accuracy were smaller than in the simultaneous cuing condition. All remaining two-way interactions and the three-way interaction were not statistically significant (all $p > 24$).

To summarize, postcuing led to faster RTs and higher accuracy rates overall than simultaneous cuing, for both languages. Further, postcuing reduced switch costs in accuracy, but not in RT, again for both languages. Finally, switch costs in both RT and accuracy were symmetric in both postcuing conditions.

Discussion

The current study investigated the mechanisms involved in bilingual language control, by manipulating cuing parameters in a picture naming language-switching paradigm to probe whole-language and lemma-specific activation and inhibition mechanisms. Participants were fairly advanced, partially immersed, but unbalanced Arabic-Hebrew bilinguals. The main findings were as follows. Replicating findings of previous studies, we found preparation effects in language switching (see Table 1). Namely, there was an overall reduction in RTs with both precuing manipulations, and switch costs in RT were reduced in the longer precuing condition. Switch costs were mostly symmetrical across cuing conditions. Precuing did not enhance accuracy, and the longer precuing condition in fact led to reduced accuracy in the L2.

Regarding postcuing and concept activation, postcuing greatly reduced overall RTs and increased accuracy in both languages. Because of the more informative nature of providing the target picture than giving target language information, responses in the postcuing conditions were significantly faster and more accurate not only than the simultaneous condition, but also than the precuing conditions. Importantly, there remained robust switch costs in both RT and accuracy in the postcuing conditions. In fact, postcuing had no effect whatsoever on switch costs in RT, but it did

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lead to a reduction of switch costs in accuracy. Finally, switch costs were symmetrical for L1 and L2 in postcuing conditions.

This complex pattern of results has several important implications for theoretical models of bilingual language control. In what follows we will outline the implications of these findings for models of global language control mechanisms and discuss the new insights gained from the novel postcuing manipulation.

Global Language Control: Precuing Conditions

Preparation. The Inhibitory Control (IC) model (Green, 1998) described global language activation/inhibition as one mechanism of control. Previous research has identified preparation effects in language switching as evidence supporting such global control. In the current study we found significant reduction in overall RTs as well as a significant reduction in switching costs when language cues preceded the target to be named. The reduction in RTs in the pre-900 cuing condition is somewhat compromised by elevated error rates for the L2 in this condition as well, leading to a possible speed–accuracy trade-off (see Philipp et al., 2007, for a similar finding). However, we suggest that this finding does not prevent us from interpreting the overall pattern as beneficial preparation effects, because the elevated error rates were limited to the L2, whereas the faster RTs were evident for both languages (see Figure 2). Further, the elevated error rates in the pre-900 condition were equal for both repetition and switch trials, thus again not seriously compromising the finding of reduced switch costs.

This pattern of beneficial preparation effects has been reported by most, but not all, previous studies investigating preparation effects in bilingual language switching (Costa & Santesteban, 2004; Fink & Goldrick, 2015; Ma et al., 2016; Verhoef et al., 2009; but see Declerck et al., 2015). Thus, the current results add to a growing body of empirical investigations of language switching and suggest that preparation effects are rather robust across diverse learner and bilingual populations and across various experimental manipulations.

The current findings are therefore in line with the theoretical predictions made by the IC model (Green, 1998). Specifically, the preparation effects support the notion that bilinguals are able, to some degree at least, to activate target language lemmas or inhibit nontarget lemmas on the basis of a language cue. This means that bilingual control is achieved at least partially by whole-language activation dynamics, as has been recently suggested using other experimental paradigms as well (e.g., Van Assche et al., 2013).

Switch cost a/symmetry. The results of the current study demonstrated mostly symmetric switching costs across L1 and L2, in a population of late, unbalanced advanced bilinguals. These findings are noteworthy, because the issue of symmetry in switching costs has received considerable interest in the literature on bilingual language control (Bobb & Wodniecka, 2013; Declerck & Philipp, 2015; Ma et al., 2016; Reynolds et al., 2016). Thus, the original IC model posited that L1 dominance in unbalanced bilinguals is expected to be expressed, interalia, in larger switching costs to the L1 (Green, 1998; Meuter & Allport, 1999). However, as in the current study, symmetrical switch costs have also been reported for unbalanced bilinguals when switching was voluntary (Gollan & Ferreira, 2009), or for unbalanced bilinguals who did show language dominance in single language naming conditions (e.g., Prior & Gollan, 2013). Further, a previous study (Verhoef et al., 2009) has also reported both symmetric and asymmetric switching costs in the same participants, depending on preparation time.

