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Monolingual and Bilingual Recognition of Regular and Irregular English Verbs: Sensitivity to Form Similarity Varies with First Language Experience

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Abstract

We used a cross-modal priming procedure to explore the processing of irregular and regular English verb forms in both monolinguals and bilinguals (Serbian-English, Chinese-English). Materials included irregular nested stem (drawn-DRAW), irregular change stem (ran-RUN), and regular past tense–present tense verb pairs that were either low (guided-GUIDE) or high (pushed-PUSH) in resonance, a measure of semantic richness. Overall, semantic richness of irregular verbs (nested and irregular change) and of regular verbs (high and low resonance) was matched. Native speakers of English revealed comparable facilitation across regularity and greater facilitation for nested than change stem irregulars. Like native speakers, Serbian, but not Chinese bilinguals matched for proficiency, showed facilitation due to form overlap between irregular past and present tense forms with a nested stem. Unlike native speakers, neither group showed reliable facilitation to stem change irregulars. Results demonstrate the influence of first language on inflectional processing in a second language.

Keywords

semantic density; language transfer; morphological facilitation; cross modal priming; regular past tense formations; irregular past tense formations; mastery of inflection in a second language

There is a long-standing debate in the word recognition literature as to whether native speakers of a language process irregular (e.g., *ran-run*) and regular (e.g., *walked-walk*) verb forms by common (single) or different (dual-route) mechanisms. Those who advocate a single processing system argue that processing of all words benefits from the extent to which words that are similar in form tend to be similar in meaning (Li, 2006; McClelland & Elman, 1986; Rueckl, Mikolinski, Raveh, Miner & Mars, 1997; Rueckl & Raveh, 1999; Rumelhart & McClelland, 1986; Seidenberg & Elman, 1999). Advocates of a more traditional dual route

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account claim that recognition of regular past-tense verbs (*talk-talked*) uses a rule-based process where an *-ed* past tense marker is affixed to the present tense form of the verb. The English language, however, possesses many irregular verbs (about 180) where the past tense does not include an *-ed* ending. As a result, all past tense forms do not preserve the (present tense) stem so that many past and present forms differ in their orthographic and phonological form. When past tense forms of irregular verbs cannot be formed by rule, purportedly they must be stored in rote memory (Pinker, 1991). More recently, it has been suggested that irregular verbs are stored as separate lexical entries in an associative memory system that is responsible for verb transformations that involve changes in “phonology but not in overt morphological sequencing [of components]” (Ullman, 2000, p. 135). In contrast, regular verb forms are more likely to use computational methods to form past tense forms. This implies that the base morpheme of common regular verbs (e.g., *talk*) is stored in the lexicon, and *-ed*, *-ing*, and *-s* endings must be added to the stem in order to form inflected word forms (e.g., *talked*, *talking*, *talks*) (Ullman, 2000).

Dual mechanism account of regular and irregular verb form processing: Dissociations

Support for differences in processing of regular and irregular verb types derives in part from manipulations of frequency. The logic is that if irregular verbs were stored in rote memory, then verb recognition should pattern according to “properties of associative memory, such as frequency and similarity” (Pinker, 1991, p. 531). In one study (Prasada, Pinker, & Snyder (1990), cited in Pinker, 1991), participants produced aloud the past tense form of verb stems that appeared on a computer screen. When stem frequencies were matched, latencies to irregular verbs with high past tense frequencies were significantly faster than to those irregular verbs that had low past tense frequencies. On the other hand, regular verb forms did not show systematic variation in production time when frequencies differed, and the null effect was interpreted as support for a rule-based process for regular morphological forms. Likewise, in studies where participants rated the acceptability of regular and irregular noun forms in sentence contexts, only for irregular forms did scores correlate with frequencies (Berent, Pinker, & Shimron, 2002; Ullman, 1999a).

