Tonal bilingualsim: the case of two related Chinese dialects

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4 Tonal Similarity Effect: The Role of Tone in the Auditory Lexical Access of Etymologically Related Translation Equivalents

Abstract

Phonological similarity affects the bilingual lexical access of etymologically related translation equivalents (called 'cognates' in earlier studies). Jinan Mandarin (JM) and Standard Chinese (SC) are closely related and share many etymologically related translation equivalents, which are usually orthographically and segmentally identical but vary in tonal similarity. In the present study, we studied SC-JM bilinguals' lexical storage of tone-identical (S+T+) and tone-non-identical (S+T−) translation equivalents, using an auditory lexical decision experiment. S+T+ and S+T− words were presented to SC tonal monolinguals in SC, and to SC-JM tonal bilinguals in both JM and SC. After controlling the possibility of within- and between-dialect repetition priming and other covariates, S+T+ and S+T− items did not show any difference in reaction time. However, the discontinuity of tonal similarity effects and the language-dominance effect support that both types of translation equivalents have dialect-dependent separate representations in the bilingual lexicon, and the retrieval is modulated by the language mode and the bilinguals' attention.

4.1 Introduction

Etymologically-related translation equivalents have a common origin and are similar in sound. They are either inherited from the common ancestor language as cognates or borrowed across languages as loan words. Using 'cognate' to refer to all such words, psycholinguists have found 'cognate facilitation effect' in many different tasks and conditions. 'Cognates' (historically related words) are produced faster than 'non-cognates' in visual word naming (Costa, Caramazza, & Sebastian-Galles, 2000; Hoshino & Kroll, 2008) and picture naming (Costa, Santesteban, & Caño, 2005), and recognized faster in visual lexical decision (Brenders, van Hell, & Dijkstra, 2011; Bultena, Dijkstra, & van Hell, 2012; Dijkstra, Grainger, & Van Heuven, 1999; Duyck, Assche, Drieghe, & Hartsuiker, 2007; Lemhöfer & Dijkstra, 2004), progressive de-masking (Dijkstra et al., 1999; Dijkstra, Miwa, Brummelhuis, Sappelli, & Baayen, 2010), word associations (Van Hell & Dijkstra, 2002), eye-tracked natural reading (Duyck et al., 2007), and self-paced reading (Bultena, Dijkstra, & van Hell, 2013)[7]. Moreover, cognates prime each other like within-language variations (Cristoffanini, Kirsner, & Milech, 1986) and they increase the participants' tendency to switch at the same position as in the prime sentence in the structure priming paradigm (Kootstra, van Hell, & Dijkstra, 2012). Cognate facilitation effect applies to many different language combinations. In a study

[7] For L2 learning children, cognate facilitation effects can be interrupted by introducing false-friends in the testing list (Brenders et.al, 2011).

involving different specific bilingual language combinations (Lemhöfer et al., 2008), the cognate status was found to be the only between-language variable that significantly affected the reaction time of L2 word identification, again shortening the reaction times. The cognate facilitation effect has been taken as an important phenomenon which reveals how the bilingual mental lexicon is organized and accessed. It supports the view that the bilingual mental lexicon is integrated and words from different languages are co-activated.

A pair of translation equivalents can be different in several dimensions, such as semantics, orthography, phonology, and relative frequency. Semantic and orthographic similarities have shown facilitatory effects in earlier studies (Dijkstra et al., 1999; Dijkstra et al., 2010). However, the effect of phonological similarity is inconsistent within and across studies (Dijkstra et al., 1999; Dijkstra et al., 2010; Duyck et al., 2007; Lemhöfer & Dijkstra, 2004). Several reasons may be responsible for the unstable effects.

First, the phonological similarity co-varies and interacts with the orthographic similarity. A recent study by Dijkstra et al. (2010) has provided important insights into the interaction of orthography and phonology. By distinguishing orthographically identical and non-identical Dutch-English cognates, they found that the orthographically identical cognates showed not only a large processing advantage compared to the non-identical ones, but also differed in their response to phonological similarity. The identical cognates were subject to facilitation from phonological similarity but the non-identical cognates were comparatively less sensitive to phonological similarity. Dijkstra and colleagues made a claim that pairs of non-identical cognates are stored as two separate lexical nodes and lexical access was slowed down by lateral inhibition. In contrast, pairs of identical cognates are stored as one common lexical node and hence not inhibited but facilitated by phonological co-activation.

Second, etymologically related words can vary along different phonemic dimensions. For instance, some have different vowels and others have different consonants. Nevertheless, considering the contribution of different phonemic dimensions, the specific bilingual language combinations investigated in the previous studies suffer from the relative scarcity of target words. This encouraged us to look for a better test case for the effect of phonological similarity along one specific phonemic dimension.

The bilingualism of Standard Chinese (SC) and Jinan Mandarin (JM) allows us to zoom into one aspect of phonological similarity while keeping other aspects constant. SC and JM are closely related Mandarin dialects. They share many etymologically related translation equivalents which are usually orthographically and segmentally identical but vary in tonal similarity. First, unlike in the previous studies, the etymologically related words are the majority in the vocabulary of these bilinguals. As a result, the majority of translation equivalents sound similar, providing many more test cases. Second, both JM and SC are written with the same logographic Chinese writing system. Thus all JM-SC historically related words are orthographically identical, which avoids the potential confound by orthography. Previous research has benefited from this logographic writing system. For instance, previous studies of speech production have used Chinese to tear apart orthographic and phonological effects (Qingfang Zhang & Weekes, 2009; Zhao, La Heij, &

Schiller, 2012). However, one common logographic writing system in two dialects used by the same bilingual speaker has been little studied. Third, the segmental differences between the historically related words are almost annihilated in the youngest bilinguals. As a result, the two translation equivalents are only different in tone. The tonal similarity between a JM word and its SC translation equivalent determines their phonological similarity. Also, while cognates can be semantically different, the translation equivalents are semantically identical, which is convenient for our experimental control. The case of SC-JM tonal bilingualism allows us to focus on the role of tone in the bilingual lexical representation and access.

As suprasegmental phonemes, lexical tones are both common and special. In production, neither sharing Mandarin tones alone (J. Y. Chen, Chen, & Dell, 2002) nor sharing both surface tones and segments (Y. Chen, Shen, & Schiller, 2011) caused facilitatory priming, unlike the case of segments. However, tonal sharing (tonemes or overt tonal realizations) accompanied with segmental sharing introduced phonological facilitation in two picture-word interference experiments (Nixon, Chen, & Schiller, 2014), similar to the case of segments. In phonological encoding, reaction times in a phoneme monitoring task (Ye & Connine, 1999) and reaction times as well as onset latency of the N200 component in a go/no-go task (Q. Zhang & Damian, 2009) showed that segmental information became available prior to tonal information. However, lexical adaptation seems to work similarly in tones and consonants (McQueen, Cutler, & Norris, 2006; Mitterer, Chen, & Zhou, 2011). The present study can provide further insights for the role of tone in lexical representation.

