Pervasive benefits of preparation in language switching

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This work was supported by the National Science Foundation Grant BCS0846147 to MG. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the NSF. Thanks to Ann Bradlow, the Northwestern SoundLab, and participants in the 53rd Annual Meeting of the Psychonomic Society for helpful discussion and comments.
Abstract

Many theories of bilingual language production assume that when bilinguals process words in their first language, representations from their second language are co-activated. Verhoef, Roelofs, and Chwilla (2009) proposed an alternative account, assuming the activation of second language representations is highly limited during first language production. Using a cued language switch task, Verhoef et al. showed that allowing participants to prepare their responses failed to facilitate first language production under some contexts. Verhoef et al. argue that this reflects a lack of co-activation of second language representations in these contexts. We report two experiments with different bilingual populations that fail to confirm the predictions of this account. Preparation consistently facilitates first language production in all contexts. This suggests that in the cued switch paradigm both L1 and L2 representations are consistently activated during L1 production.
Preparation in language switching

Pervasive benefits of preparation during language switching

Most theories of bilingual language production assume that when bilinguals process words in one language, representations from the other language are co-activated (see, e.g., Kroll, Bobb, Misra, & Guo, 2008, for a review). However, based on patterns of performance in an experimental language switching paradigm, Verhoef, Roelofs, and Chwilla (2009) claimed that during first language (L1) processing, second language (L2) representations are not typically activated. We report results from two experiments that disconfirm the predictions of this account, supporting the co-activation of L1 and L2 representations during L1 production.

Verhoef et al. (2009) built on previous studies of bilingual language production using the cued language switching paradigm. Language cues (e.g., colored squares or national flags) prompt bilinguals to alternate naming targets (e.g., digits or pictures) in their L1 and L2 (Meuter & Allport, 1999). The resulting mixed language blocks include switch trials, where the language of response differs from the language spoken on the previous trial, and repeat or stay trials, where the language of response matches that spoken on the preceding trial. Parallel to other domains (Monsell, 2003), comparison of response times (RTs) and error rates across these trial types reliably shows a switch cost, such that switch trials have longer RTs and higher error rates than repeat trials. Bilingual language switch costs are commonly attributed to the difficulty of inhibiting the previously used language when a switch is required (Green, 1998; but see Bobb & Wodniecka, 2013, for a review of arguments against this account).

Verhoef et al. (2009) examined how preparation influenced performance in this paradigm. Dutch-English bilinguals performed cued-switching with either a short (500 ms) or long (1250 ms) interval between the language cue and stimulus presentation. Parallel to cued switching tasks in other domains (Kiesel, Steinhauser, Wendt, Falkenstein, Jost, Philipp, & Koch, 2010),
preparation tended to facilitate responses. Interestingly, there was no benefit of preparation for L1 repeat trials. This resulted in a significant three-way interaction of stimulus type, trial type, and preparation length. The participants showed asymmetric switch costs (larger in L1 Dutch than L2 English) with a short preparation interval but symmetric switch costs with a long preparation interval. Because preparation did not affect the RT for L1 repeat trials (which were shorter than L1 switch trials), the difference between L1 repeat and switch trials decreased with preparation. In contrast, the difference between L2 repeat and switch trials remained constant, making L1 switch costs equivalent to those in L2 at the longer preparation interval.

Verhoef et al. (2009) drew strong conclusions from this finding. They attribute benefits of preparation to inhibition of the non-target language. They claim that the lack of such a benefit for L1 repeat trials is due to a failure to activate the L2 in this context. Since non-target language representations are not activated, there is no need to employ inhibition to respond (and hence no benefit for preparation). This argument contradicts the claim of many theories of bilingual language production, which incorporate mechanisms that automatically activate representations in the non-target language (either the L1 or the L2) in all contexts (Kroll et al., 2008). In contrast, Verhoef et al. (2009) propose co-activation is non-automatic—requiring a distinct set of mechanisms that control whether or not activation flows to non-target language representations.