Dissociations in processing between regular and irregular verb types in neurologically impaired clinical populations also are interpreted as evidence of distinct processing mechanisms. In support of the distinction, individuals suffering from Alzheimer’s disease appear to have more difficulty producing past tense forms of irregular verbs as compared to regular forms (Miozzo, 2003). In contrast, Parkinson’s disease patients appear to manifest greater errors in producing regular than irregular verbs (Ullman, Corkin, Pinker, Coppola, Locascio, & Growdon, 1993). Finally, individuals with Specific Language Impairment (SLI), a developmental disorder, less accurately form regular verb forms as contrasted with irregular verb forms (Pinker, 1991; Ullman, 2000). In summary, clinical evidence of dissociations in processing is consistent with differential processing across verb types.

Single processing mechanism account: Semantic density and form similarity varies between regulars and irregulars

Many interpret the dissociations associated with regularity of past tense formation as support for a dual system account of processing, although some recent work challenges the claim. Whereas, previous studies have acknowledged that regular and irregular past tense forms differ from their stems with respect to orthographic and phonological similarity, recent evidence suggests that regular and irregular verb types also differ with respect to “subtle graded semantic distributional properties” (Baayen & Moscoso del Prado Martín, 2005, p. 2). By implication,

not only form similarity but also semantic density may contribute to purported regularity effects (see also Ramscar, 2002; Seidenberg, 2005).

In a corpus-based analysis of irregular and regular verbs in three Germanic languages (English, Dutch, and German), Baayen and Moscoso del Prado Martín (2005) examined the number of synsets (synonym sets) for each of 1,600 (146 irregular and 1454 regular) English verbs (Miller, 1990) and determined that when frequency was controlled, irregular verbs typically had more synsets than did regular verbs. Not only did irregulars tend to differ semantically from regulars with respect to number of meanings but also, substitution of a single letter in a regular verb was more likely to generate an orthographic neighbor that was an irregular verb. Further, analyses of behavioral data from the University of South Florida word association norms (Nelson, McEvoy, & Schreiber, 1998) revealed that irregulars in English have higher connectivity (i.e., the number of connections between associates of a word), larger cue set sizes (i.e., the number of associates given to a word) and greater resonance strength (i.e., the sum of the forward and backward strength for each associate) values than do regulars (Baayen & Moscoso del Prado Martín, 2005). Finally, decision (but not naming) latencies obtained from the Balota database (Balota, Cortese, Hutchison, Neely, Nelson, Simpson, & Treiman, 2002) for these verbs differed significantly with regularity. Semantic influences on decision latencies are consistent with the observation that the lexical decision task is more amenable to semantic influences, whereas the pronunciation task is more influenced by form (Baayen, Feldman, & Schreuder, 2006).

Stated generally, evidence is accruing that irregular and regular verbs differ not only in form similarity among relatives, but also in semantic density and the interconnectivity of meanings. In essence, the corpus-based analyses reported by Baayen and Moscoso del Prado Martín (2005) have profound implications for any study that purports to interpret differences in the recognition of regular and irregular inflectional relatives in terms of differing processing mechanisms.

The cross-modal priming paradigm: a methodology to explore the processing of regular and irregular verb forms

Differences between irregular and regular verb forms emerge when auditory prime words precede target words that are visual (Allen & Badecker, 2002; Marslen-Wilson, Hare, & Older, 1993). A typical outcome in the cross-modal priming paradigm is that regular verbs produce facilitation, while irregular verb forms (i.e., *gave-give*) do so only when they serve as primes and precede targets that are stems (Marslen-Wilson et al. 1993).

