Translation Distractors Facilitate Production in Single- and Mixed-Language Picture Naming

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Abstract

In the picture-word interference (PWI) task, semantically related distractors slow production, while translation-equivalent distractors speed it, possibly implying a language-specific bilingual production system (Costa, Miozzo & Caramazza, 1999). However, in most previous PWI studies bilinguals responded in just one language, an artificial task restriction. We investigated translation facilitation effects in PWI with language switching. Spanish-English bilinguals named pictures in single- or mixed-language-response blocks, with distractors in the target language (Experiment 1), or in the non-target language (Experiment 2). Both experiments replicated previously reported translation facilitation effects in both single-language and mixed-language-response blocks. However, language dominance was reversed in mixed-language response blocks, implying inhibition of the dominant language and competition between languages. These results may be explained by a language non-specific selection model in which bilinguals do not restrict selection to one language, with translation facilitation being caused by facilitation at the semantic level offsetting competition at the lexical level.
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Speaking two languages seems effortless for many bilinguals despite some of the cognitive challenges that come with it. There is substantial evidence that both languages are active when a bilingual is comprehending (e.g., Dijkstra & Van Heuven, 2002; Thierry & Wu, 2007, see Kroll & De Groot, 2009 for review) and producing (see de Bot, 2000 or Kroll & Gollan, 2013 for a review, though see Costa, Pannunzi, Deco, & Pickering, 2017, for a competing account) just one of their two languages. Thus, to speak one of these languages without interference from the other, a bilingual must inhibit non-target language information. While considerable work has been invested towards understanding language selection in bilinguals, many questions remain about the nature of these mechanisms.

The picture-word interference task allows exploration of how semantic and lexical information becomes active during speech production in real time. In this task, a speaker names a picture while attempting to ignore distractor words written over the picture (for review see Hall, 2011; Roelofs, 1992; Roelofs, 1998). For example, when a semantically related word appears on the to-be-named picture (e.g., the word *cat* is superimposed on the picture of a dog), naming latencies are slowed relative to an unrelated word (e.g., when the word *table* appears on the picture of a dog). This is referred to as the *semantic interference effect*. Interestingly though, other types of distractor words facilitate production. For example, when a phonologically related word appears on the to-be-named picture (e.g., the word *doll* appears on the picture of a dog), naming latencies are speeded relative to unrelated words, known as the *phonological facilitation effect*.

Bilingual distractor words have provided critical evidence shaping alternative models of lexical access in bilingual speech production. A widely cited paper by Costa, Miozzo and Caramazza (1999) asked if lexical access in bilinguals is language-specific or non-specific. In particular, they investigated whether bilinguals can select lexical representations by considering only candidates in the target language, thereby being completely unaffected by the degree of activity of representations in the non-target language. If so, distractor words from another language should have no effect on naming times. Catalan-Spanish bilinguals named pictures in Catalan with both target language (Catalan) and non-target language (Spanish) distractors. In addition to finding the within-language interference effects discussed above (semantic interference and phonological facilitation), they also found similar between-language effects when the bilinguals named Catalan pictures with Spanish distractors. For example, naming a picture of a dog (*gos* in Catalan) was slower when the word imposed was semantically related (e.g. *lobo,* the Spanish translation of wolf) and faster when the superimposed word was phonologically related (e.g. *golpe,* the Spanish translation of punch) relative to an unrelated Spanish word.

However, of great interest, Costa et al. (1999) found *facilitation effects* from translation distractors. For example, bilinguals named a picture of a dog more quickly in Catalan when *perro* (its translation) was the distractor relative to the unrelated Spanish word. This was a surprising result because if there is competition between languages at the lexical level, then translations should have elicited unusually strong interference effects (Hermans, Bongaerts, De Bot & Schreuder, 1998). Costa et al. (1999) suggested that translation facilitation effects support a language-specific model in which the non-target language is set aside as a whole before the lexical level (i.e. the pre-verbal intent to speak in a particular language does not allow lexical items from the non-target language to enter into competition, though they may be activated at lexical and phonological levels); if lexical access were language non-specific, translation and non-target-language semantic distractors should have elicited effects similar to semantically related distractors. But in a language-specific model, the translation distractors can only affect (and in this case boost) activation of the intended target at a semantic level, and cannot compete for selection at the lexical level, thereby speeding (rather than interfering with) production times.

This effect was further explored in Roelofs, Piai, Rodriguez and Chwilla (2016). In this study Dutch-English bilinguals completed a picture-word interference task in their second language (L2) English in which some distractor items were presented in their first language (L1) Dutch, while EEG was recorded. In addition to replicating the commonly reported semantic interference and phonological facilitation effects on response times, they found a reduction in N400 amplitude (greater differences in N400 amplitude are typically interpreted as difficulty in semantic integration, see Kutas and Hillyard, 1980) for both semantically related and translation distractors. These authors suggested that a reduction in N400 amplitude indicates that both semantic distractors and translation distractors facilitate semantic access to the name of the picture. Because the modulation of semantic processing manifests as interference for within-language semantic distractors and facilitation for between-language translation distractors, the data support a language-specific model of lexical access where only items from the same language compete for production (see Piai, Roelofs, Jensen, Schoffelen & Bonnefond, 2014 for additional discussion of neurocognitive results).

To account for the facilitating effects of translation distractors, models that do not assume language-specific selection can simply assume that semantic facilitation outweighs the effect of competition for selection for translation equivalents, which overlap much more in meaning than semantically related words (Hall, 2011; Hermans et al., 2000). Other such language non-specific models of selection include the Multilingual Processing Model (de Bot, 2004) and the Response Exclusion Hypothesis (Finkbeiner & Caramazza, 2006). In these models, words are selected for production and the pre-verbal intent to speak in only one language allows for the correct language to be selected at the lexical stage (as in the

Multilingual Processing Model) or as late as the articulation stage (in the Response Exclusion Hypothesis). In the Multilingual Processing Model, the pre-verbal intent specifies both semantic information and which language is to be spoken, which proceed through different pathways. The semantic information cascades to lexical and phonological nodes while the language intent flows to an external language node that then controls selection at the lexical and phonological levels. Competition at the lexical and phonological levels is thereby resolved by this external language node. The Response Exclusion Hypothesis, on the other hand, suggests that words from both languages reach an articulatory buffer after passing through semantic, lexical and phonological stages and are selected based on response relevance; a speaker considers each possible response as it enters the buffer and discards the response-irrelevant item. Under this hypothesis, when presented with a translation distractor, the speaker benefits from the semantic overlap of the translation equivalent (semantic priming) but can discard the non-target-language response in the articulatory buffer as it is not the pre-verbally intended language, yielding a net facilitation effect. There are several limitations to such models. Dylman and Barry (2018) show translation facilitation effects from within-language synonyms (e.g. *dog* and *hound*) which, under this hypothesis, should produce interference as both items are of the same language and therefore response-relevant. Additionally, Abdel Rahman and Aristei (2010) show that semantic interference effects can be found even without overt naming suggesting an articulatory buffer may not be involved. Though limited, both language non-specific production models suggest that differing levels of semantic facilitation and lexical interference could cause a net facilitation effect and can therefore successfully account for translation facilitation effects in picture-word tasks.