However, it is not clear if such a radical revision of existing proposals is required. Data from other populations (high proficiency bilinguals and trilinguals) fail to replicate Verhoef et al.’s (2009) key finding that preparation offers no benefit on L1 repeat trials. Costa and Santesteban (2004) provided high-proficiency Spanish-Catalan bilinguals with 0, 500, or 800 ms cue-to-stimulus intervals in a cued language switching paradigm. They found that bilinguals were faster to name pictures on all trials (including L1 repeat) when preparation was present. In
fact, a significant interaction of trial type x SOA (i.e., preparation) revealed that preparation had a stronger effect on repeat compared to switch trials, causing a reduction in switch costs as preparation increased. Philipp, Gade, and Koch (2007) found similar results when native German-speaking trilinguals were asked to switch languages while naming digits. Participants had either 100 or 1000 ms to prepare the response language before stimulus presentation; RTs proved significantly faster on all trials with the long preparation interval. This preparation effect was also more pronounced for repeat trials (in both languages) compared to switch trials. However, it is possible that these preparation benefits reflect the fact that such speakers (highly proficient bilinguals and trilinguals) are very experienced at language switching.

Given the theoretical import of Verhoef et al.’s (2009) results, we attempted a conceptual replication (using digits rather than pictures in the same paradigm) of their study with other populations of medium- to low-proficiency bilinguals. In experiment 1, we examined how preparation influenced the language switching performance of bilinguals whose native languages varied, but who all spoke English as a second language. These bilinguals performed the experiment while attending university in an L2 environment, rather than an L1 environment like Verhoef et al.’s participants. In experiment 2, we tested Northwestern undergraduates who were second language learners of Spanish. Using the groups’ self-reported proficiency ratings and age of acquisition, we identified these populations as distinct from Verhoef et al.’s participants in terms of bilingual proficiency: experiment 1 participants were slightly higher than Verhoef et al.’s, while experiment 2 participants were decidedly lower. Although both experiments replicate the facilitatory effect of preparation documented by Verhoef et al., we find that these benefits extend to all trials—including L1 repeat trials. This is consistent with the activation of the non-target language in all contexts within the cued-switching paradigm, suggesting that existing
theories of bilingual language production can accommodate cued language switching performance.

**Experiment 1**

**Methods**

**Subjects.** Fourteen bilingual graduate students were recruited from the Northwestern University community during their first month in the United States and received payment for their participation. All participants had passed a minimum threshold on standardized tests of English proficiency (TOEFL internet-based-test: 79; IELTS: 6.5) or received degrees from accredited universities where English is the language of instruction. Participants spoke a variety of native languages (Amharic, Arabic, German, Greek (2), Hebrew, Japanese, Mandarin, Romanian, Spanish, Taiwanese Mandarin, Turkish (3)), but all began learning English as a second language between the ages of 6 and 14 (M=9.7). All participants (13 male, 1 female) had normal or normal-to-corrected vision, and none reported any history of speech or cognitive impairment. Age ranged from 21 to 39 years (M=26.1), and all participants gave informed consent. Table 1 provides additional participant characteristics. These data show that the participants are slightly higher in proficiency in L2 than those of Verhoef et al. (2009). In their study, the mean self-rated proficiency for L2 compared to L1 was 2.75/5 (where 1 = balanced, 5 = L2 much worse than L1); mean age of acquisition was 11.5 yrs.

**Materials and procedure.** The design mirrored that of Verhoef et al. (2009) except for the use of digit instead of pictorial stimuli. Digits have been widely utilized in language switching research (e.g., the seminal study of Meuter & Allport, 1999). While they tend to evoke weaker effects than pictorial stimuli, digits also produce reliable switch costs (Declerck, Koch, & Philipp, 2012). We utilized them here to control for name agreement across the varied L1
backgrounds of the participants. Participants named the digits 1-9 in mixed language blocks, where they alternated naming in their first or second language according to language cues. Repeat and switch trials were pseudo-randomized so that sequences of the same trial type exceeded no longer than 5 trials.

We manipulated 3 within-subject factors: language (L1 vs. L2), preparation length (short/500 ms vs. long/1250 ms), and trial type (repeat vs. switch), yielding a total of 8 conditions. Each trial began with a 250 ms presentation of a language cue in the form of a yellow or blue square. Color assignment to L1 and L2 was counterbalanced across participants. After the cue, a blank screen appeared for a preparation interval of either 500 or 1250 ms, followed by a black digit stimulus for 250 ms. A blank screen was then shown after the digit, while the participant gave a verbal response and then clicked the mouse to move to the next trial. This was followed by a randomly varying inter-trial interval (ITI) of 1000 or 1250 ms.