In light of these mixed reports in the literature, recently Bobb and Wodniecka (2013) have cautioned that symmetry in switching costs, or lack thereof, is but one feature of language switching in bilinguals and further evidence from diverse populations and experimental designs is needed before definite conclusions regarding its significance can be reached. Similarly, Declerck and Philipp (2015) have also suggested that symmetric or asymmetric switch costs could arise from different phases of processing in language production, and reflect more than a single mechanism, such as global language inhibition (see also Van Assche et al., 2013).

The present results indeed show that a single bilingual population, switching between the same L1 and L2, can show both symmetric and marginally asymmetric switching costs under different experimental conditions. Specifically, in the current study the precuing conditions led to marginally asymmetric switching costs, suggesting perhaps that the ability and necessity of whole-language inhibition in unbalanced bilingual might not be equal across the dominant L1 and the nondominant L2. We suggest, therefore, that the issue of symmetry of switch costs might not be a "hallmark" of balanced bilingualism, might be more susceptible to experimental manipulations than previously thought, and could reflect the joint influence of more than a single-language control mechanism (Bobb & Wodniecka, 2013; Declerck & Philipp, 2015; Reynolds et al., 2016).

Finally, several language-switching studies have also reported general slowing of the L1 relative to L2 naming in mixed blocks (e.g., Christoffels, Firk, & Schiller, 2007; Costa et al., 2006). This pattern has also been taken as evidence for whole-language control, and specifically an indication of greater L1 inhibition (Bobb & Wodniecka, 2013; Kroll & Gollan, 2014). Participants in the current study were faster and more accurate in L1 than in L2 in the single-naming blocks. In the mixed-language blocks participants retained their accuracy advantage for L1, but were equally fast in both languages, thus losing the RT advantage for L1. Thus, this aspect of the current findings also supports to some extent predictions based on global language control.

Global and Local Control: Postcuing Conditions

Of greater interest and novelty, the present study also allowed us to probe the effect of language cuing that follows concept presentation and requires language selection after lexical access to specific translation-equivalent lemmas has been initiated. The results allow us to identify several important aspects of the dynamics of lemma activation, the persistence of language schema and resolution of competition during language selection.

First, posttarget language cues acted as delayed naming cues and led to shorter overall RTs. Because latencies were measured from cue onset, participants could make use of the target-cue interval to activate both translation equivalents and were thus able to produce the appropriate label more quickly when cued for the language. Further, overall RTs in the postcuing condition were faster and more accurate than in the precuing conditions, demonstrating that bilingual performance benefitted more from specific concept information than from general language schema information. This

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can be understood because identification of a specific concept is more informative (limiting naming options to two translation-equivalent lemmas) than identification of a target language (limiting naming options to an entire lexicon). However, this result must be interpreted with some caution, because a recent language-switching study has reported no reduction in overall RTs with posttarget language cuing (Ma et al., 2016). Of relevance, Ma and colleagues (2016) did not directly compare postcuing with a simultaneous cuing condition, and participants in their study named digits (with many repetitions) rather than objects, as in the current study. These methodological differences might have contributed to the different patterns of performance, and deserve more careful attention in future studies.

In terms of global control processes evident in the postcuing conditions, switch costs in RT in the postcuing conditions were not significantly reduced relative to simultaneous cuing. This means that in the postcuing blocks, there was persisting activation of the language schema and the associated lemmas from the most recently used language. Thus, following, for example, an L2 naming trial, the L2 lemma on the following trial was more strongly activated (or the L1 lemma continued to be inhibited) such that if the language cue then required an L1 response naming latencies were longer. This pattern applied equally to L1 and L2. In contrast, switch costs in accuracy were significantly smaller in the postcuing conditions (see Figure 3). We interpret this finding again as resulting from the difference in providing concept versus language information. The postcuing allowed bilinguals a longer interval to search, access, and activate the appropriate lemmas in both languages and resulted in fewer cases of a failure in lexical access resulting in erroneous responses. However, this increased ability to reach the appropriate lemmas still did not eliminate the recent activation of the previous language schema, and thus did not influence switching costs in RT.

These findings lend support to the importance of whole-language activation/inhibition dynamics. Interestingly, Ma and colleagues (2016) have recently reported similar findings, of robust language-switching costs under conditions in which a language cue follows a target to be named. This leads to the conclusion that language schema continue to exert their influence in sequential trials, similar to processes described for task schema in the task-switching literature, even when a single lemma can be identified in each language (Kiesel et al., 2010).