Picture-word tasks are not, however, the only paradigm to test bilingual selection models. In fact, the controlled situation elicited in a picture-word task in which speech is restricted to just one language while the other language is continuously intermixed in just one modality is somewhat artificial and certainly uncommon outside the laboratory setting, which could reflect a mode of processing that only arises in such unusual circumstances. In circumstances that involve switching back and forth between languages there is more consistent evidence for competition between languages. Specifically, when bilinguals must switch between languages, they name pictures more slowly than when they speak the same language they used on the previous response (Meuter & Allport, 1999; for review see Declerck & Philipp, 2015). Furthermore, these costs are often asymmetric, that is, switch costs are larger for switching into the dominant than the non-dominant language. To explain the switch cost asymmetry, inhibition of the dominant language in the service of non-dominant language production is often invoked; switch costs are larger when switching back to the dominant language because it was necessary to have inhibited it more strongly to be able to use the non-dominant language (Green, 1998; Abutalebi & Green, 2007). Such effects may also manifest as reversed language dominance, an effect in which the non-dominant language is produced faster than the dominant language in the mixed-language response block. This is explained as proactive inhibition of the dominant language when bilinguals are forced to produce in both languages (see Declerck, Kleinman & Gollan, 2020). The notion of inhibitory control presupposes competition between languages, which might be greater when bilinguals switch back and forth between languages, but also functional when bilinguals speak in just one language (i.e., inconsistent with the view developed by Costa et al., 1999).

In all of the picture-word studies discussed above, bilinguals knew in advance they would never have to produce any words in the non-target language (i.e., they only named pictures in one language while distractor words were sometimes in the same language, and sometimes in the non-target language). If bilinguals were tested with the same picture-word interference task but were also cued to switch languages on some trials, what would language-specific and language non-specific models predict? A language non-specific model might predict that translation distractors elicit interference – or at least a reduction in facilitation. While such distractors might provide the same amount of semantic facilitation, responses in both languages would be possible and therefore should slow production at the lexical stage (as in the Multilingual Processing Model) or affect the articulatory buffer's ability to quickly discard one language (as in the Response Exclusion Hypothesis), causing translation distractors to have a smaller facilitation effect or a reversal to interference (if the introduced competition is greater than the semantic priming). A language-specific model of selection on the other hand would predict no change to the translation facilitation effect, as non-target-language distractors can only impact the semantic level causing facilitation.

Only one experiment to date explored if language switching modulates translation facilitation effects. In Experiment 2 of Costa et al. (1999), Catalan-Spanish bilinguals named pictures in a mixed-language response block. In this block, subjects named 30% of the trials in their non-dominant language, Spanish. However, these trials were considered fillers, causing several notable differences between this study and a typical language switching task, and making it difficult to determine whether language switching might change the nature of translation facilitation effects or not. First, the pictures were different from the critical Catalan naming pictures and were only presented four times as compared to the critical trials' six presentations. Second, the authors did not report on any of the effects in the non-dominant language. Third, the Spanish translations that acted as semantically related and unrelated targets that appeared on the critical Catalan naming trials were always cognates (e.g. the Spanish word *armario, armari in Catalan,* superimposed on a picture of a table, *taula* in Catalan). Though it was not a full exploration of translation distractor effects in language mixing, this experiment did demonstrate that a robust facilitatory effect of Spanish translation identity remains in Catalan naming even when bilinguals switch back and forth between languages in their naming responses.

Here we explored whether lexical selection is language-specific or non-specific using translation facilitation effect in a language mixing task. In Experiment 1, Spanish-English bilinguals completed six blocks of picture naming, two blocks in which they produced names only in Spanish, two in which they produced picture names only in English (*single-language response blocks*) and two intermixed blocks in which they were cued to name pictures in English on half the trials, and in Spanish on the other half (*mixed-language response blocks*). In each block words were superimposed over the picture in one of four conditions, mimicking the experimental conditions of Roelofs et al. (2016): control (a row of XXXXs), same-language semantically related (the word *nose* superimposed on a picture of an eye), same-language semantically unrelated (the word *napkin* superimposed on a picture of an eye), and translation equivalent (the word *ojo* superimposed on the picture of an eye). Several key differences exist between this and Costa et al. First, all distractors were non-cognate translations. In order to test language-wide inhibition, we test translation facilitation between non-cognate items, as cognates facilitate naming (for example see Costa et al., 2000; de Groot & Nas, 1991). Second, we examined both Spanish and English picture naming responses to reveal the impact of language switching on translation facilitation effects in both the dominant and the non-dominant languages. Third, we increased switching rate to 50%. Finally, we manipulated language mixing within-subject to maximize power for detecting differences in the nature of translation facilitation effects between block types. Experiment 2 further explored translation facilitation in language mixing by presenting all distractors in the non-target language.

If lexical selection is language non-specific, translation facilitation should become interference, or at least be significantly diminished, in mixed-language response blocks relative to single-language response blocks. In other words, the presence of two languages spoken in a single testing block should make it harder for bilinguals to exclude alternative responses in one of the languages whether using pre-verbal intent and an external language node (as in the Multilingual Processing Model) or an articulatory buffer (as in the Response Exclusion Hypothesis). Response times should also show a reduction or reversal of language dominance in the mixed-language response blocks, as competition between languages might lead bilinguals to inhibit the dominant language. If, however, lexical selection is language-specific, translations should facilitate production in mixed-language response blocks to the same extent than in single-language response blocks, suggesting that translation distractors prime at the semantic level and induce no competition at the lexical level.

Experiment 1

Method

Subjects. Spanish-English bilingual undergraduates (N = 48) at the University of California San Diego (UCSD) participated for credit. All bilinguals spoke Spanish and English fluently and completed the Multilingual Naming Task (MINT; Gollan, Weissberger, Runnqvist, Montoya & Cera, 2012) as a metric of language proficiency and dominance (Tomoschuk, Ferreira & Gollan, 2018). The MINT score determined their dominance classification. Forty-two bilinguals scored higher on the MINT in English than Spanish, and six scored higher in Spanish than English. Subject characteristics are shown in Table 1.

<Insert Table 1 about here>

Materials. Thirty-two Spanish-English translations selected from eight semantic categories were selected to resemble those used in Roelofs et al. (2016). The number of characters in the English translations (*M* = 5.16, *SD* = 1.83) and the number of characters in the Spanish translations (*M* = 5.69, *SD* = 1.42) did not differ significantly. Each item was paired with three items among different semantic categories to create the four conditions. The distractors were five Xs (control condition), a translation of the picture name in the non-target language (translation condition), a semantically related word in the target language from the same semantic category (related condition), and a semantically unrelated word also in the target language taken from another semantic category (unrelated condition). Each of these pairings were consistent across blocks and across languages. For example, when a bilingual was to name a picture of a nose in English, the Spanish translation *nariz* appeared on the picture in the translation condition, the English word *eye* appeared in the semantically related condition, and the English word *glass* appeared in the semantically unrelated condition. Likewise, when naming the picture as *nariz* in Spanish, the English translation *nose* appeared in the translation condition, the Spanish word *ojo* appeared in the semantically related condition, and the Spanish word *vaso* appeared in the semantically unrelated condition. A comprehensive list of the materials is shown in Appendix A. Example materials are shown in Table 2.