Table 1. Participant’s self-reported L2 knowledge.

<table>
<thead>
<tr>
<th></th>
<th>Experiment 1</th>
<th>Experiment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>L2 = English</td>
<td>Mean (SD)</td>
<td>L2 = Spanish</td>
</tr>
<tr>
<td>Age of acquisition</td>
<td>9.7 (3.0)</td>
<td>12.7 (3.0)</td>
</tr>
<tr>
<td>Percent daily usage</td>
<td>53.8 (25.6)</td>
<td>4.8 (3.6)</td>
</tr>
<tr>
<td>Writing skills (1-10)</td>
<td>7.0 (1.2)</td>
<td>5.7 (1.4)</td>
</tr>
<tr>
<td>Reading skills (1-10)</td>
<td>7.7 (1.5)</td>
<td>6.1 (1.4)</td>
</tr>
<tr>
<td>Speaking skills (1-10)</td>
<td>6.7 (1.6)</td>
<td>5.3 (1.5)</td>
</tr>
<tr>
<td>Listening skills (1-10)</td>
<td>7.4 (1.7)</td>
<td>5.0 (1.8)</td>
</tr>
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</table>
Each session began with participants completing a language background questionnaire. Participants received 10 practice trials to acclimate them to the language mixing procedure. They then completed 8 mixed blocks of 144 digit-naming trials (18 trials in each of the 8 conditions), for a total of 1152 mixed language trials.

**Data pre-processing.** RTs were automatically extracted using a series of scripts in Praat (Boersma & Weenik, 2012). Participant data was recorded in stereo files, with audio markers corresponding to stimulus onsets on one channel and participant speech on the other. After detecting the audio markers corresponding to stimulus onsets, speech onsets were detected using intensity thresholds. Each trial was first equalized to an average root mean square intensity of 0.02 Pascal. The Praat *Intensity* function was used to estimate the intensity contour of the normalized signal. Speech onset was then detected by sampling this contour at 1-millisecond increments to detect when the normalized speech signal passed a 60 dB threshold. RT was defined as the difference between stimulus and speech onsets.

**Results**

Initial trials from each block were excluded, along with incorrect responses (non-target language productions, dysfluencies, false starts) and recording errors (totaling 2.9% of trials). After the exclusion of RTs below 200 milliseconds and above 3 seconds, outlier trimming removed data points more than 3 standard deviations away from each subject’s mean. This eliminated an additional 3.1% of trials. The remaining RTs were then log transformed to compensate for positive skew (Baayen & Milin, 2010).

A linear mixed effects regression model (Baayen, Davidson, & Bates, 2008) was built, contrast coding the following contrast-coded fixed effects: language (L1, L2), trial type (repeat, switch), and preparation (500 ms, 1250 ms). Following the recommendations of Barr, Levy,
Scheepers, and Tily (2013), we implemented the maximal random effects structure supported by the data. This included random intercepts for each participant and item, as well as random by-participant slopes for all predictors and their two-way interactions. Significance for fixed effects was determined via nested model comparison (Barr et al., 2013).

As shown in Figure 1, participants did not respond any faster in their native languages compared to L2 English ($\beta=0.006$, s.e. = 0.021, $\chi^2(1)=0.08$, $p>0.05$). They did perform faster on repeat trials than on switch trials ($\beta=0.085$, s.e. = 0.009, $\chi^2(1)=27.08$, $p<0.001$), replicating the standard finding of a switch cost. The interaction of language and trial type was not significant ($\beta=-0.005$, s.e. = 0.010, $\chi^2(1)=0.27$, $p>0.05$), showing that participants’ switch costs were symmetric overall.