Using prosodic cues on the lexical level, lexical tones should function similarly to lexical stress in the mental representation of words as abstract lexical frames (Levelt, Roelofs, & Meyer, 1999). Dutch minimal stress pairs did not prime each other compared with neutral controls with two unrelated words (Cutler & Van Donselaar, 2001; Jongenburger, 1996). JM tonal minimal pairs primed each other negatively in lexical decision, different from word pairs with lexically non-contrastive tonal variations (Wu, Chen, Van Heuven, & Schiller, 2014). These findings support that stress and tonal minimal pairs have distinctive representations in lexical access. However, the role of tone in bilingual lexical representation and access needs further investigation.

Another aspect under consideration is the relative frequency of the translation equivalents. Language-dominance effects in lexical access are considered to be mediated by the relative frequencies of lexical representations in the integrated bilingual lexicon (W. J. B. Van Heuven, Dijkstra, & Grainger, 1998). The dominant language is used more frequently in general, and thus activated more easily compared to its translation equivalent. Such language dominance effects are usually taken as granted for normal translation equivalents and reported together with the asymmetrical translation priming effects (Basnight-Brown & Altarriba, 2007) and the asymmetrical cognate facilitation effects (Brenders et al., 2011; Van Hell & Dijkstra, 2002). The frequency-based account for this language dominance effect is built on an important assumption that the translation equivalents have two lexical representations (Altarriba, 1992). Nevertheless, we cannot rule out the possibility that identical translation equivalents are instead represented with one single lexical node. The frequency-based account for the language dominance effect predicts that if a pair of translation equivalents shares a single lexical representation, they cannot be assigned different lexical frequencies and the common lexical node should be activated with the same speed in different language modes, showing no language dominance effect. As previously mentioned, the common representation for the orthographically identical Dutch-English translation equivalents in visual word recognition was supported with empirical evidence (Dijkstra et al., 2010). However, the previous discussion on language-dominance effects rarely considered the identical or near-identical translation equivalents.

In order to study the role of tone in bilingual lexical representation and access of etymologically related translation equivalents, the present study investigated how the cross-linguistic tonal similarity affects the cognate facilitation effect. More specifically, we are looking into whether tonal similarity affects the cognate facilitation effect on segmentally identical translation equivalents and, if it does, whether tonal similarity affects tone-identical (S+T+) and tone-non-identical (S+T−) translation equivalents in the same way.

Different viewpoints with respect to the role of lexical tone in lexical representation provide different answers to these questions. In the discussion of the following three viewpoints as shown in Figure 1, we assume a localist connectionist account for the mental representation of translation equivalents. Under this framework, it is assumed that lexical representations made up by different phonemes are also different within and across languages (Dijkstra et al., 1999). According to this account, there can be a single representation for identical translation equivalents, but at least two representations are needed for non-identical translation equivalents. Dijkstra et al.'s study (2010) supported this account for bilingual visual word recognition. The crucial evidence was that the reaction time sharply increased in nearly identical cognates compared with fully identical cognates, revealing a lateral inhibition effect (Dijkstra et al., 2010). Does this point also apply to the usage of tone in lexical storage by bilinguals who use two closely related tonal dialects rich in segmentally identical translation equivalents? There is evidence indicating that suprasegmental cues on the lexical level are exploited in recognizing spoken words (Cutler & Van Donselaar, 2001; V. J. van Heuven, 1988; Wu et al., 2014). However, does it mean that lexical representations made up by identical segments but different tones across languages/dialects are also different?

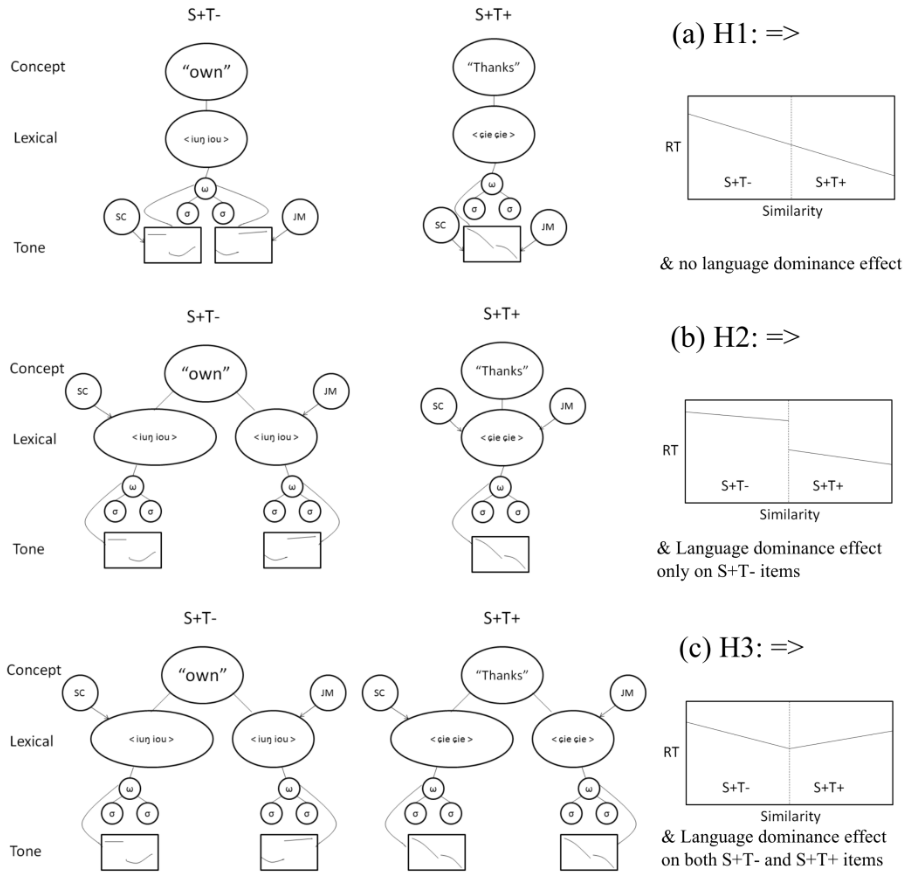

Figure 1. *Three alternative hypotheses on the mental representation of tonally identical (S+T+) and tonally non-identical (S+T−) translation equivalents.*

As mentioned above SC-JM tonal bilinguals speak two closely related tonal dialects, which are teaming with etymologically related translation equivalents. If these tonal bilinguals' lexical representations depend on segmental compositions but tones are assigned later depending on the language mode, S+T+ and S+T− translation equivalents would both be stored as single representations. Then S+T+ translation equivalents could be processed faster than S+T− translation equivalents due to the facilitation from the additional phonological similarity, but the decrease of reaction time with the increase of similarity should be continuous across both types of translation equivalents. Moreover, since language-dominance effects in lexical access are considered to be as mediated by the relative frequencies of lexical representations in the integrated bilingual lexicon (W. J. B. Van Heuven et al., 1998), language-dominance effect should appear on neither type of translation equivalents, as both types are commonly represented.

If SC-JM tonal bilinguals' lexical representations depend on both segmental and tonal compositions but not on the language attribution, S+T+ translation equivalents would be stored as a single representation but S+T− translation equivalents would be stored as two separate representations. Then S+T− translation equivalents would be processed much slower than S+T+ translation equivalents, revealing a similar lateral inhibition effect as found earlier on Dutch-English non-identical cognates (Dijkstra et al., 2010). A general facilitation from tonal similarity could still exist, but the S+T+ translation equivalents should enjoy a large discontinuous processing advantage as found earlier (Dijkstra et al., 2010). Moreover, the language-dominance effect should only appear on the separately represented S+T− translation equivalents but not on the commonly represented S+T+ translation equivalents.