<Insert Table 2 about here>

Procedure. Bilinguals first completed a language history questionnaire and then were shown the pictures along with the names to be used in the task and were asked to familiarise themselves with the names. Bilinguals then completed the picture naming task. In this task, bilinguals were first instructed to name the picture as quickly and accurately as possible, based on the flag cue shown at the top of the screen (the American flag cued English responses, and the Mexican flag cued Spanish responses). First, a fixation cross appeared on the screen for 350 ms, followed by a blank screen for 150 ms, the flag cue for 250 ms, and last the picture appeared. Bilinguals had 3 seconds from the onset of the picture in which to respond before the picture disappeared. Distractors appeared simultaneously with the picture, and remained until the picture disappeared, and voice onset triggered both to disappear. There was an inter-stimulus interval of 850 milliseconds before the next picture appeared. At the beginning of the first block, bilinguals were given three practice trials in English to assess the sensitivity of the microphone. Bilinguals then completed six blocks of this task: two in

Spanish, two in English, and two mixed-language response blocks. Each of the 32 pictures was shown in each block, with each distractor for each word present once in each response block. The order was counterbalanced across bilinguals using a sandwich design such that half of subjects performed single-language response blocks at the beginning and end of the experiment with mixed-language response blocks in the middle and half performed mixed-language response blocks at the beginning and end of the experiment with single-language response blocks in the middle. After these tasks were completed, bilinguals completed the MINT. Results are shown in Table 1.

Analysis. Data were analyzed in R (R Core Team, 2013). All responses with a response time (RT) less than 100 ms or greater than 3000 ms were removed. Trials with erroneous microphone triggers or incorrect naming were removed from the analysis. Response times were log transformed and then entered into by-subject (F_1) and by-item (F_2) repeated measure analyses of variance (ANOVA). This was chosen over mixed-effect models, to match analyses reported by Roelofs et al., (2016; and because design complexity led to convergence issues in the mixed-effects models, Barr, Levy, Scheepers & Tily, 2013). (Note also that Barr et al, 2013, showed that for continuous measures such as response times, F1xF2 analyses are at least as suitable as mixed-effect models.) We report the results of the critical distractor conditions looking at only trials with semantically unrelated and translation distractors as these index translation distractor effects as reported in Costa et al., (1999; the control and semantically related conditions were included to replicate the procedure in Roelofs et al., 2016, and are analyzed together with the unrelated and translation distractor conditions in Appendix B). We also report logistic mixed-effect regression models of the errors looking for the critical distractor conditions, in order to rule out the possibility of error rates driving the effects. Finally, we report by-subject and by-item analyses within mixed-language-response blocks reintroducing trial type as a factor for the critical conditions.

Results

Figures 1A and 1B, and Table 3 show the response times for Experiment 1 organised by picture-word interference condition and language mixing, shaded by language dominance. Figure 2 shows the response times of the critical conditions reported as difference scores (unrelated condition minus translation condition). In this section, we focus our analysis on the results of the two critical conditions that make up the translation facilitation effect, unrelated and translation distractors; a response time analysis of all four conditions, including the control and semantically related distractor conditions, is shown in Appendix B. We found that bilinguals named pictures 147 ms slower in mixed-language response conditions compared to single-language response conditions, $F_1(1,41) = 172.46$, $MSE = 478{,}601$, $p < .001$, $F_2(1,26) = 269.87$, $MSE = 307{,}284$, $p < .001$. Bilinguals named pictures 60 ms faster when the distractor was the translation as compared to the unrelated word, $F_1(1,40) = 78.63$, $MSE = 199{,}232$, $p < .001$, $F_2(1,25) = 29.77$, $MSE = 517{,}755$, $p < .001$. Bilinguals named pictures equally quickly in their two languages, a non-significant effect of language dominance (*F*s <1). The translation facilitation effect was greater when bilinguals named pictures in the non-dominant than the dominant language (but see the below interaction with block type), $F_1(1,44) = 21.63$, $MSE = 89{,}818$, $p < .001$, $F_2(1,29) = 13.38$, $MSE = 141{,}246$, $p = .001$. Bilinguals also named pictures more slowly in the non-dominant than the dominant language in the single-language response block, but exhibited reversed dominance effects in the mixed-language response blocks, $F_1(1,45) = 12.36$, $MSE = 105{,}220$, $p = .001$, $F_2(1,30) = 7.05$, $MSE = 182{,}590$, $p = .013$.

Of great interest, translation facilitation effects were larger in the single-language response blocks than in the mixed-language response block in the by-subject analysis, $F_1(1,43) = 13.31$, $MSE = 54{,}070$, $p < .001$, $F_2(1,28) = 3.53$, $MSE = 218{,}340$, $p =.071$. However, a post-hoc analysis showed that only in the non-dominant language translation facilitation was significantly larger (by-subjects) in the single-language vs. in mixed-language response blocks ($F_1(1,46) = 13.04$, $MSE = 55,540$, $p < .001$, $F_2(1,31) = 3.93$, $MSE = 198,401$, $p = .056$), and not in the dominant language ($F_1(1,46) = 0.01$, $MSE = 88,963$, $p = .93$, $F_2(1,31) = 0.00$, $MSE = 160,141$, $p = .985$). Finally, with unrelated distractors, bilinguals named pictures faster in the dominant language, but with translation distractors language dominance effects reversed, such that bilinguals named pictures faster in the non-dominant language, a significant 3-way interaction language dominance, block type, and distractor type, $F_1(1,46) = 6.87$, $MSE = 118,489$, $p < .001$, $F_2(1,31) = 4.40$, $MSE = 169,995$, $p = .044$.

Figures 1C and 1D and Table 3 show the naming error data, which were analyzed using logistic mixed-effect regression models to compare unrelated and translation conditions. Bilinguals produced more errors in mixed-language response blocks than in single-language response blocks ($\chi^2 = 32.4$, $p < .001$). Bilinguals also produced more errors when naming pictures in the non-dominant than the dominant language ($\chi^2 = 4.28$, $p = .039$). Finally, bilinguals produced more errors in the non-dominant than in the dominant language when the distractor was unrelated as compared to the translation distractor, specifically in the mixed-language response blocks as compared to the single-language response block, causing a three-way interaction between language dominance, block type, and distractor type ($\chi^2 = 4.67$, $p = .030$). All other effects were non-significant (*p*s > .14).

Though not the focus of these analyses, we additionally analyzed switching effects within the mixed-language response blocks, shown in Table 4. In a by-subject and by-item analysis of trial type (stay vs. switch), distractor type (focusing only on the unrelated vs. translation distractor conditions), and language dominance, we found that bilinguals were 68 ms slower to name pictures on switch trials than on stay trials $F_1(1,41) = 79.46$, $MSE = 115,875$, $p < .001$, $F_2(1,21) = 11.41$, $MSE = 338,643$, $p < .01$. They also named pictures in the non-dominant language 19 ms faster than in the dominant language, $F_1(1,42) = 13.39$, $MSE =$

170,378, $p < .001$, $F_2(1,27) = 11.51$, $MSE = 169{,}452$, $p < .01$, and named pictures with translation distractors 42 ms faster than unrelated distractors $F_1(1,40) = 22.46$, $MSE = 104{,}567$, $p < .001$, $F_2(1,25) = 9.21$, $MSE = 246{,}990$, $p < .01$. No interactions were significant (*p*s > .13).

<Insert Figure 1 about here>

<Insert Figure 2 about here>

<Insert Table 3 and 4 about here>

Discussion

In Experiment 1, we mixed responses in a picture-word interference task to examine disparate predictions of language-specific vs. non-specific models of bilingual language production. In a language non-specific model, mixing the language of response (i.e., so that bilinguals needed to name pictures in one language half the time, and in the other language the other half of the time) should reduce the extent to which an articulatory buffer or external language node can be used to discard non-target-language responses, thereby eliminating or reducing translation facilitation effects. Such an effect may even cause translation distractors to slow picture naming, compared to unrelated distractors, revealing competition between translation equivalents in an experimental design that better matches circumstances bilinguals face in naturalistic language use (in which languages are mixed in speech production and comprehension alike, not just in one modality). Instead we found that translation facilitation effects are maintained in mixed-language-response blocks for the dominant language, and though translation facilitation effects were significantly reduced for the non-dominant language, here too translation distractors facilitated responses.