Two additional aspects of performance in the postcuing condition are noteworthy. First, there was no difference in RTs between L1 and L2, despite clear L1 dominance in the single-naming blocks. Once participants were provided with conceptual target information, and as early as following a 300 ms language cue, translation-equivalent lemmas in L1 and L2 were equally activated. Similar findings have recently been reported in a digit naming study with an even shorter target-cue interval of 200 ms (Ma et al., 2016). Thus, providing bilinguals with conceptual information can allow them to reach equal levels of lemma activation in L1 and L2 (see also Declerck et al., 2015), and overcome classic patterns of L1 dominance in naming latencies.

Second, the finding of symmetrical L1/L2 switch costs with posttarget language cuing suggests that the local inhibitory connections between translation-equivalent lemmas are equally strong in both directions (L1 to L2 and L2 to L1, see also Ma et al., 2016). Specifically, at the point when the language cue was presented in the postcuing conditions, we assume that lexical access has been mostly achieved for the lemmas in both L1 and L2, with the lemma in the target language of the previous trial being more strongly activated. The symmetry of the switch costs in the postcuing conditions demonstrates that under these conditions, it is not easier for bilinguals to inhibit the L2 lemma to allow for L1 production, or vice versa. Thus, at least in the relatively advanced but unbalanced bilingual population investigated in the current study, participants' ability to select one lemma from two activated options was equal for L1 and L2 candidates. This supports the notion that local, lateral inhibition links between translation-equivalent lemmas are equally strong in both directions. Future research is needed to ascertain if less advanced learners might show L1 dominance in this aspect of performance as well.

Conclusion

The comprehensive design of the current study enabled us to identify important aspects of bilingual language control. In terms of global control, we replicate previous preparation effects in language switching, but do not find support for asymmetric switching costs in unbalanced bilinguals. Thus, we find partial support for the specific predictions of the IC model (Green, 1998). Further, the novel posttarget language cuing manipulation used in the current study demonstrated that persisting language schema activation was equal for both the languages of unbalanced bilinguals even after specific translation-equivalent lemmas had been selected. In terms of local control, we show that lemma selection among two activated translation equivalents was again equal for L1 and L2, even in the study population of unbalanced bilinguals. This finding suggests that inhibitory local connections between translation equivalents are symmetrical. Further, including both pre- and posttarget language cuing in a single group of participants illustrated how experimental manipulations can have dissociable influences on overall RTs, accuracy, and switch costs.

References

Abutalebi, J., Annoni, J. M., Zimine, I., Pegna, A. J., Seghier, M. L., Lee-Jahnke, H., . . . Khateb, A. (2008). Language control and lexical competition in bilinguals: An event-related fMRI study. *Cerebral Cortex, 18,* 1496–1505. http://dx.doi.org/10.1093/cercor/bhm182

Abutalebi, J., & Green, D. (2007). Bilingual language production: The neurocognition of language representation and control. *Journal of Neurolinguistics, 20,* 242–275. http://dx.doi.org/10.1016/j.jneuroling.2006.10.003

Bobb, S., & Wodniecka, Z. (2013). Language switching in picture naming. What asymmetric switch costs (do not) tell us about inhibition in bilingual speech planning. *Journal of Cognitive Psychology, 25,* 568–585. http://dx.doi.org/10.1080/20445911.2013.792822

Caramazza, A., & Costa, A. (2000). The semantic interference effect in the picture–word interference paradigm: Does the response set matter? *Cognition, 75,* B51–B64. http://dx.doi.org/10.1016/S0010-0277(99)00082-7

Christoffels, I. K., Firk, C., & Schiller, N. O. (2007). Bilingual language control: An event-related brain potential study. *Brain Research, 1147,* 192–208. http://dx.doi.org/10.1016/j.brainres.2007.01.137

Colomé, A. (2001). Lexical activation in bilinguals' speech production: Language-specific or language independent? *Journal of Memory and Language, 45,* 721–736. http://dx.doi.org/10.1006/jmla.2001.2793

Costa, A., Miozzo, M., & Caramazza, A. (1999). Lexical selection in bilinguals: Do words in the bilingual's two lexicons compete for selection? *Journal of Memory and Language, 41,* 365–397. http://dx.doi.org/10.1006/jmla.1999.2651

Costa, A., & Santesteban, M. (2004). Lexical access in bilingual speech production: Evidence from language switching in highly proficient bilinguals and L2 learners. *Journal of Memory and Language, 50,* 491–511. http://dx.doi.org/10.1016/j.jml.2004.02.002