Alternatively, if SC-JM tonal bilinguals' lexical representations not only depend on segmental and tonal compositions but also on the language attribution, not only S+T− but also S+T+ translation equivalents would be stored as two separate representations. In this case, both types of translation equivalents would have lateral inhibition and the difference between S+T− and S+T+ translation equivalents would be very small. Nevertheless, the increase of tonal similarity should yield different effects on the reaction times (RTs) of S+T− and S+T+ items. Since the two representations of S+T+ translation equivalents are nearly identical, we expect to see the lateral inhibition effect increase with the increase of tonal similarity. As for the more different S+T+ translation equivalents, the co-activation facilitation could be more dominant than the lateral inhibition and we would observe increased facilitation with the increase of tonal similarity. Moreover, the language-dominance effect should appear on both S+T− and S+T+ translation equivalents, since both types are represented separately.

4.2 Experiment

4.2.1 Participants

Forty-eight native tonal monolinguals of SC from Beijing (7 male and 41 female, the age ranged from 19 to 30, M = 22.73, SD = 2.95) and 54 native SC-JM tonal bilinguals from Jinan (15 male and 39 female, the age ranged from 19 to 36, M = 22.59, SD = 3.88, 44 SC dominant or balanced, 10 JM dominant) participated in this experiment in exchange for payment. Both groups were right-handed, received their literacy educations in SC, and have learned some English at school. A few participants from each group also have some knowledge of other non-tonal foreign languages, such as French and German.

4.2.2 Design and stimuli

An unbalanced mixed design, since no data was available before the experiment for the phonological similarity between SC-JM translation equivalents, was adopted with Tonal Identity, Tonal Similarity, Word Frequency, Language Mode, and Block as predictors. We first composed a list including 54 pairs of disyllabic SC-JM translation equivalents. Since no measurement of phonological similarity between

SC-JM translation equivalents was available before the experiment, the first author (a trained phonetician with Putonghua Proficiency Test Certificates- Level1B) judged the words from a JM audio corpus (200 high-frequency and 200 low-frequency words by 42 JM speakers collected in our earlier study) for their phonological similarity to their SC counterparts. Then 27 S+T+ and 27 S+T− pairs of translation equivalents were selected (four were later excluded because of segmental differences). Since many JM words were produced with different variants in the corpus, we selected words with dominant-variant probabilities greater than 0.85 and only used the only or highly dominant variants in our experiment. The S+T+ and S+T− candidates were matched with respect to their Chinese word frequency and dominant-variant probability. We also composed a list including 54 pairs of disyllabic non-words using non-existing combinations of Chinese characters. These words and non-words were then produced in both JM and SC by a male native bilingual who is highly proficient in both dialects (also a trained phonetician with Putonghua Proficiency Test Certificates- Level1B). After the main experiment, the translation equivalents were marked again as identical or non-identical according to the similarity rating by both SC monolinguals and SC-JM bilinguals.

The whole SC version of the words and non-words were presented to Beijing tonal monolinguals. The bilinguals were tested in both SC and JM. To eliminate the possibility of within- and between-dialect repetition priming, each bilingual heard only one member of each pair and only heard each stimulus once. The list of pairs was split into two halves (List-A & List-B) with matched number of between-dialect identical candidates, word frequency, dominant-variant probability, style, and tonal categories. Half of the participants heard the SC part of List-A and the JM part of List-B; the other half of the participants heard the SC part of List-B and the JM part of List-A. The SC words and JM words were presented in blocks separated by short breaks. Half of the bilinguals were tested with the SC block first and the other half were tested with the JM block first. Half-lists, language modes, and the test order of language modes were counterbalanced across the bilinguals as shown in Table 1.

Table 1. Counterbalanced design

	JM	SC	Test Order of Language Modes
Bilingual 1	List-A	List-B	JM first
Bilingual 2	List-B	List-A	JM first
Bilingual 3	List-A	List-B	SC first
Bilingual 4	List-B	List-A	SC first

4.2.3 Procedure

Participants were tested individually in a quiet room using the E-Prime software (Schneider, Eschman, & Zuccolotto, 2002). They were told that they would hear a series of sound sequences and they had to decide whether or not each of these sound sequences was a real word. Each item was played binaurally through headphones, with instructions on the screen. A new trial started 1,000 ms after the participant responded to an item, or 1,500 ms after the response time exceeded 5 s. SC and JM words were presented in two blocks separated by a break, in random order. The critical trials of each block were preceded by a practice block including 10 words and 10 non-words.

The language mode was implicitly hinted. At the beginning of each block, the participants heard instructions in the test dialect. Identical translation equivalents were avoided in the practice block. All the trials in one block were in the same dialect, except for the identical translation equivalents, which could be ambiguous regarding the dialect.

After the main experiment, both bilinguals and monolinguals rated all the SC-JM item pairs for cross-linguistic phonological similarity on a five-point scale. Each pair was aurally presented twice to the same participant in two blocks, once with the SC item first and once with the JM item first. The order of SC-first and JM-first presentations was counterbalanced across participants. None of the participants noticed the cross-linguistic tonal similarity of the translation equivalents before the rating phase.

4.3 Analysis and results

4.3.1 Tonal similarity and tonal identity

The similarity rating for each pair was calculated by averaging the ratings across the participants. We compared the average by-item similarity ratings by bilinguals and monolinguals and found a strong by-item correlation, $r = .98$. By-item paired t-test showed that bilinguals generally rated the pairs as more similar, $t(49) = -4.65$, $p < 0.001$. This bias was removed by z-normalizing the mean by-item ratings, $t(49) = 0.79$, $p > 0.05$. Since the SC-JM translation equivalents in the present study are segmentally identical but vary in tonal similarity, we treated the rating of phonological similarity by the bilinguals for each item as the Tonal Similarity of the item.

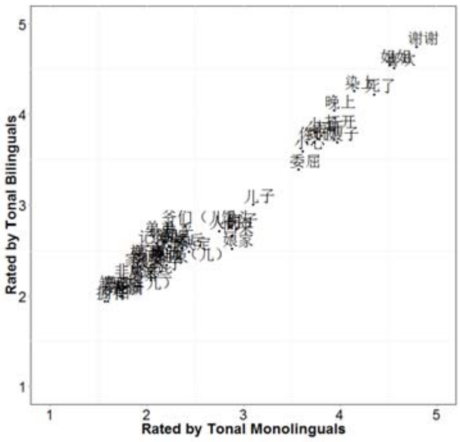

Figure 2. *A scatter plot for the similarity rating (1 = quite dissimilar, 5 = identical) by tonal monolinguals (along the horizontal axis) and tonal bilinguals (along the vertical axis). Each pair of translation equivalents is represented as a point in the plot with their common written form marked.*

The similarity rating showed a smooth dual-peak distribution as shown in Figure 2. We wrote a derivative-based algorithm to detect the virtual bottom of the valley between the two peaks and classified the pairs as tonally identical (S+T+) and tonally non-identical (S+T−) translation equivalents (threshold = 3.30). In the following analysis of RTs, we introduced the factor *Tonal Identity* specifying whether the SC and JM pronunciations are S+T+ or S+T−.