In the error rates, there were almost no effects in the single-language response blocks. Bilinguals were, however, more likely to make an error in their non-dominant language in the unrelated condition of the mixed-language response blocks relative to the translation condition (i.e., an effect of translation facilitation for the non-dominant language in the mixed-language-response block, see General Discussion).

The robust facilitation effects seen in the dominant language provide some support for Costa et al.'s model, in which languages do not compete even when mixed. There are, however, some caveats. First, the translation effect was smaller in the non-dominant language in the mixed-language response block than the single-language response block (a three-way interaction, significant by-subjects and marginally significant by-items), as predicted by language non-specific models. Second, in single-language response blocks, bilinguals responded more slowly in the non-dominant language, significantly so in the unrelated condition (and numerically in the same direction in both the control and related conditions). By contrast, in mixed-language response conditions, bilinguals tended to exhibit reversed language dominance effects (bilinguals named pictures faster in the non-dominant than the dominant language in all but the XXXXX control condition). In a purely language-specific model of selection, why would bilinguals inhibit a language that does not compete for selection? The reversal of language dominance on only some trials matches a pattern reported by Meuter and Allport (1999) in which dominance was reversed only on switch trials (see Introduction). It could be that in the picture-word interference paradigm, inhibition is applied only on trials in which the language of the task is uncertain (i.e., in mixed-language blocks) and the speaker must also resolve distractor word information, which would be more in line with language non-specific models in which the competition between languages demands greater control resources.

In other words, the pattern of results that would have provided more unequivocal support for language-specific control models in Experiment 1 would have been translation facilitation effects of equal size across all languages and conditions. Instead, translation facilitation was larger in the non-dominant language in single-language than in mixed-language response blocks. However, the pattern of results that would have unequivocally supported language non-specific models would have been if translation distractors caused interference across mixed conditions in both languages. Instead, translation distractors facilitated responses, significantly so in both languages, and in both single-language response and mixed-language response blocks.

Experiment 2

In Experiment 2 we presented all of the distractors in the non-target language, as in Experiment 3 of Costa et al. (1999). Thus, when bilinguals named pictures in English, all distractors (semantically related, semantically unrelated, and translation) were presented in Spanish in Experiment 2, whereas only the translation distractors were in Spanish in Experiment 1 (as in Roelofs et al., 2016). Under a language non-specific model of selection, having all distractors in the same language, regardless of condition, should increase the likelihood of translation distractors reducing or reversing facilitation. Translation trials are no longer separable from the other conditions on distractor language alone. Both languages must be considered in all trials with distractors. Under a language-specific model of selection, translation facilitation would remain robust in this condition as distractor language information is irrelevant in lexical selection. Such a model might also predict that the reversed language dominance effects seen in the mixed trials of Experiment 1 would disappear as both languages are now present in all trials with distractors, making it much more difficult to inhibit the nontarget language.

We might also expect to see differences across experiments due to the consistency in distractor language in Experiment 2. Under a language non-specific model, we might see a speed up in both single and mixed-language response blocks in Experiment 2 relative to Experiment 1; if all distractors are presented in the non-target language, the non-target language responses will be easier to discard from the articulatory buffer. Alternatively, under a language-specific model, it may be that having a language-specific cue will not help, as subjects can already represent which language to use to respond.

Method

Subjects. Spanish-English bilingual students (N = 48) from the same pool of subjects but that had not participated in Experiment 1 were recruited and completed the study for course credit. All bilinguals spoke Spanish and English fluently and MINT score determined their dominance classification. Forty-five subjects scored higher on the English MINT than the Spanish MINT and three subjects scored higher on the Spanish MINT than the English MINT. Full participant characteristics are listed in Table 1.

Materials, Procedure, Analysis. The materials, procedure and analyses were identical between Experiments 1 and 2, with one exception: distractor words in the semantically related and unrelated conditions appeared in the non-target language. For example, when the picture of a nose was to be named in English, the semantically related distractor appearing on the picture was no longer the English word *eye* but its Spanish translation equivalent *ojo*, and the semantically unrelated word was *vaso* rather than *glass*. Likewise when naming the picture as *nariz* in Spanish, the semantically related distractor was *eye,* and the semantically unrelated distractor was *glass.* Word pairings were still consistent across blocks and languages, and identical to Experiment 1 except in distractor language. Example materials shown in Table 5.

<Insert Table 5 and 6 about here>

Results

Figures 3A and 3B and Table 6 show the response times for Experiment 2 organised by picture-word interference condition and language mixing, shaded by language dominance. Figure 4 shows the response times of the critical conditions reported as difference scores (unrelated condition minus translation condition). As in Experiment 1, we focus our analysis on the results of the two critical distractor conditions, unrelated and translation distractors; response time analysis of all four conditions, is shown in Appendix B. Among these critical distractor conditions, bilinguals named pictures 136 ms slower in the mixed-language response blocks relative to single-language response blocks $F_1(1,42) = 104.88$, $MSE = 708,853$, $p < .001$, $F_2(1,26) = 253.53$, $MSE = 296,738$, $p < .001$. They named pictures 61 ms more quickly with translation than with unrelated distractors, $F_1(1,41) = 156.72$, $MSE = 109,228$, $p < .001$, $F_2(1,25) = 57.92$, $MSE = 296,805$, $p < .001$, and named pictures equally quickly in their two languages, a non-significant effect of language dominance, $F_1(1,43) = 1.14$, $MSE = 409,090$, $p = .29$, $F_2(1.27) = 0.99$, $MSE = 419,935$, $p = .33$. The translation facilitation effect was also greater in the non-dominant language than the dominant language block in the by-subject analysis, $F_1(1,45) = 6.36$, $MSE = 96,383$, $p = .015$, $F_2(1,29) = 2.80$, $MSE = 215,551$, $p = .11$. None of the remaining two-way, nor three-way interactions were significant (ps > .47).

Figures 3C and 3D and Table 6 show the naming error data, which were analyzed using mixed-effect models to examine the unrelated and translation conditions. Among these conditions, bilinguals produced more errors in mixed-language than in single-language response blocks ($\chi^2 = 43.9$, $p < .001$), and they produced fewer errors in the translation condition than in the unrelated condition, that is, a significant translation facilitation effect, ($\chi^2 = 5.53$, $p = .019$). All other effects were non-significant (ps > .13).

As in Experiment 1, we additionally analyzed switching effects within the mixed-language response blocks, shown in Table 4. In a by-subject and by-item analysis of trial type (stay vs. switch), distractor type (focusing only on the critical distractor conditions, unrelated vs. translation), and language dominance, we found that bilinguals produced switch trials 59 ms slower than stay trials $F_1(1,42) = 64.28$, $MSE = 95,955$, $p < .001$, $F_2(1,21) = 6.14$, $MSE = 484,350$, $p = .022$. They also produced pictures with translation distractors 63 ms faster than unrelated distractors $F_1(1,40) = 45.27$, $MSE = 106,592$, $p < .001$, $F_2(1,25) = 29.31$, $MSE = 158,938$, $p < .001$. Bilinguals named pictures equally quickly in the two languages, and none of the interactions were significant (ps $\geq .18$).