![Graph showing mean response time for different conditions.](image)

**Figure 1.** Performance of medium proficiency bilinguals (n=14) in Experiment 1, with varied preparation. Error bars show standard error.
Replicating Verhoef et al. (2009), preparation had a facilitatory effect on RTs ($\beta=0.059$, s.e. = 0.008, $\chi^2(1)=23.46$, p<0.001), such that responses were faster with a longer preparation interval (i.e. 1250 ms). A significant interaction of preparation and trial type revealed that the benefit of longer preparation was more pronounced for switch than for repeat trials ($\beta=0.037$, s.e. = 0.012, $\chi^2(1)=7.30$, p<0.01). As a result, participants experienced a reduction in switch costs with increased preparation; this finding replicates Costa and Santesteban (2004) in a within-rather than between-participants design. Preparation did not interact with language ($-\beta=0.007$, s.e. = 0.009, $\chi^2(1)=0.063$, p>0.05). Crucially, in contrast to Verhoef et al. (2009), the three-way interaction of language, preparation, and trial type failed to reach significance ($\beta=-0.025$, s.e. = 0.017, $\chi^2(1)=2.15$, p>0.05).

To confirm that preparation specifically influenced L1 repeat trials, we performed an analysis on these trials alone. The results reveal that preparation had a reliable facilitatory effect on L1 repeat trials, such that more preparation time (i.e. 1250 ms) yielded faster responses. This indicates that preparation can improve performance on all trials.

**Discussion**

The results of Experiment 1 confirm Verhoef et al.’s (2009) finding—consistent with work in other domains (Kissel et al., 2010)—that preparation facilitates responses in the cued language switching paradigm. Diverging from their results, we found that this extended to all trial types. A follow-up analysis confirmed that there is a significant effect of preparation on L1 repeat trials—unlike the null effect observed by Verhoef et al. This result undermines their claim that L1 repeat trials are free from cross-language competition. Instead, it appears that even repeated performance in a bilingual’s native language is improved by additional time to prepare.
One factor that could have caused this group’s performance to differ from Verhoef et al.’s (2009) group is that the current study examined language switching performance in an L2 dominant environment. In contrast, Verhoef et al.’s (2009) study took place in an L1 dominant environment. If being immersed in an L2 environment strengthens participants’ L2 representations relative to their native languages (Christoffels et al., 2007; Linck, Kroll, & Sunderman, 2009), then it might improve the balance between those languages—leading to greater co-activation between the L1 and L2 (and hence different effects of preparation).

However, recent work suggests such immersion effects only apply to low frequency and non-cognate words (Baus, Costa, & Carreiras, 2013). Given that the high degree of phonological overlap in digit names across languages causes them to behave like cognates (Declerck et al., 2012), the immersion account is unlikely to explain the current data.

Another possible reason behind these divergent results could be that our participant sample was higher proficiency and therefore not comparable to Verhoef et al.’s (2009) low proficiency group. Participants’ self-ratings suggest they are medium proficiency (see Table 1); this assessment gains support from our observation of equivalent switch costs in the L1 and L2. Previous studies using this paradigm showed that low proficiency bilinguals tend to exhibit asymmetric switch costs, i.e. larger in L1 than in L2 (Costa & Santesteban 2004; Meuter & Allport, 1999; but see Christoffels, Firk, & Schiller, 2007), while high proficiency bilinguals tend to exhibit symmetric switch costs (Costa & Santesteban, 2004; Costa, Santesteban, & Ivanova, 2006). One hypothesis proposes that these distinct patterns arise because high and low proficiency bilinguals use distinct selection mechanisms during production (Costa & Santesteban 2004). If our participants engaged different mechanisms than Verhoef et al.’s, this may have lead to different effects of preparation.
Experiment 2

To address these issues, Experiment 2 examined performance of clearly low-proficiency speakers immersed in an L1 dominant environment. We examined the language switching performance of English-speaking undergraduates who were learning Spanish as a second language. These participants differed from those in Experiment 1 in several ways, as they (i) shared a uniform language background, (ii) acquired their L2 slightly later on average, and (iii) performed the experiment in an L1 rather than L2 environment. These late-acquiring learners have relatively low L2 proficiency (see Table 1 and below), and we expect that performance of the experiment in an L1 environment may enhance their L1 dominance.

Experiment 2 also differs from Experiment 1 by including a no preparation baseline condition. This baseline allows comparison to language switching performance as in Meuter and Allport’s (1999) seminal study, which presented bilinguals with simultaneous language cues and digit stimuli during cued language switching.