4.3.2 Reaction times

RT analysis was only based on the correct trials. We excluded the 10 JM-dominant bilinguals and one bilingual with a suspicious accent in the analysis of reaction times (RT)[8]. To improve the distribution of the data, RT data were log-transformed (natural log). The RT outliers were excluded for each participant using a distribution based approach (method I) (van der Loo, 2010) on the log transformed RTs, leaving 2143 data points from the monolinguals and 1846 data points from the bilinguals (930 to JM stimuli, 916 to SC stimuli).

In the following analysis, a model was first fitted with all data points, and then in a model criticism we removed data points with standardized residuals exceeding 2.5 standard deviation units from the data set (less than 2.5% of the data) and refitted the model with the trimmed data set. We report the model statistics from the trimmed models.

Since the *Tonal Identity* was a factor derived from the *Tonal Similarity* rating, these two predictors were inherently highly correlated. We first built a set of Linear Mixed Effect (LME) models (Bates, Maechler, Bolker, & Walker, 2013) including only the factorial *Tonal Identity* but not the *Tonal Similarity* in the set of fixed predictors, to investigate the tonal identity effects and its interaction with the other factors. Then we built separate models for S+T+ and S+T− items, including the rating of *Tonal Similarity* and the other fixed predictors, in search of the potential discontinuity of tonal similarity effects. The random terms include by-pair and by-participant intercepts or slopes for the effect of Trial, selected via model comparison based on likelihood ratio tests. The LME models are summarized in the **Appendices** with Satterthwaite approximation for degrees of freedom (Kuznetsova, Brockhoff, & Christensen, 2013; SAS, 1978).

Language dominance and word frequency effects. As shown in Appendix 1, the first LME model only used the bilinguals' reaction time data and included *Tonal Identity*, *Word Frequency*, *Language Mode*, *Block*, scaled *Trial Order*, and the two-way and three-way interactions of the first four factors as the fixed predictors. The chosen random terms were by-pair random intercepts and by-participant random slopes for the effect of scaled *Trial Order*. The main effects of *Word Frequency*, *Language Mode*, and *Block* and the interaction between *Word*

[8] The 10-JM dominant participants seem to show a different pattern in reaction times. However, the variance was too big and we were not able to recruit enough such participants.

Frequency and *Language Mode* were significant. However, the main effect and interactions of *Tonal Identity* were not.

Since the monolinguals listened to all the SC items in one block, two separated LME models were built to compare the bilinguals' RTs in different blocks with the monolinguals' RTs, as shown in Appendices 2 & 3. Both models included *Tonal Identity*, *Word Frequency*, *Language Mode* (in SC by monolinguals, in SC by bilinguals, and in JM by bilinguals), scaled *Trial Order*, and the two-way and three-way interactions of the first three factors as the fixed predictors. The chosen random terms were also by-pair random intercepts and by-participant random slopes for the effect of scaled *Trial Order*. The main effects of *Word Frequency* were significant for both blocks. However, the main effect of *Language Mode* was only significant in the model for the second block but insignificant in the model for the first block. The main effect and interactions of *Tonal Identity* were still insignificant in these two models.

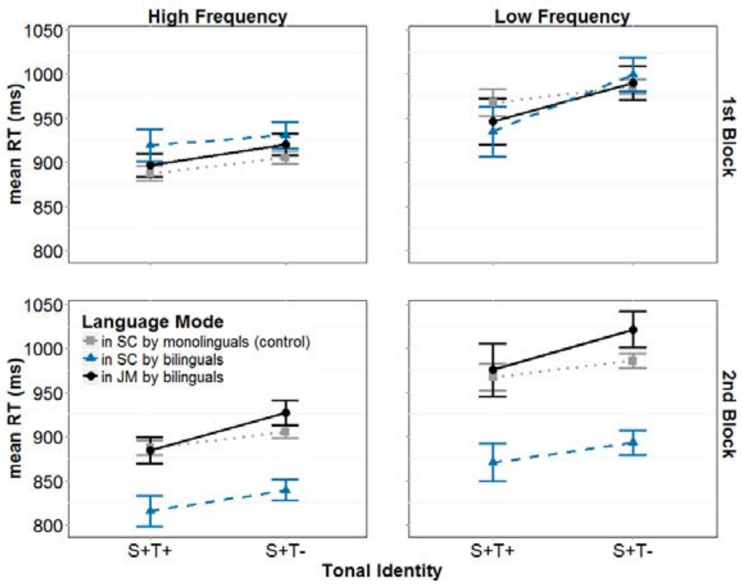

Figure 3. *Mean RT (ms, correct lexical decisions only) for equivalent pairs with and without tonal similarity (S+T+ v.s. S+T−) broken down by three groups of listeners (JM bilinguals, SC bilinguals, SC monolinguals = control). Results are separated for high frequency (left column) and low frequency words (right column) and for first (top row) and second (bottom row) stimulus blocks. Error bars are +/− 1 SE.*

According to the Post-hoc analysis of Differences of Least Squares Means (DLSM) for these models and the descriptive statistics shown in Figure 3, high-frequency words were processed significantly faster than low-frequency words and SC items were processed faster than JM items by the bilinguals in the second block, showing a language dominance effect. The language dominance effect was greater for low-frequency words than for high-frequency words. The bilinguals' RTs in the first block were not different from the monolinguals' RTs but in the second block bilinguals responded significantly faster than the monolinguals to the SC items. Nevertheless, the S+T+ items were not significantly faster than the S+T− items under any condition.

Reversed tonal similarity effects for S+T− and S+T+ items.

The following models investigate the discontinuity of tonal similarity effects on tonal bilinguals. Note that the Tonal Similarity ratings used here were scaled and centralized for the S+T+ and S+T− items separately. The general difference of Tonal Similarity between the S+T+ and S+T− items was removed in this analysis.

Two separated LME models were first built for the bilinguals' RTs to the S+T+ and S+T− items, as shown in Appendices 4 &5. Both models included scaled *Tonal Similarity*, *Word Frequency*, *Language Mode*, *Block*, and the two-way, three-way, and four-way interactions of the four factors as the fixed predictors. The chosen random terms for the S+T+ model were by-pair and by-participant random intercepts. The chosen random terms for the S+T− mode were by-pair random intercepts and by-participant random slopes for the effect of scaled *Trial Order*. The main effects of *Language Mode* and *Block* were significant in both models. As for the S+T+ items, the main effects of *Tonal Similarity* and *Word Frequency* were insignificant, but the interaction of *Tonal Similarity*, *Language Mode*, and *Block* was significant. As for the S+T− items, the main effect of *Tonal Similarity* and *Word Frequency* was significant. The two-way interactions of *Tonal Similarity* and *Language Mode*, of *Word Frequency* and *Language Mode*, and the three-way interactions of *Tonal Similarity*, *Language Mode*, and *Block*, of *Word Frequency* and *Language Mode* and *Block* were also significant.