We also asked whether response times were faster across Experiment 2 relative to Experiment 1 as a result of the change of distractor language. To assess this, we performed a by-subject and by-item analysis of response times using experiment, language response blocks, and distractor type as factors. Bilinguals named pictures 14 ms faster in Experiment 2 relative to Experiment 1 yielding a marginally significant difference, $F_1(1,90) = 3.04$, $MSE = 1.55e15$, $p = .085$, $F_2(1,28) = 3.33$, $MSE = 1.46e15$, $p = .08$, and these differences were equivalent between single-language response and mixed-language response blocks, and between different distractor types (Fs < 1).

<Insert Figure 3 about here>

<Insert Figure 4 about here>

Discussion

In Experiment 2, a language-specific model of selection predicted that translation facilitation would again be robust, even in the presence of other distractors of the same language, and indeed we found a significant translation facilitation effect in the response times. The error rates showed the same pattern as in Experiment 1. Bilinguals were more likely to make an error in their non-dominant language in the unrelated condition of the mixed-language response blocks, though the three-way interaction was not significant in Experiment 2.

On the other hand, a language non-specific model predicted that with all distractors appearing in the non-target language (which was not the case in Experiment 1) the consistent language of the distractor might be used strategically to eliminate a competing response. Indeed, we saw that response times across Experiment 2 were somewhat faster – about 15 ms

– but that this difference was only marginally significant and therefore inconclusive. Critically, though, regardless of distractor language, translation facilitation remained robust in response times across experiments, block type, and language.

General Discussion

Two experiments showed that the translation facilitation effect is robust in both single language and mixed-language response blocks. In Experiment 1, we found translation facilitation effects in both single-language response blocks (aligning with typical picture-word interference tasks) and mixed-language response blocks, in which bilinguals switched between languages. Additionally, translation facilitation was greater in the single language than in the mixed-language response blocks but only for the non-dominant language (and with trends in the opposite direction in errors). In Experiment 2, we changed only the language of the unrelated and semantically related distractor conditions from the target language to the non-target language (so that all distractors were in the non-target language), and found robust translation facilitation effects of equal magnitude in the single- and mixed-language response blocks in both languages. Finally, in both experiments, bilinguals named pictures in the dominant language faster than in the non-dominant language in single-language response blocks, but dominance effects were reversed so that bilinguals named pictures faster in non-dominant than in the dominant language in the mixed-language response blocks (significant by-subjects and items in Experiment 1, and by-subjects in Experiment 2).

Language non-specific models of control in bilingual lexical access like the Multilingual Processing Model and the Response Exclusion Hypothesis predict that translation facilitation effects should become translation interference effects (or reduced facilitation effects) when the task in a picture-word interference experiment involves production in both languages. Experiment 2 of Costa et al. (1999) began to explore this effect, showing that the "Spanish identity condition" (in this experiment a Spanish cognate distractor was superimposed on a picture to be named in Catalan), produced significant facilitation in a mixed response language block. Here, in two experiments, we replicated and extended that effect, showing that translation facilitation did not become interference in mixed-language response blocks, even with non-cognate distractors, with the same subjects tested in both single- and mixed-language response blocks, and with materials counterbalanced across languages. An external language node mitigating competition at the lexical level or an articulatory buffer in which bilinguals discard a response just before production cannot account for this facilitation when a bilingual does not know which language they will need to produce on an upcoming trial. As such, Costa et al.'s (1999) original explanation of translation facilitation, in which semantic-level activation spreads between languages after language-wide inhibition is activated, remains the theory that is most consistent with this aspect of the results.

A language-specific model such as Costa's, however, also does not seem to account for all of the patterns of data seen here. In Experiment 1, we saw that translation facilitation was greater in the non-dominant language in the single-language response blocks than in mixed-language response blocks, causing a significant three-way interaction that would support a language non-specific model of selection. However, error rates exhibited the opposite pattern such that the non-dominant language showed *greater* translation facilitation in the mixed-language-response blocks than the single-language-response blocks. This possible speed-accuracy tradeoff in the magnitude of translation facilitation effects across block types, the failure to replicate it in Experiment 2, and the robustness of translation facilitation effects in Experiment 2, make it difficult to argue that block type (single- vs. mixed-language response) impacts translation facilitation effects.

If the reversal in error rates was caused by floor effects, it is possible the reduction of translation facilitation for the non-dominant language (in RTs) between single- and mixed-language response blocks was caused by the difficulty of the mixed-language block increasing competition at the lexical level and offsetting the benefit of semantic priming in translation distractor condition. Why, though, would the translation facilitation effect be greater in single-language response blocks and only in the non-dominant language? And why didn't this effect appear in Experiment 2, in which all distractors were in the dominant language in the single-language response block? To speculate, it may be that the presence of only dominant language translation distractors on a non-dominant naming trial in Experiment 1 (in which all other trials were non-dominant in both response and distractor type) was particularly facilitating. Perhaps the dominant language was the most heavily inhibited in these trials, as it only appeared in translation distractor trials throughout the entire block, and only as a distractor, which allowed speakers to discard it more quickly as a possible response within the context of this block. In mixed-language response blocks and in single-language response blocks with all dominant language distractors (as in Experiment 2), the dominant language could not be unilaterally suppressed, as it was either present in the response set (in mixed-language response blocks) or on all distractor items (in the single-language response block), and therefore responses could not be discarded as quickly. Future studies may consider paradigms that reduce error rates (e.g. increased inter-stimulus intervals), to potentially allow for effects to manifest solely in response times, or paradigms that increase error rates to remove the possibility of floor effects.

Also in line with language non-specific models, in both experiments we found that in mixed-language response blocks, bilinguals named pictures faster in the non-dominant than in the dominant language, a reversed dominance effect. This effect suggests that on trials in which both languages were in competition (typically switch trials) bilinguals proactively inhibited the dominant language in order to more easily produce the non-dominant language. In the experiments reported here, the dominant language was produced faster than the non-dominant language in single-language response blocks and slower in the mixed-language response blocks. This suggests that, in order to efficiently produce both languages within the same block, bilinguals actively suppressed their dominant language, strongly implying competition for selection between languages.

Thus, on one hand, the robustness of the translation facilitation effect in the dominant language of Experiment 1 and in both languages in Experiment 2 supports a language-specific model of lexical selection. On the other hand, the reversed dominance effects and the reduction of the facilitation effect for the non-dominant language in Experiment 1, are more consistent with a language non-selective model in which lexical items compete for selection across languages. Neither model can fully account for every aspect of the data shown in these experiments. While it is difficult to isolate semantic and lexical level processing in an experimental paradigm, the studies here show that even Hall's (2011) synthesis in which languages compete for selection but semantic facilitation and lexical interference can cause a net translation facilitation effect has difficulty accounting for picture-word interference effects in mixed-language response blocks. In both experiments, translation facilitation was robust and un-mitigated in mixed-language response blocks relative to single-language response blocks in the dominant language, despite the fact that a mixed-language response block should drive up competition at the lexical level, and therefore should at least shrink the facilitation effect driven by the semantic priming, if not reverse it entirely.

One possible explanation of our results is that the control mechanisms at play in picture-word tasks can act independently and in parallel from those at play in language switching tasks. To speculate, if the attentional system actively inhibits articulation of the non-target language at the articulatory stage (as suggested by the Response Exclusion

Hypothesis), it may be that non-attentional control mechanisms drive translation facilitation and other picture-word interference effects at the semantic and lexical levels. This independence of control mechanisms would account for the robustness of the translation facilitation effects in our data as well as the reverse dominance effects seen in mixed-language response blocks.