Methods

Participants. We recruited 16 Northwestern University undergraduates who (a) had completed 2 years of college-level Spanish or (b) were currently enrolled in their second year of college-level Spanish. All participants were native speakers of English who began studying Spanish as a second language between the ages of 7 and 19 (M=12.7). Self-reported Spanish proficiency measures are provided in Table 1. All group members (4 male, 12 female) had normal or normal-to-corrected vision, and none reported any history of speech or cognitive impairment. Age ranged from 18 to 22 years (M=19.6).

Materials and procedure. The materials and procedure combined the designs of Verhoef et al. (2009) and Meuter and Allport (1999), incorporating both trials with and without a
cue-to-stimulus preparation interval. Therefore, these mixed language blocks manipulated 4 within-subject factors: language (L1, L2), trial type (repeat, switch), preparation (present, absent), and preparation length (short/500 ms, long/1250 ms).

On mixed language trials with preparation, a 500 ms fixation cross was followed by a 250 ms presentation of a language cue, in the form of a blue or red square. Color assignment was counterbalanced across participants. Next, the screen blanked for 500 or 1250 ms of preparation time, before a color-coded digit stimulus appeared for 250 ms. After the stimulus, the screen blanked again until the participant gave a verbal response and clicked the mouse to move on. Between all trials, a variable inter-trial interval (ITI) of 1000 or 1250 ms occurred.

On mixed language trials without preparation, the 500 ms fixation cross was immediately followed by the 250 ms presentation of a color-coded digit stimulus. The screen then blanked until the participant gave a verbal response and clicked the mouse to continue. After the variable ITI, the next trial began. Note that across both preparation conditions, the stimuli were identical in form, containing embedded language cues. This design helps ensure that any preparation effects that emerge can be reasonably attributed to the availability of an additional cue-to-stimulus interval, rather than visual differences in the stimulus presentation.

Experiment 2 utilized the same equipment and general procedures as Experiment 1. Participants completed 4 mixed language blocks of 216 trials each (18 per condition).

**Results**

Data pre-processing and trimming procedures followed Experiment 1. The removal of errors eliminated 2.5% of the data set, while outlier trimming removed an additional 2.8%.

The linear mixed effect model included contrast-coded fixed effects of language (L1, L2), trial type (repeat, switch), preparation (present, absent), and, within the trials with preparation, a
contrast examining the effect of preparation length (short/500 ms, long/1250 ms). The maximal random effects structure supported by the data included random intercepts for participants and items, as well as random by-participant and by-item slopes for each main effect (excluding interaction terms and the by-participant slope for trial type).

Participants demonstrated a language dominance effect, responding faster overall on L1 English trials compared to L2 Spanish trials ($\beta=0.049$, s.e.$=0.020$, $\chi^2(1)=5.66$, $p<0.05$; see Figure 2). They replicated standard switch costs, responding significantly slower on switch trials than repeat trials ($\beta=0.053$, s.e.$=0.005$, $\chi^2(1)=35.84$, $p<0.001$). As expected among low proficiency bilinguals, these switch costs were asymmetric, i.e. larger in L1 than in L2 ($\beta=-0.041$, s.e.$=0.007$, $\chi^2(1)=33.94$, $p<0.001$).

![Figure 2. Performance of L2 Spanish learners (n=16) in Experiment 2, incorporating trials with and without preparation. Error bars show standard error.](image)

While switch costs were highly reduced in L2 with preparation, analysis of these trials alone indicates a statistically reliable switch cost (mean RTs for L2 trials with preparation: switch $= 678$ ms, repeat $= 663$ ms; $\beta=0.025$, s.e.$=0.009$, $\chi^2(1)=6.48$, $p<0.05$).
Replicating Verhoef et al. (2009) and Experiment 1, preparation had a facilitatory effect on RTs, with participants responding faster on trials with preparation (either 500 or 1250 ms) than on trials without any preparation ($\beta=0.135$, s.e. = 0.016, $\chi^2(1)=27.46$, p<0.001). This effect interacted with both language and trial type. Specifically, the presence of preparation had a larger impact on L1 than L2 trials ($\beta=-0.033$, s.e. = 0.011, $\chi^2(1)=7.63$, p<0.01), and it improved performance on switch trials significantly more than on repeat trials ($\beta=0.034$, s.e. = 0.008, $\chi^2(1)=20.92$, p<0.001).