As shown by the model estimates in Figure 4, with S+T+ items, RT increased with the increase of tonal similarity or at least did not decrease with it. *Tonal Similarity* interacted with *Language Mode* differently in the first and second blocks. In the first block, the RT difference introduced by *Language Mode* increased with the increase of *Tonal Similarity*. In the second block, the RT difference introduced by *Language Mode* decreased with the increase of *Tonal Similarity*. Also, SC items were processed faster than their JM counterparts in the second block. S+T− items showed a very different pattern, i.e. RT decreased with the increase of tonal similarity. In the first block, only the *Word Frequency* effect was salient. However, in the second block, not only the effect of *Word Frequency* but also the effect of *Language Mode* was salient. Low-frequency JM words seemed to be the least sensitive to the increase of tonal similarity and the RT difference introduced by *Language Mode* increased with *Tonal Similarity* for low frequency words.

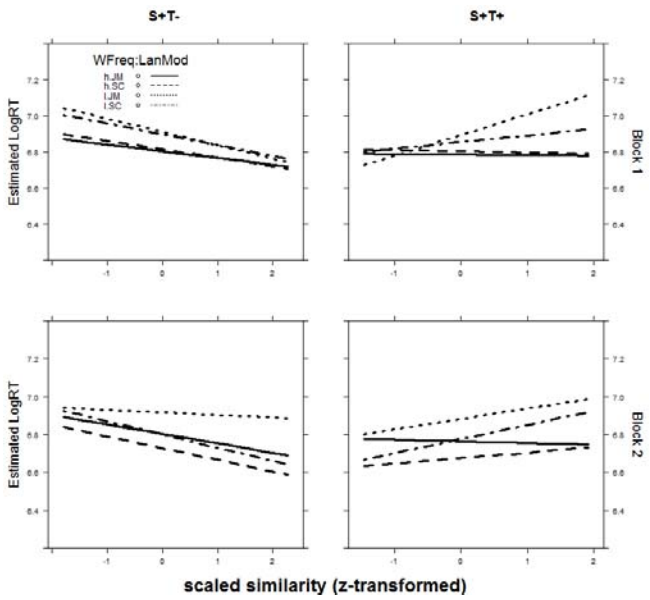

Figure 4. *Mean (estimated) bilingual lexical decision time (natural logarithm, ms) as a function of (z-normalized) judged tonal similarity between SC and JM counterparts presented separately for words with high and low Word Frequency and Language Mode. Linear regression lines are indicated for each combination of Word Frequency and Language Mode. Results are paneled by stimulus block (top row: first block, bottom row: second block) and by absence versus presence of tonal identity (left column: S+T−; right column: S+T+).*

However, similar decrease of RTs with the increase of tonal similarity was also found in the monolinguals' RTs to the S+T− items, $F (1) = 17.31$, $p < 0.001$, as shown in Appendices 6 & 7. To investigate the real tonal similarity effect, we compared the effect of *Tonal Similarity* on the bilinguals with the effect obtained for the monolinguals. Since *Block* showed important interactions with the other predictors, two LME models were built for the bilinguals' RTs in the first and second blocks respectively, as shown in Appendices 8 & 9. Both models included scaled *Tonal Similarity*, *Word Frequency*, *Language Mode* (in SC by monolinguals, in SC by bilinguals, and in JM by bilinguals), scaled *Trial Order*, and the two-way and three-way interactions of the first three factors as the fixed predictors. The main effects of *Tonal Similarity* and *Word Frequency* were significant in both the first and the second blocks. However, the interaction of *Tonal Similarity* and *Language Mode* was only significant in the second block.

As shown by the model estimates in Figure 5, although the bilinguals were not different from the monolinguals in the first block of S+T− items, in the second block the bilinguals showed a steeper slope to SC items compared with the slopes of monolinguals, indicating a real facilitation (i.e. shortening the lexical decision time) with the increase of tonal similarity. The bilinguals' slopes to JM items were not different from the slopes by monolinguals in the first block and shallower than the slopes by monolinguals in the second block, indicating an actual interference in RTs with the increase of tonal similarity.

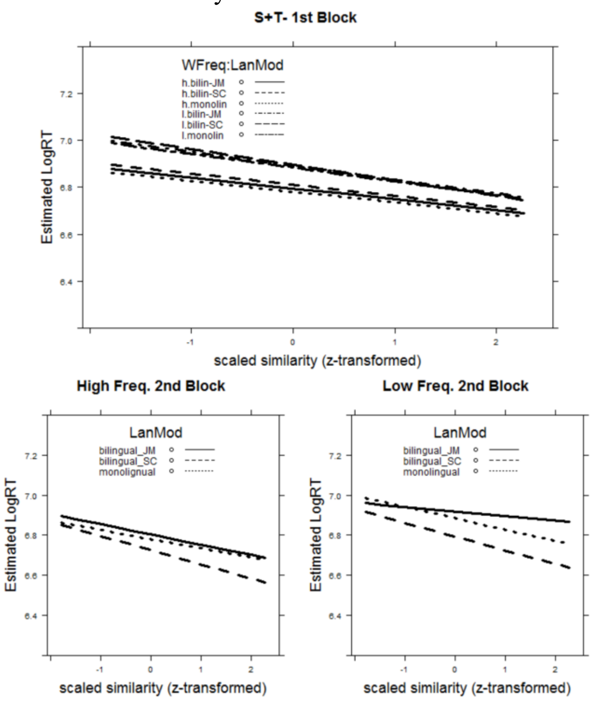

Figure 5. *Mean (estimated) lexical decision time (natural logarithm, ms) obtained for S+T− items as a function of (z-normalized) judged tonal similarity between SC and JM counterparts. Results are paneled by Block (top row: first block, bottom row: second block) and by Word Frequency (left column: high-frequency; right column: low frequency) in the second row. In the upper panel, linear regression lines are indicated for each combination of Word Frequency, Listener Group, and Language Mode (WFreq: h = high, l = low; LanMod: bilin-JM = bilinguals in JM, bilin-SC = bilinguals in SC; monolin = monolinguals in SC). In the lower panel, linear regression lines are indicated for each combination of listener group and Language Mode.*

4.4 Discussion

4.4.1 Main findings

As predicted by the dialect-dependent separate representation hypothesis, the discontinuity of tonal similarity effects and the language-dominance effect were verified on SC-JM tonal bilinguals. First, no significant difference in lexical decision times was found between S+T+ and S+T− translation equivalents. This finding can be understood if we assume that both S+T− and S+T+ translation equivalents are subject to lateral inhibition between two separate lexical nodes. Second, tonal similarity showed different effects on S+T+ and S+T− translation equivalents. Although the main effect was insignificant, the increase of tonal similarity in many conditions increased the reaction times to the S+T+ items, revealing a prevalence of lateral inhibition effects. However, the increase of tonal similarity instead reduced the reaction times to the S+T− items, revealing a prevalence of facilitatory coactivation. Third, and more importantly, a language dominance effect was found on the SC words against their JM counterparts in the second block. Such a language dominance effect should only be found for translation equivalents, if these are stored separately. All these findings are consistent with the predictions from the dialect-dependent separate representation hypothesis.