Some argue that the cross-modal priming task is preferable to the forward masked priming task because it minimizes the influence of form similarity for native speakers (Marslen-Wilson et al., 1993; Marslen-Wilson, Tyler, Waksler, & Older, 1994), as well as for non-native speakers (Feldman, Kostić & Pastizzo, under review). However, there is evidence that the cross-modal priming procedure is not fully immune to form-based effects. Allen and Badecker (2002) observed inhibition for orthographically related words (e.g., *slam-slim*). Interestingly, facilitation was significant (45 ms) for dissimilar items (*fought-fight*), but was not present for irregular verbs that were highly similar in form (*wrote-write*). Allen and Badecker (2002) explained the absence of morphological facilitation for irregular verb forms with high orthographic overlap between the stem and inflected form, by implicating inhibition similar to what arises for orthographically related words in studies when the prime and target are both visual (Feldman, 2000; Feldman & Andjelković, 1992; Grainger, Colé, & Segui, 1991; Stolz & Feldman, 1995). A high percentage of irregular verbs in the English language are highly similar in form (*wrote-write*) and many of the irregulars in previous studies adhered to this pattern (Marslen-Wilson et al., 1993). Therefore, perhaps it is not surprising that evidence of

irregular morphological facilitation has not been documented consistently. In conclusion, consistent with the findings of Allen and Badecker (2002), the cross-modal priming paradigm can be sensitive to form similarity between prime and target. Moreover, facilitation can be observed for irregular verbs when similarity is manipulated systematically.

The Current Study

The goal of the current study was to compare magnitudes of facilitation in native (Experiment 1) and non-native (Experiments 2a & 2b) English speakers for regular and irregular verb forms presented cross-modally in the lexical decision task. One motivation for examining how these different verb types are processed in non-native speakers is because there is enhanced importance of a word's orthographic form and attenuation of its semantic properties relative to native speakers. Specifically, form similarity assumes a greater importance when proficiency is low and semantic representations are relatively impoverished (Talamas, Kroll, & Dufour, 1999). Secondly, in the past few decades, much of the work on language processing in bilinguals has focused on semantic memory and on the lexical organization of a bilingual's two languages (Chen & Ng, 1989; de Groot & Nas, 1991; Kroll & Stewart, 1994; see Altarriba & Basnight-Brown, in press, and Francis, 1999 for reviews). Even though this is and continues to be an important question, provocative findings in other domains of bilingual research (i.e., morphological, syntactic) are emerging.

Experiment 1

The primary focus of Experiment 1 was whether magnitudes of facilitation for native English speakers vary systematically with regularity when regular and irregular verbs were matched on semantics richness, a variable that has not been included in previous word recognition experiments. In addition, we examined magnitudes of facilitation for verbs (*irregular change*) that show changes in form between the stem and inflected form (e.g., bought-BUY), and for verbs (*irregular nested*) whose stems recur in the irregular past participle (e.g., drawn-DRAW), thereby retaining a higher degree of orthographic and phonological overlap). Insofar as both are irregular, but nested pairs are more phonologically and orthographically similar, single but not dual route accounts would posit greater magnitudes of facilitation for nested forms. Finally, we compared morphological facilitation for regular verbs that varied on resonance, a measure of semantic richness. Insofar as richness reflects connectivity between stored forms, its impact on decision latencies and on facilitation for regular word formation should be minimal in a dual route account.

Method

Participants—Forty-eight students from the University at Albany, State University of New York participated in partial fulfillment of the introductory to psychology course requirements. All were monolingual English speakers, with no known reading or speech disorders, and all had normal or normal-to-corrected vision.

Materials—Two hundred different letter strings served as targets, 100 were real words in English and 100 were nonwords derived from English words. Multiple aspects of semantic density: resonance strength, mean connectivity, cue set size, family size and neighborhood size were held constant across the irregular and regulars verbs (collapsed across both types of irregulars and both types of regulars) because each of these variables has been known to covary with recognition latencies.