Unlike in Experiment 1, the exact amount of preparation available had little impact on participants' RTs ($\beta=0.002$, s.e. = 0.009, $\chi^2(1)=0.05$, p>0.05). This null effect of preparation length was consistent across languages ($\beta=-0.007$, s.e. = 0.009, $\chi^2(1)=0.81$, p>0.05) and trial types ($\beta=-0.012$, s.e. = 0.009, $\chi^2(1)=2.06$, p>0.05). The 3-way interaction of trial type x language x preparation failed to reach significance ($\beta=-0.022$, s.e. = 0.015, $\chi^2(1)=2.17$, p>0.05), as did the interaction of trial type x language x preparation length ($\beta=0.016$, s.e. = 0.017, $\chi^2(1)=0.90$, p>0.05); participants' switch cost asymmetries persisted across all preparation conditions.

As in Experiment 1, a follow-up analysis was conducted to explore the effects of preparation specifically on L1 repeat trials. The results showed that the presence of a cue-to-stimulus preparation interval significantly improved participants' performance on such trials ($\beta=0.129$, s.e. = 0.020, $\chi^2(1)=20.73$, p<0.001), yielding faster RTs on trials with preparation (either 500 or 1250 ms) compared to trials without any preparation. Similar to the overall analysis, the exact length of preparation had little effect on participants’ L1 repeat performance ($\beta=0.015$, s.e. = 0.014, $\chi^2(1)=1.12$, p>0.05).
Discussion

The results of Experiment 2 once again indicate the widespread benefits of preparation time for language switching performance. These benefits are observed across bilinguals’ languages and across trial types, although preparation proves especially helpful on trials in L1 and trials involving a language switch.

Critically, we observed robust preparation benefits on L1 repeat trials, in contrast to the null effect observed by Verhoef et al. (2009). This suggests that even second language learners with limited L2 experience (i.e., 2 years of study, no study abroad/immersion) encounter L2 competition during repetition of their native language; they therefore benefit from extra time to overcome that interference.

Both Verhoef et al. (2009) and Experiment 1 showed that greater amounts of preparation time facilitated production. In contrast, while Experiment 2 showed a general facilitatory effect for preparation vs. no preparation, there was no effect of preparation length. This could reflect a shift in participants’ response strategy. Participants may have grouped trials into two categories, those with and without preparation, therefore treating trials with short and long preparation intervals the same. As a result, they may have underutilized the extra time available on the latter trials. This account aligns with the broader proposal of Bobb and Wodniecka (2013), who observed that such task-related factors appear to strongly affect cued switching performance, potentially modulating the symmetry of bilingual switch cost patterns.

General Discussion

The goal of the current study was to explore the generality of Verhoef et al.’s (2009) language switching results, which had important ramifications for theories assuming widespread cross-language activation during bilingual language production. Verhoef et al. found that
increased cue-to-stimulus preparation time facilitated performance in the cued language switching task (consistent with other task switching paradigms). However, no such preparation benefit was found on L1 repeat trials. The authors interpreted this as evidence that the weaker L2 does not compete for selection on such trials. In contrast, in two groups of bilinguals we find pervasive benefits of preparation for both L1 and L2 trials. This suggests cross-language activation is not limited to L2 processing, but also occurs on L1 target trials. Such results challenge the proposal that mechanisms sensitive to language dominance and/or other factors (e.g., task, language environment) determine whether or not activation spreads to representations in the non-target language. Instead, the current study supports the more parsimonious assumption that cross-language activation is ubiquitous during bilingual production.

This claim is consistent with an extensive body of work showing language mixing costs, where bilinguals respond slower and make more errors while mixing languages than during single language production. Crucially, several studies have shown specifically that repeat trials—in both L1 and L2—are slower in mixed vs. single language conditions (Christoffels et al., 2007; Gollan & Ferreira, 2009; Weissberger, Wierenga, Bondi, & Gollan, 2012). Such costs are expected if, in mixed vs. single language contexts, enhanced cross-language activation occurs on both L1 and L2 target trials (Gollan & Ferreira, 2009; Kroll et al., 2008).

In summary, our results provide evidence against Verhoef et al.’s (2009) claim that the L2 is not activated during L1 target processing. Consistent with findings from other paradigms, these data suggest that bilingual language production does not entail selective activation of only the target language during spoken production. Instead, during first and second language processing there is co-activation of both of a bilingual’s languages.
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