Tonal similarity also showed different complex interactions with *Language Mode* and *Block* on S+T+ and S+T− translation equivalents, some of which were not predicted by any of the candidate hypotheses. Here we first consider the interactions in the second block, where a general language dominance effect was found (see the lower plots in Figure 3). The increase of tonal similarity reduced the RT difference between the SC and JM translation equivalents if they were tone identical (S+T+) but increased such RT difference if the translation equivalents were tonally non-identical (S+T−) (see the interaction of *Language Mode* and *Tonal Similarity* in the lower panel of Figure 4 and the lower panel of Figure 5.) The RT difference between the SC and JM translation equivalents reveals a language dominance effect. Thus, language dominance effects are modulated by tonal similarity in different ways with the S+T+ and S+T− translation equivalents. These findings again suggest that tonal similarity influences the bilingual lexical access of S+T+ and S+T− translation equivalents in different ways and are in line with the claim that both types of translation equivalents should be stored as two separate representations. Looking at such interactions from another perspective, the interaction with *Language Mode* plays an important role in modulating the way *Tonal Similarity* takes effect. With S+T+ translation equivalents, although the processing of the other types of items was negatively affected by the increase of tonal similarity, the processing of high-frequency JM items was not sensitive to tonal similarity at all (see the lower right panel in Figure 4). Also with S+T− translation equivalents, further comparison with monolinguals showed that tonal similarity actually only facilitated the bilinguals' responses to the SC items but interfered with the bilinguals' responses to the JM items (see the lower right panel in Figure 5). Taken together, with S+T+ translation equivalents, tonal similarity reduces the language dominance effect and interferes with the lexical access of SC words and low-frequency JM words. With S+T− translation equivalents, tonal similarity strengthens the language dominance effect, facilitates the lexical access of SC words, but interferes with the lexical access of low-frequency JM words; and the lexical access of high-frequency JM words is not sensitive to tonal similarity. Note that these findings only apply to the second block. In the first block, the S+T+ translation equivalents showed a reversed interaction of *Language Mode* and *Tonal Similarity* (strengthens the language dominance effect) on the low frequency words and showed no effect or interaction on the high frequency words; and the S+T− translation equivalents were only sensitive to *Word Frequency*. The theoretical interpretations for these interactions are provided in the following section.

4.4.2 Theoretical implications

Just like lexical stress (Levelt et al., 1999; Schiller & Costa, 2006), lexical tone functions like abstract lexical frame. Just like minimal stress pairs (Cutler & Van Donselaar, 2001), tonal minimal pairs have distinctive lexical representations (Wu et al., 2014). Lexical tone not only distinguishes lexical representations with different meanings within one language (Wu et al., 2014) but also distinguishes the lexical representations of translation equivalents in the bilingual lexicons, which is supported by the current finding that language dominance affects the reaction times of translation equivalents which are only different in tone. Moreover, it seems that language mode itself is sufficient for distinguishing bilingual lexical representations in the current case of bilingualism because even when the translation equivalents were not only segmentally but also tonally identical, the language dominance effect persisted.

The language dominance effects we found support separated-representations for all the orthographically identical translation equivalents. Since both S+T+ and S+T− stimuli in the current study are comparable to the orthographically identical Dutch-English cognates used in (Dijkstra et al., 2010), our claim seems inconsistent with the earlier claim that the orthographically identical cognates share one common lexical representation (Dijkstra et al., 2010). However, this inconsistency may be attributed to two causes. First, the previous study used visual stimuli and the current study used auditory stimuli. The inconsistent findings invite us to consider the possibility that the underlying lexical representations accessed via the auditory route may differ from those accessed via the visual route. Second, Dutch and English are two different languages but SC and JM are two closely related tonal dialects. As shown in a previous study (Lemhöfer et al., 2008), the different cognate status of translation equivalents in different language combinations affect L2 word identification. It is reasonable to believe that a bilingual lexicon dominated by etymologically related translation equivalents would function differently from a bilingual lexicon where etymologically related translation equivalents (cognates) only exist sporadically. The bilingualism involving closely related dialects needs further investigation.

The language dominance effect in the current study is related but not directly comparable to the asymmetrical cognate facilitation effects found in earlier studies. L2 words with L1 cognates were more likely to show cognate facilitation effects than vice versa (Brenders et al., 2011) and L1 words with L2 cognates were more likely to show cognate facilitation effects than L1 words with L3 cognates (Van Hell & Dijkstra, 2002). Both studies used language-specific words as controls. However, in the current study too few unrelated control words were available and hence were not included. Instead, the monolinguals' reaction times to the same SC words were used as monolingual controls. The difference in the type of control makes the current results not directly comparable to the earlier findings. The tonal bilinguals' reactions to the JM words were not faster than the monolinguals' reaction times to the SC counterparts. However, the bilinguals' reactions to the SC words were even faster than the monolinguals'. Thus, if what we found counts as cognate facilitations, the cognate facilitation is stronger on the dominant dialect SC, which is different from the earlier findings where the cognate facilitation was stronger on L2. Such difference can again be attributed to the different structure of bilingual mental lexicon as previously discussed. Nevertheless, the SC-JM bilinguals are simultaneous bilinguals and both dialects are their L1. The difference of sequential and simultaneous bilingualism can be another resource of the different direction of asymmetry.

The language dominance effect found on these tonal bilinguals even made the same SC words accessed faster by the bilinguals than by the monolinguals, yielding an unusual bilingual lexical advantage. Most previous studies showed that bilinguals are slower in lexical access compared with monolinguals (Bialystok, 2009; Martin et al., 2012; Ransdell & Fischler, 1987). The bilingual lexical disadvantage was explained by the way that bilinguals have a denser lexical neighborhood and hence suffer from more lateral inhibitions than monolinguals (Ransdell & Fischler, 1987). This mechanism is also verified by computer simulation: just like adding words from the original language, adding words from a new language increases reaction times (Dijkstra, 2003). More importantly, even with the same cognates, the bilinguals were still mostly found to be slower than the monolinguals in cognate production (Costa et al., 2000) and in visual word recognition (Dijkstra et al., 1999; Lemhöfer, Dijkstra, & Michel, 2004; Lemhöfer et al., 2008; Mulder, Dijkstra, Schreuder, & Baayen, 2014). This is not surprising because in the cases of bilingualism studied previously, cognates are usually orthographically and phonologically non-identical and hence the neighborhoods are also denser than those of the monolinguals. However, as discussed in the previous paragraphs, the SC-JM bilingual lexicon is dominated by orthographically identical and phonologically related translation equivalents. Moreover, the language dominance effect on the translation equivalents support that the SC and JM translation equivalents are stored as separated lexical nodes. Thus, in a similarly dense neighborhood, the two lexical nodes for the SC-JM translation equivalents may interact in a different way compared with the separated lexical nodes stored in the Dutch-English bilingual lexicon. The segmentally identical translation equivalents in the JM-SC bilingual lexicon may benefit more from the coactivation and suffer less from the lateral inhibition. Furthermore, the facilitatory coactivation may be in dominance in the SC-JM bilingual lexicon (with tonal similarity providing minute adjustments on this basis) and provide the bilinguals some advantage in lexical access compared with the monolinguals.