Whether bilinguals named pictures exclusively in one language across an entire block of trials, or in the more difficult mixed-language-response blocks, translation facilitation effects remained significant and robust in both languages. This was true when the translation distractors were presented in the non-target language only, or when distractors in both languages were presented. A language-specific selection model as Costa et al. (1999) put forth does account for this robustness but has difficulty explaining other effects observed herein (reversed dominance effects, reduction of translation facilitation in the non-dominant language in Experiment 1). While a language non-specific model needs to make additional assumptions to explain how translations cause facilitation at the semantic level and offsets competition at the lexical level as Hermans (2000) and Hall (2011) suggested, this is perhaps the most complete view of the data presented here. Additional investigation is needed to determine which control mechanisms are at play in picture-word tasks and language switching tasks, and which types of tasks elicit translation facilitation versus competition and might perhaps be directed at more naturalistic paradigms that elicit production of full sentences and without massive repetition of items (which can flip even cognate facilitation effects into inhibition; Li & Gollan, 2018). Having said that, the robustness of the translation facilitation effect demonstrated here remains a puzzle in research on bilingual language production that likely has broader implications for understanding speech production in general.

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Table 1. *Subject characteristics for Experiments 1 and 2.*

	Experiment 1						Experiment 2					
	English			Spanish			English			Spanish		
	M	SD	Range	M	SD	Range	M	SD	Range	M	SD	Range
% Words produced	59.13	5.64	36-65	49.71	8.30	22-62	61.17	2.86	55-68	48.50	9.71	28-65
Self-rated Listening	6.67	0.60	5-7	6.63	0.73	4-7	6.67	0.52	5-7	6.52	0.65	5-7
Self-rated Speaking	6.41	0.75	5-7	6.15	0.92	4-7	6.52	0.68	5-7	5.81	1.00	4-7
Self-rated Reading	6.59	0.66	5-7	6.23	0.97	4-7	6.67	0.60	5-7	5.80	0.96	4-7
Self-rated Writing	6.43	0.81	5-7	5.65	1.23	3-7	6.44	0.71	5-7	5.35	1.04	3-7

Table 2. *Example materials for Experiment 1, showing response language, picture name, and superimposed distractor.*

		Control	Unrelated	Related	Translation
English	Picture name	eye	eye	eye	eye
	Distractor	XXXXX	napkin	nose	ojo
Spanish	Picture name	ojo	ojo	ojo	ojo
	Distractor	XXXXX	servilleta	nariz	nose

Table 3. *Response time means and standard deviations and error rates (in percent) by language block, language dominance, and distractor type for Experiment 1.*

		Control		Related		Unrelated		Translation	
		M (SD)	% Error	M (SD)	% Error	M (SD)	% Error	M (SD)	% Error
Single-language	Dominant	861 (307)	0.30	988 (356)	1.27	937 (321)	0.78	900 (297)	0.34
	Non-dominant	868 (292)	0.72	997 (341)	1.13	972 (329)	0.89	871 (284)	0.92
Mixed-language	Dominant	1045 (378)	2.14	1139 (394)	3.84	1101 (388)	1.92	1066 (386)	2.33
	Non-dominant	1047 (404)	2.74	1118 (393)	3.36	1076 (382)	3.79	1027 (374)	2.51

Table 4. *Response times means and standard deviations for Experiments 1 and 2 by trial type (stay versus switch), language dominance, and distractor type.*

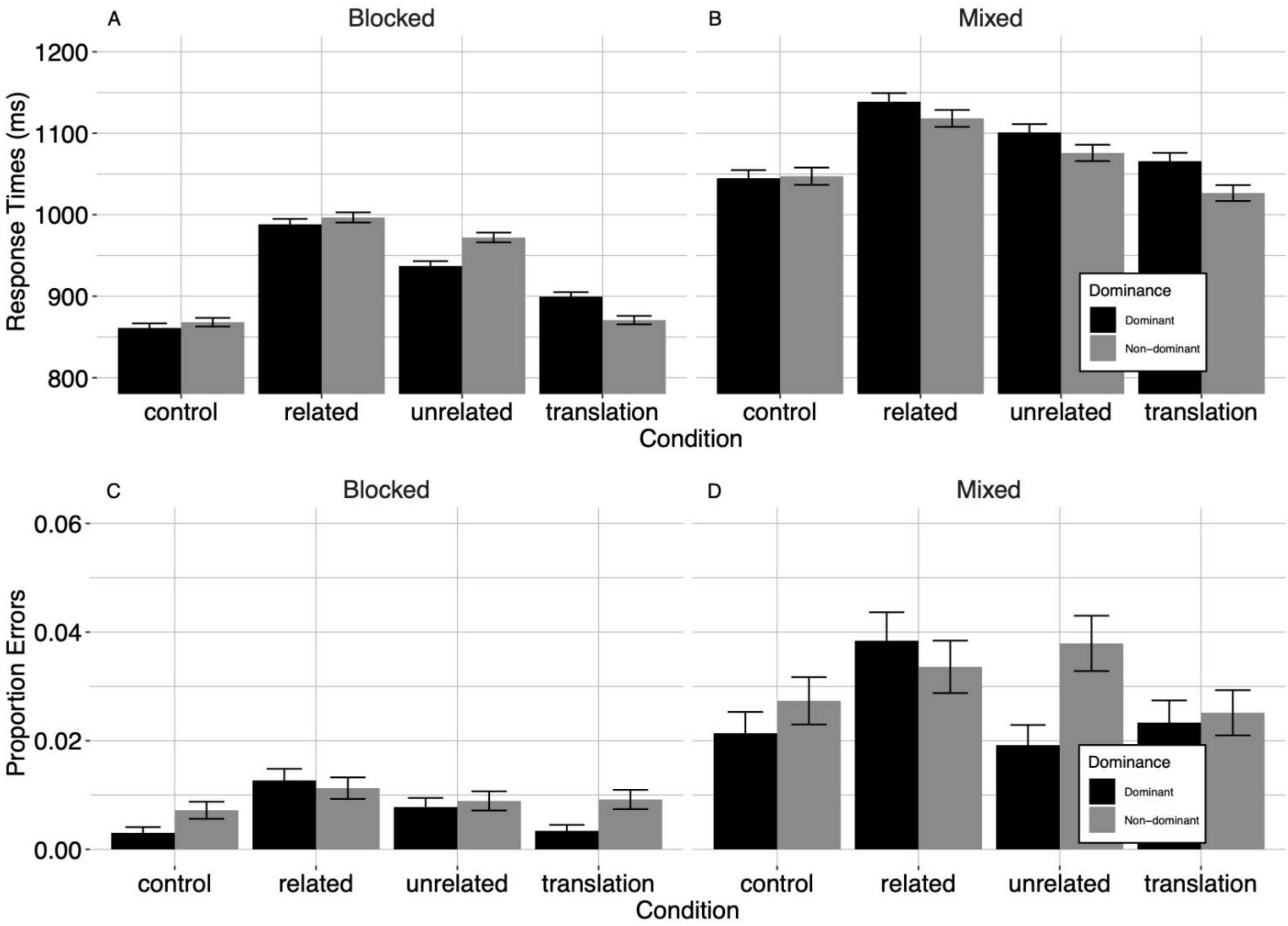
		Control		Unrelated		Related		Translation	
		Stay	Switch	Stay	Switch	Stay	Switch	Stay	Switch
Experiment 1	Dominant	995 (363)	1084 (384)	1074 (385)	1131 (390)	1100 (379)	1170 (405)	1021 (345)	1114 (423)
	Non-dominant	996 (400)	1068 (381)	1015 (363)	1121 (382)	1086 (386)	1135 (376)	986 (333)	1062 (403)
Experiment 2	Dominant	971 (347)	1054 (378)	1037 (369)	1113 (392)	1044 (374)	1120 (401)	1000 (367)	1044 (358)
	Non-dominant	973 (348)	1042 (374)	1036 (363)	1109 (403)	1098 (401)	1106 (395)	975 (353)	1037 (369)