Costa, A., Santesteban, M., & Ivanova, I. (2006). How do highly-proficient bilinguals control their lexicalization process? Inhibitory and language-specific selection mechanisms are both functional. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32,* 1057–1074. http://dx.doi.org/10.1037/0278-7393.32.5.1057

Cycowicz, Y. M., Friedman, D., Rothstein, M., & Snodgrass, J. G. (1997). Picture naming by young children: Norms for name agreement, familiarity, and visual complexity. *Journal of Experimental Child Psychology, 65,* 171–237. http://dx.doi.org/10.1006/jecp.1996.2356

Declerck, M., Koch, I., & Philipp, A. M. (2012). Digits vs. pictures: The influence of stimulus type on language switching. *Bilingualism: Language and Cognition, 15,* 896–904. http://dx.doi.org/10.1017/S1366728912000193

Declerck, M., Koch, I., & Philipp, A. M. (2015). The minimum requirements of language control: Evidence from sequential predictability effects in language switching. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 41,* 377–394. http://dx.doi.org/10.1037/xlm0000021

Declerck, M., & Philipp, A. M. (2015). A review of control processes and their locus in language switching. *Psychonomic Bulletin & Review, 22,* 1630–1645. http://dx.doi.org/10.3758/s13423-015-0836-1

Declerck, M., Philipp, A. M., & Koch, I. (2013). Bilingual control: Sequential memory in language switching. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 39,* 1793–1806. http://dx.doi.org/10.1037/a0033094

Declerck, M., Thoma, A. M., Koch, I., & Philipp, A. M. (2015). Highly proficient bilinguals implement inhibition—Evidence from *n*-2 language repetition costs. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 41,* 1911–1916. http://dx.doi.org/10.1037/xlm0000138

Dijkstra, A., & Van Heuven, W. J. B. (2002). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition, 5,* 175–197. http://dx.doi.org/10.1017/S1366728902003012

Fink, A., & Goldrick, M. (2015). Pervasive benefits of preparation in language switching. *Psychonomic Bulletin & Review, 22,* 808–814. http://dx.doi.org/10.3758/s13423-014-0739-6

Gollan, T. H., & Ferreira, V. S. (2009). Should I stay, or should I switch? A cost–benefit analysis of voluntary language-switching in young and aging bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35,* 640–665. http://dx.doi.org/10.1037/a0014981

Green, D. W. (1998). Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and Cognition, 1,* 67–81. http://dx.doi.org/10.1017/S1366728998000133

Hoshino, N., & Kroll, J. F. (2008). Cognate effects in picture naming: Does cross-language activation survive a change of script? *Cognition, 106,* 501–511. http://dx.doi.org/10.1016/j.cognition.2007.02.001

Khateb, A., Abutalebi, J., Michel, C. M., Pegna, A. J., Lee-Jahnke, H., & Annoni, J. M. (2007). Language selection in bilinguals: A spatio-temporal analysis of electric brain activity. *International Journal of Psychophysiology, 65,* 201–213. http://dx.doi.org/10.1016/j.ijpsycho.2007.04.008

Kiesel, A., Steinhauser, M., Wendt, M., Falkenstein, M., Jost, K., Philipp, A. M., & Koch, I. (2010). Control and interference in task switching: A review. *Psychological Bulletin, 136,* 849–874. http://dx.doi.org/10.1037/a0019842

Kleinman, D., & Gollan, T. H. (2016). Speaking two languages for the price of one: Bypassing language control mechanisms via accessibility-driven switches. *Psychological Science, 27,* 700–714. http://dx.doi.org/10.1177/0956797616634633

Kroll, J. F., Bobb, S. C., & Hoshino, N. (2014). Two languages in mind: Bilingualism as a tool to investigate language, cognition and the brain. *Current Directions in Psychological Science, 23,* 159–163. http://dx.doi.org/10.1177/0963721414528511

Kroll, J. F., & Gollan, T. H. (2014). Speech planning in two languages: What bilinguals tell us about language production. In V. Ferreira, M. Goldrick, & M. Miozzo (Eds.), *The Oxford handbook of language production* (pp. 165–181). New York, NY: Oxford University Press.