Tonal similarity showed discontinuous effects on the S+T+ and S+T− translation equivalents. The discontinuous effects of tonal similarity are in line with the earlier findings. Dijkstra et al. (2010) also found discontinuous effects of phonological similarity. The increase of phonological similarity facilitated the lexical decision of orthographically identical Dutch-English cognates but not on the orthographically non-identical cognates (Dijkstra et al., 2010). The discontinuity was attributed to the lateral inhibition effects introduced by the additional lexical representation of the orthographically near-identical cognates (Dijkstra et al., 2010). Lateral inhibition increases with the increase of similarity between the representations concerned. Indeed, in the current study, with the S+T+ translation equivalents, we found reaction times increased with the increase of tonal similarity on the SC words, revealing a dominant lateral inhibition effect. However, such effects were scarce on the comparable S+T− translation equivalents, where facilitatory coactivation was dominant instead.

Moreover, the discontinuous interactions of tonal similarity with language modes suggest that lexical nodes from the dominant dialect may be more sensitive to both the facilitatory coactivation and the lateral inhibition. The RT difference between a pair of translation equivalents reveals language dominance effect (W. J. B. Van Heuven et al., 1998). The SC-dominant tonal bilinguals responded faster to the SC words than their JM counterparts because they use the SC versions more often. However, the increase of tonal similarity reduced the language dominance effect on S+T+ translation equivalents but enhanced the language dominance effect on S+T− translation equivalents. One possible interpretation is that the translation equivalents with smaller language dominance effect have more balanced relative frequency of the SC and JM forms. However, there is no reason to assume a relation between the between-dialect tonal similarity and the relative frequency of word usage. Another interpretation may be more reasonable. Lexical nodes from the dominant dialect SC are more sensitive to both the facilitatory coactivation and the lateral inhibition than their counterparts from the less dominant dialect JM. As a result, with the S+T+ translation equivalents, where the reaction times increase with the increase of tonal similarity, the reaction times to the SC words increased faster and approached the reaction times to their JM counterparts; and with the S+T− translation equivalents, where the reaction times decrease with the increase of tonal similarity, the reaction times to the SC words decreased faster and deviated even more from their JM counterparts.

Most of the above-mentioned findings were only found in the second block. In the first block, except for some general word frequency effects, no language dominance effect and not many tonal similarity effects were found. Such block effects need to be put in context of bilingual cognitive control.

The differences between the first and second block seem to be more related to the bilinguals' general control of attention. Previous studies have shown that bilingual lexical access may be more or less language-selective depending on the language mode (language-specific vs. general) (Dijkstra, De Bruijn, Schriefers, & Ten Brinke, 2000) and the construction of list (mixed vs. monolingual) (Brenders et al., 2011; Caramazza & Brones, 1979; Dijkstra, De Bruijn et al., 2000; Dijkstra, Timmermans, & Schriefers, 2000). In the current study, the language mode was implicitly hinted and the participants first came across a monolingual list and then switched to the other dialect. It could be that the bilinguals' attention was first directed to the first-appeared dialect alone and tuned into a more selective mode of lexical access until the second block started. When the second block started, the bilinguals noticed that the dialect changed and they were in a bilingual situation, they became less selective and that is why most of the bilingual effects emerged in the second block.

Two alternative explanations can be ruled out. First, the block asymmetry is not due to asymmetrical translation priming. Translation equivalents can prime each other (Duyck & Warlop, 2009) but forward translation priming (dominant language to non-dominant language or L1 to L2) is more robust than backward translation priming (non-dominant language to dominant language or L2 to L1) (Alvarez, Holcomb, & Grainger, 2003; Finkbeiner, Forster, Nicol, & Nakamura, 2004; Gollan, Forster, & Frost, 1997; Midgley, Holcomb, & Grainger, 2009). Such asymmetrical translation priming is not applicable in the current study because the two members of the same pair of translation equivalents were never presented to the same participant in the current study.

Second, since the second block is always in a different dialect compared to the first block, the current block-dependent asymmetry may relate to the asymmetrical switching costs. Switching from the non-dominant language to the dominant language causes greater switching cost than vice versa in speech production (Costa & Santesteban, 2004; Meuter & Allport, 1999). Similar asymmetrical global switching costs between different language blocks were also found when bilinguals name the same set of pictures first in L1 and then in L2 (Guo, Liu, Misra, & Kroll, 2011). However, when cognates were embedded in monolingual sentences, neither local switching cost was found when switching the language of the sentence, nor different magnitudes of cognate facilitation were found between blocks when the language of the sentences was blocked (Gullifer, Kroll, & Dussias, 2013). The blocking of the current study is similar to the case of global switching (Guo et al., 2011), except that it taps into recognition instead of production and bilinguals never heard the two members of the same pair of translation equivalent repeated. However, our finding is still different. Instead of observing greater switching costs in the block of the dominant dialect (Guo et al., 2011) or null effect of global switching (Gullifer et al., 2013), words from the dominant dialects SC were not only processed faster than their JM counterparts in the second block but also faster than the same SC words processed by the monolinguals controls. Thus what we found is a language dominance effect and a bilingual lexical advantage but not a classical asymmetrical switching cost.

In sum, the new findings of language dominance effects and bilingual lexical advantage by the SC-JM tonal bilinguals remind us to pay more attention to the structure of the bilingual lexicon. A bilingual lexicon filled with etymologically related translation equivalents may be organized and function differently from a bilingual lexicon dominated with etymologically irrelevant translation equivalents. The new findings of discontinuous tonal similarity effects and its interaction with the language dominance effect provide us further insights into the role of lexical tones in the bilingual lexical representation and lexical access. The strengths of facilitatory coactivation and lateral inhibition may be not only related to the similarity of the translation equivalents but also dynamically modulated by the language mode and the bilinguals' attention. These findings together with the block effect also suggest that bilingual lexical access may be more or less language-selective depending on the bilinguals' language environment.

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Appendices

Appendix 1. The model investigating the effects on the bilinguals

Fixed effects	Df	F	p
Tonal Identity	45.43	0.92	> 0.05 (ns)
Word Frequency	45.45	6.96	< 0.05
Language Mode (JM/ SC)	1683.73	53.77	< 0.001
Block	1685.13	46.03	< 0.001
Scaled Trial Order	38.2	0.93	> 0.05 (ns)
Tonal Identity × Word Frequency	45.43	0.04	> 0.05 (ns)
Tonal Identity × Language Mode	1683.58	0.26	> 0.05 (ns)
Word Frequency × Language Mode	1697.71	6.60	< 0.05
Tonal Identity × Block	1679.9	0.65	> 0.05 (ns)
Word Frequency × Block	1695.77	2.20	> 0.05 (ns)
Language Mode × Block	41.77	2.10	> 0.05 (ns)
Tonal Identity × Word Frequency × Language Mode	1692.27	0.038	> 0.05 (ns)
Tonal Identity × Word Frequency × Block	1691.18	0.863	> 0.05 (ns)
Tonal Identity × Language Mode × Block	1679.99	0.096	> 0.05 (ns)
Word Frequency × Language Mode × Block	1687.32	0.503	> 0.05 (ns)
Tonal Identity × Word Frequency × Language Mode × Block	1682.15	0.015	> 0.05 (ns)
Random effects		χ^2	
1 + Scaled Trial Order |participant		28.93	<0.001
1 | pair		679.12	<0.001