Table 5. *Example materials for Experiment 2, showing response language, picture name, and superimposed distractor.*

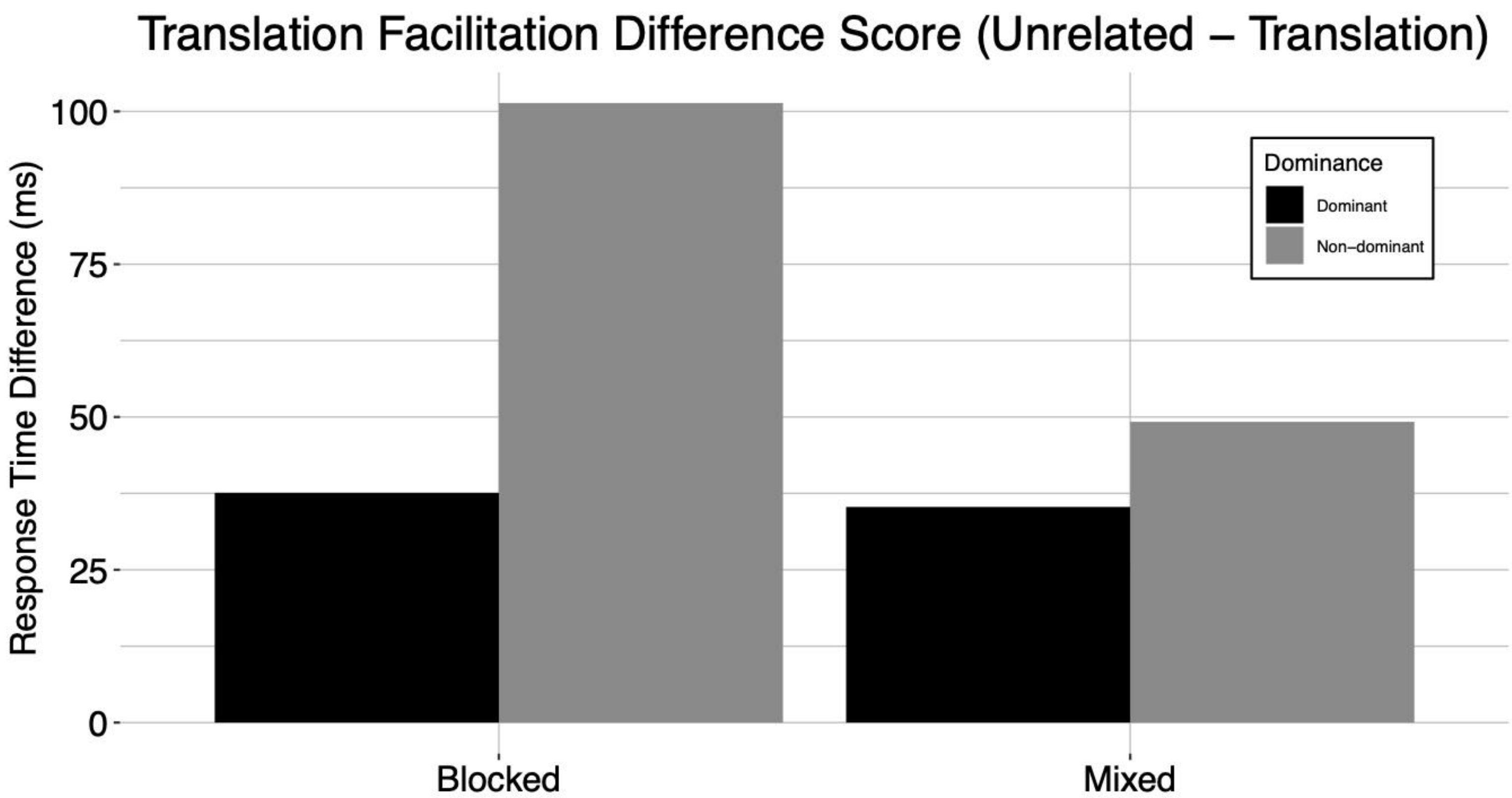
		Control	Unrelated	Related	Translation
English	Picture name	eye	eye	eye	eye
	Distractor	XXXXX	servilleta	nariz	ojo
Spanish	Picture name	ojo	ojo	ojo	ojo
	Distractor	XXXXX	napkin	nose	nose

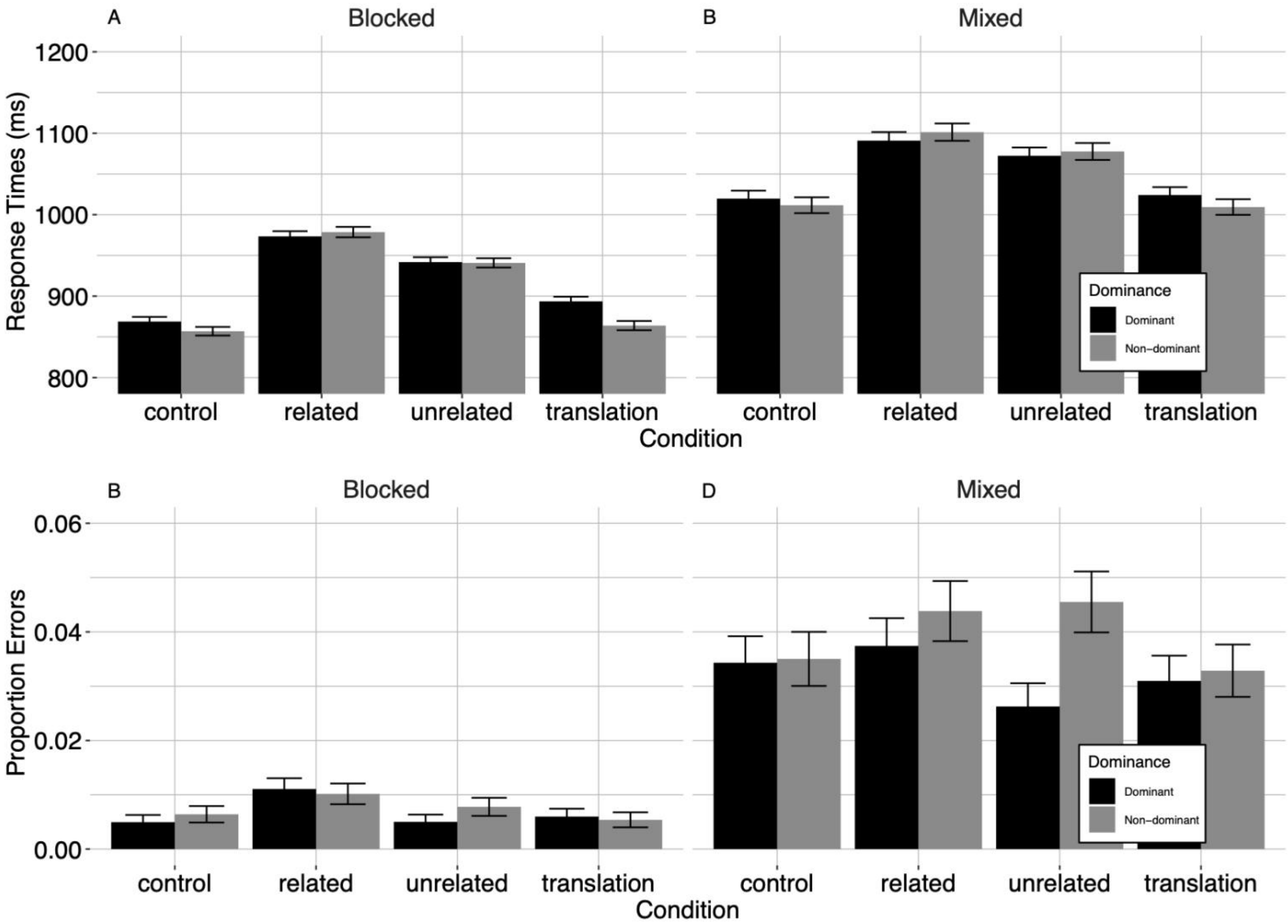
Table 6. *Response time means and standard deviations and error rates (in percent) by language block, language dominance, and distractor type for Experiment 2.*