Kroll, J. F., & Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. *Journal of Memory and Language, 33,* 149–174. http://dx.doi.org/10.1006/jmla.1994.1008

Kroll, J. F., Van Hell, J. G., Tokowicz, N., & Green, D. W. (2010). The revised Hierarchical model: A critical review and assessment. *Bilingualism: Language and Cognition, 13,* 373–381. http://dx.doi.org/10.1017/S136672891000009X

Lee, M. W., & Williams, J. N. (2001). Lexical access in spoken word production by bilinguals: Evidence from the semantic competitor priming paradigm. *Bilingualism: Language and Cognition, 4,* 233–248. http://dx.doi.org/10.1017/S1366728901000426

Ma, F., Li, S., & Guo, T. (2016). Reactive and proactive control in bilingual word production: An investigation of influential factors. *Journal of Memory and Language, 86,* 35–59. http://dx.doi.org/10.1016/j.jml.2015.08.004

Macizo, P., Bajo, T., & Paolieri, D. (2012). Language-switching and language competition. *Second Language Research, 28,* 131–149. http://dx.doi.org/10.1177/0267658311434893

Meiran, N. (1996). Reconfiguration of processing mode prior to task performance. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22,* 1423–1442. http://dx.doi.org/10.1037/0278-7393.22.6.1423

Meuter, R. F. I., & Allport, A. (1999). Bilingual language-switching in naming: Asymmetrical costs of language selection. *Journal of Memory and Language, 40,* 25–40. http://dx.doi.org/10.1006/jmla.1998.2602

Misra, M., Guo, T., Bobb, S. C., & Kroll, J. F. (2012). When bilinguals choose a single word to speak: Electrophysiological evidence for inhibition of the native language. *Journal of Memory and Language, 67,* 224–237. http://dx.doi.org/10.1016/j.jml.2012.05.001

Monsell, S., & Mizon, G. A. (2006). Can the task-cuing paradigm measure an endogenous task-set reconfiguration process? *Journal of Experimental Psychology: Human Perception and Performance, 32,* 493–516. http://dx.doi.org/10.1037/0096-1523.32.3.493

Mosca, M., & Clahsen, H. (2016). Examining language switching in bilinguals: The role of preparation time. *Bilingualism: Language and Cognition, 19,* 415–424. http://dx.doi.org/10.1017/S1366728915000693

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologia, 9,* 97–113.

Philipp, A. M., Gade, M., & Koch, I. (2007). Inhibitory processes in language switching? Evidence from switching language-defined response sets. *European Journal of Cognitive Psychology, 19,* 395–416. http://dx.doi.org/10.1080/09541440600758812

Prior, A. (2012). Too much of a good thing: Stronger bilingual inhibition leads to larger lag-2 task repetition costs. *Cognition, 125,* 1–12. http://dx.doi.org/10.1016/j.cognition.2012.06.019

Prior, A., & Gollan, T. H. (2013). The elusive link between language control and executive control: A case of limited transfer. *Journal of Cognitive Psychology, 25,* 622–645. http://dx.doi.org/10.1080/20445911.2013.821993

Reynolds, M. G., Schlöffel, S., & Peressotti, F. (2016). Asymmetric switch costs in numeral naming and number word reading: Implications for models of bilingual language production. *Frontiers in Psychology, 6,* 2011. http://dx.doi.org/10.3389/fpsyg.2015.02011

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Rogers, R. D., & Monsell, S. (1995). The costs of a predictable switch between simple cognitive tasks. *Journal of Experimental Psychology: General, 124,* 207–231. http://dx.doi.org/10.1037/0096-3445.124.2.207

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 174–215. http://dx.doi.org/10.1037/0278-7393.6.2.174

Sudevan, P., & Taylor, D. A. (1987). The cuing and priming of cognitive operations. *Journal of Experimental Psychology: Human Perception and Performance, 13,* 89–103. http://dx.doi.org/10.1037/0096-1523.13.1.89

Thierry, G., & Wu, Y. J. (2007). Brain potentials reveal unconscious translation during foreign language comprehension. *Proceedings of the National Academy of Sciences of the United States of America, 104,* 12530–12535. http://dx.doi.org/10.1073/pnas.0609927104

Thomas, M. S., & Allport, A. (2000). Language-switching costs in bilingual visual word recognition. *Journal of Memory and Language, 43,* 44–66. http://dx.doi.org/10.1006/jmla.1999.2700

Van Assche, E., Duyck, W., & Gollan, T. H. (2013). Whole language and item-specific control in bilingual language production. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 39,* 1781–1792. http://dx.doi.org/10.1037/a0032859

Verhoef, K., Roelofs, A., & Chwilla, D. J. (2009). Role of inhibition in language switching: Evidence from event-related brain potentials in overt picture naming. *Cognition, 110,* 84–99. http://dx.doi.org/10.1016/j.cognition.2008.10.013

Wartenburger, I., Heekeren, H. R., Abutalebi, J., Cappa, S. F., Villringer, A., & Perani, D. (2003). Early setting of grammatical processing in the bilingual brain. *Neuron, 37,* 159–170.

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