Appendix 2. The model investigating the effects in Block 1

Fixed effects	Df	F	p
Tonal Identity	47.26	0.61	> 0.05 (ns)
Word Frequency	47.25	9.64	< 0.01
Language Mode (in SC by monolingual/ in SC by bilingual/ in JM by bilingual)	94.21	0.01	> 0.05 (ns)
Scaled Trial Order	71.38	9.05	< 0.01
Tonal Identity × Word Frequency	47.22	0.05	> 0.05 (ns)
Tonal Identity × Language Mode	2802.56	0.41	> 0.05 (ns)
Word Frequency × Language Mode	2825.11	2.56	> 0.05 (ns)
Tonal Identity × Word Frequency × Language Mode	2818.32	0.32	> 0.05 (ns)
Random effects		χ^2	
1 + Scaled Trial Order |participant		69.41	<0.001
1 | pair		993.96	<0.001

Appendix 3. The model investigating the effects in Block 2

Fixed effects	Df	F	p
Tonal Identity	47.23	1.32	> 0.05 (ns)
Word Frequency	47.21	11.06	< 0.01
Language Mode (in SC by monolingual/ in SC by bilingual/ in JM by bilingual)	95.84	5.63	< 0.01
Scaled Trial Order	63.75	0.81	> 0.05 (ns)
Tonal Identity × Word Frequency	47.16	0.01	> 0.05 (ns)
Tonal Identity × Language Mode	2812.86	2.3	> 0.05 (ns)
Word Frequency × Language Mode	2836.11	2.91	> 0.05 (ns)
Tonal Identity × Word Frequency × Language Mode	2818.39	0.12	> 0.05 (ns)
Random effects		χ^2	
1 + Scaled Trial Order |participant		77.1	<0.001
1 | pair		966.22	<0.001

Appendix 4. The model investigating the effect of Tonal Similarity on S + T + items by the bilinguals

Fixed effects	Df	F	p
scaled Tonal Similarity	10.12	2.16	> 0.05 (ns)
Word Frequency	10.2	4.00	> 0.05 (ns)
Language Mode	487.83	19.31	< 0.001
Block	487.63	23.58	< 0.001
scaled Tonal Similarity × Word Frequency	10.12	1.86	> 0.05 (ns)
scaled Tonal Similarity × Language Mode	505.89	0.23	> 0.05 (ns)
Word Frequency × Language Mode	486.49	2.28	> 0.05 (ns)
scaled Tonal Similarity × Block	506.44	0.02	> 0.05 (ns)
Word Frequency × Block	485.81	1.46	> 0.05 (ns)
Language Mode × Block	44.62	1.87	> 0.05 (ns)
scaled Tonal Similarity × Word Frequency × Language Mode	493.41	3.26	> 0.05 (ns)
scaled Tonal Similarity × Word Frequency × Block	493.88	1.01	> 0.05 (ns)
scaled Tonal Similarity × Language Mode × Block	482.3	7.89	<0.01
Word Frequency × Language Mode × Block	483.4	0.65	> 0.05 (ns)
scaled Tonal Similarity × Word Frequency × Language Mode × Block	482.4	1.3	> 0.05 (ns)
Random effects		χ^2	
1 |participant		178.15	<0.001
1 | pair		109.9	<0.001

Appendix 5. The model investigating the effect of Tonal Similarity on S + T− items by the bilinguals

Fixed effects	Df	F	p
scaled Tonal Similarity	31.93	10.39	< 0.01
Word Frequency	31.53	8.46	< 0.01
Language Mode	1156.74	45	< 0.001
Block	1155.82	37.95	< 0.001
scaled Tonal Similarity × Word Frequency	31.91	0.03	> 0.05 (ns)
scaled Tonal Similarity × Language Mode	1165.66	4.56	< 0.05
Word Frequency × Language Mode	1164.52	5.15	< 0.05
scaled Tonal Similarity × Block	1152.41	0.54	> 0.05 (ns)
Word Frequency × Block	1160.53	0.02	> 0.05 (ns)
Language Mode × Block	39.87	2.61	> 0.05 (ns)
scaled Tonal Similarity × Word Frequency × Language Mode	1187.86	0.43	> 0.05 (ns)
scaled Tonal Similarity × Word Frequency × Block	1180.69	5.8	< 0.05
scaled Tonal Similarity × Language Mode × Block	1161.96	6.04	< 0.05
Word Frequency × Language Mode × Block	1154.31	0.39	> 0.05 (ns)
scaled Tonal Similarity × Word Frequency × Language Mode × Block	1162.22	5.35	< 0.05
Random effects		χ^2	
1 + Scaled Trial Order |participant		15.87	<0.001
1 | pair		397.03	<0.001

Appendix 6. The model investigating the effect of Tonal Similarity on S + T + items by the monolingual controls

Fixed effects	Df	F	p
scaled Tonal Similarity	10.05	0.82	> 0.05 (ns)
Word Frequency	10.1	6.76	< 0.05
Scaled Trial Order	44.81	7.32	< 0.01
scaled Tonal Similarity × Word Frequency	10.04	0.7	> 0.05 (ns)
Random effects		χ^2	
1 + Scaled Trial Order |participant		17.92	<0.001
1 | pair		127.33	<0.001

Appendix 7. The model investigating the effect of Tonal Similarity on S + T− items by the monolingual controls

Fixed effects	Df	F	p
scaled Tonal Similarity	31.38	17.31	< 0.001
Word Frequency	31.16	16.84	< 0.001
scaled Tonal Similarity × Word Frequency	31.4	0.25	> 0.05 (ns)
Random effects		χ^2	
1 + Scaled Trial Order |participant		28.08	< 0.001
1 | pair		287.58	< 0.001

Appendix 8. The model investigating the effect of Tonal Similarity on S+T− items in the first Block

Fixed effects	Df	F	p
scaled Tonal Similarity	33.93	15.84	< 0.001
Word Frequency	33.39	12.06	< 0.01
Language Mode	91.46	0.04	> 0.05 (ns)
Scaled Trial Order	67.98	4.62	<0.05
scaled Tonal Similarity × Word Frequency	34.78	0.27	> 0.05 (ns)
scaled Tonal Similarity × Language Mode	1952.56	0.23	> 0.05 (ns)
Word Frequency × Language Mode	1939.34	0.65	> 0.05 (ns)
scaled Tonal Similarity × Word Frequency × Language Mode	2008.74	0.05	> 0.05 (ns)
Random effects		χ^2	
1 + Scaled Trial Order |participant		24.48	< 0.001
1 | pair		505.10	< 0.001

Appendix 9. The model investigating the effect of Tonal Similarity on S+T− items in the second Block

Fixed effects	Df	F	p
scaled Tonal Similarity	33.54	15.06	< 0.001
Word Frequency	33.17	12.12	< 0.01
Language Mode	93.23	4.49	< 0.05
Scaled Trial Order	61.84	0.22	> 0.05 (ns)
scaled Tonal Similarity × Word Frequency	34.3	0.03	> 0.05 (ns)
scaled Tonal Similarity × Language Mode	1982.16	4.76	< 0.01
Word Frequency × Language Mode	1986.52	4.05	< 0.05
scaled Tonal Similarity × Word Frequency × Language Mode	2017.78	2.08	> 0.05 (ns)
Random effects		χ^2	
1 + Scaled Trial Order |participant		28.65	< 0.001
1 | pair		469.26	< 0.001