		Control		Related		Unrelated		Translation	
		M (SD)	% Error	M (SD)	% Error	M (SD)	% Error	M (SD)	% Error
Single-language	Dominant	869 (314)	0.50	973 (348)	1.11	942 (325)	0.50	894 (311)	0.60
	Non-dominant	857 (287)	0.64	979 (345)	1.02	941 (309)	0.78	864 (309)	0.54
Mixed-language	Dominant	1020 (370)	3.43	1091 (396)	3.74	1072 (385)	2.63	1024 (367)	3.10
	Non-dominant	1012 (365)	3.50	1101 (398)	4.38	1078 (390)	4.55	1009 (361)	3.29



A
Blocked
B
Mixed
Response Times (ms)
1200
1100
1000
900
800
control
related
unrelated
translation
Condition
Dominance
Dominant
Non-dominant
C
Blocked
D
Mixed
Proportion Errors
0.06
0.04
0.02
0.00
control
related
unrelated
translation
Condition
Dominance
Dominant
Non-dominant


Translation Facilitation Difference Score (Unrelated – Translation)
Response Time Difference (ms)
100
75
50
25
0
Blocked
Mixed
Dominance
Dominant
Non–dominant


A
Blocked
B
Mixed
Response Times (ms)
1200
1100
1000
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800
control
related
unrelated
translation
Condition
Dominance
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Non−dominant
B
Blocked
D
Mixed
Proportion Errors
0.06
0.04
0.02
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Dominance
Dominant
Non−dominant

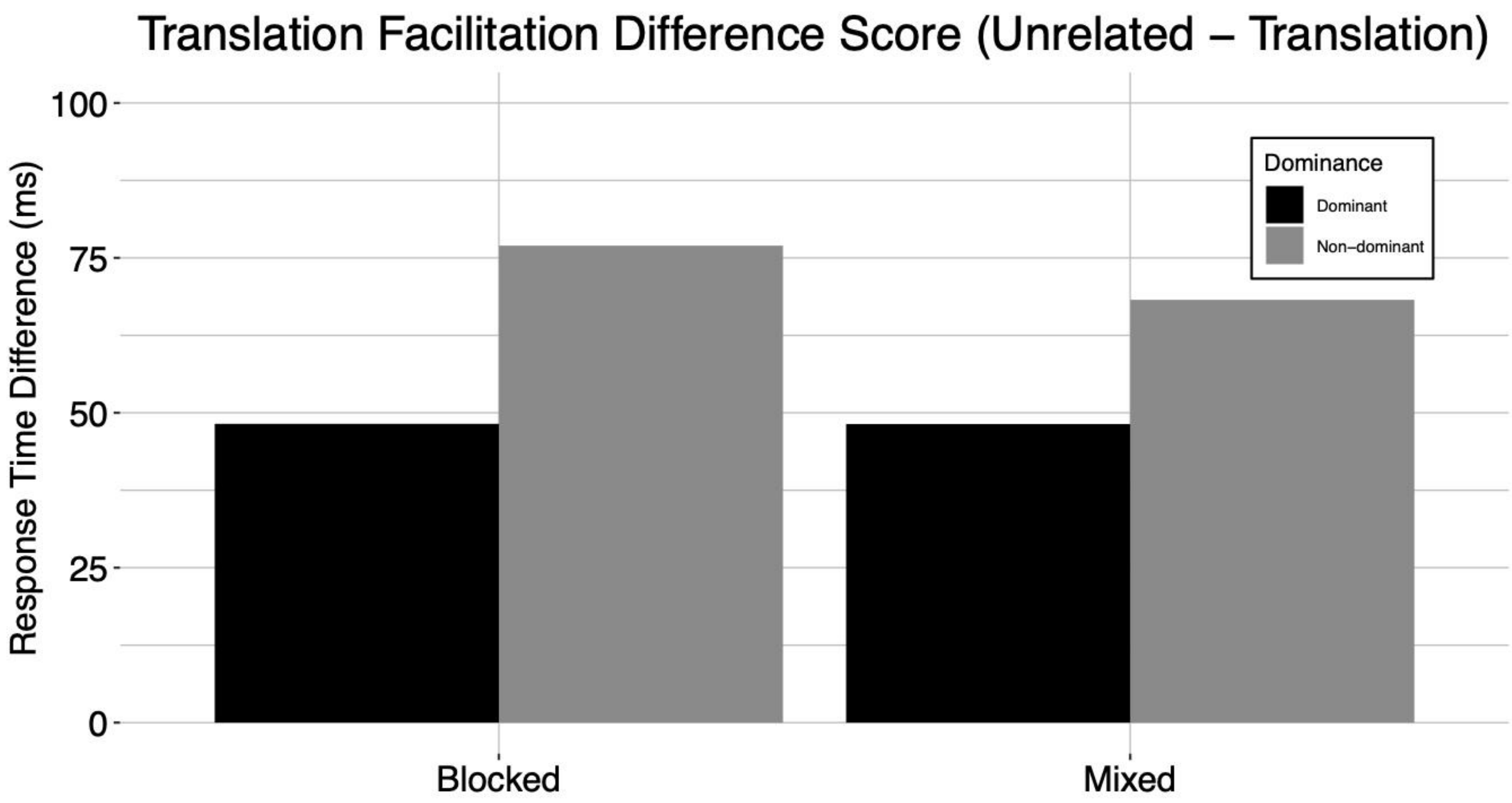
Translation Facilitation Difference Score (Unrelated – Translation)
Response Time Difference (ms)
100
75
50
25
0
Blocked
Mixed
Dominance
Dominant
Non–dominant

Figure Captions.

Figure 1. *Response times and error rates for Experiment 1 grouped by distractor condition and block type, shaded by language dominance. Error bars represent standard error.*

Figure 2. *Response times for Experiment 1 plotted as difference scores, the Unrelated condition minus the Translation condition, shaded by language dominance.*

Figure 3. *Response times and error rates for Experiment 2 grouped by distractor condition and block type, shaded by language dominance. Error bars represent standard error.*

Figure 4. *Response times for Experiment 2 plotted as difference scores, the Unrelated condition minus the Translation condition, shaded by language dominance.*