Resonance strength (Nelson et al., 1998) is described as a measure that takes into account the number of associates that a word has, as well as their forward and backward associative strength with the target (see Baayen & Moscoso del Prado Martin, 2005 for the equation used to

determine resonance strength). Mean connectivity is the average number of connections *between* each pair of associates for a specific word. Cue set size is the number of associates for a word (Nelson et al., 1998). Lastly, family size and neighborhood size are described, respectively, as the number of different derived and compound words that share a base morpheme (e.g., *talk* – *talker*, *talkative*, etc.), and the number of words that differ from the target by a single letter and thus share similar phonology and orthography, but not meaning (e.g., *beat* – *meat*, *seat*, etc.). It is useful to note that one variable that often differs between regulars and irregulars, inflectional entropy, that is based on the distribution of frequencies of inflectional variants of a word, was not matched in the current study (see Baayen & Moscoso del Prado Martín, 2005, for further exploration of this variable). Planned comparisons, however, conducted on the means for each of the semantic factors of primary interest failed to reveal significant differences between the sets of regular and irregular verbs.

Twelve target words had irregular nested past-tense verb forms (i.e., present tense is nested in the irregular past tense participle target (e.g., drawn-DRAW)). None of these items required a sound change between the nested past and the present tense form, therefore items such as write-WRITTEN were not included. The number of nested items is small because they occur infrequently in the English language. In fact, we suspect that we may have exhausted the population of nested forms without sound and/or spelling changes with frequencies below 100/million. We assigned the remaining nested items, those with extremely high frequencies, to practice trials. Twenty-eight targets were irregular change verbs (i.e., irregular verb with stem change to form past tense (e.g., swung-SWING). Regular verbs varied with respect to resonance. Twenty target words were regular, no stem change verbs with low resonance (<.10, e.g., guided-GUIDE). Twenty target words were regular, no stem change verbs with high resonance values (>.10, e.g., pushed-PUSH). The remaining twenty word targets served as unrelated filler pairs. These items were included in order to decrease the relatedness proportion (RP) across the experiment, thereby minimizing the use of strategic processes by participants (see Neely, 1991). Stimulus attributes are summarized in Table 1 and stimuli are listed in Appendix A.

Morphologically related and unrelated primes were matched on frequency and length. Each prime word appeared as a past tense verb form, while the target word always appeared in the present tense form. The first letter and phoneme of the unrelated and related prime words were always the same, and were matched to that of the target. One hundred word-nonword pairs were created to imitate the form of the word-word pairs. Fifty of the word-nonword pairs emulated regular pairs by affixing “ed” on each prime word (e.g., elated-ELAT). Thirty-eight word-nonword pairs imitated an irregular change past tense by introducing a change to a vowel or consonant to the word prime (e.g., birth-BORTH). Twelve word-nonword pairs appeared as nested targets and included the addition of “n”, “pt”, or “en” at the end of the prime, so as to form a nonword target (e.g., slow-SLOWN). Of these, half of the word-nonword pairs retained form similarity and half were unrelated to the target.

Design—We created two counterbalanced lists, each of which consisted of 200 trials. The same targets appeared in each list and each target appeared only once per list, only the prime words differed across lists. Each participant was randomly assigned to one list that included both morphologically related and unrelated prime-target verb pairs. Prime and target words pairs were morphologically related on forty percent of the word-word trials and unrelated on sixty percent of the trials. Type of prime (morphological or unrelated) was a repeated factor in the analyses by participants and by items. Type of verb (irregular or regular) was a repeated factor by participants, but not by items. Irregular targets varied with respect to style of stem change (nested or irregular). Degree of resonance was matched across regular and irregular verbs but was manipulated within regular verbs.

Procedure—Each cross-modal priming trial consisted of an auditorily presented prime word and a visually presented target. Prime words were spoken by a native male English speaker and were recorded at a sampling rate of 44.1 kHz. Each prime was edited into a separate file using SoundEdit 16 and PRAAT version 4.2.12. Items were presented in a different random order for each participant. All stimuli were left justified in the center of the screen and were presented on a white screen in black lowercase 18 point Courier font.

Each trial began with a fixation “+” for 450 ms, followed by a 50 ms blank screen, before the auditory prime was presented. Immediately after the offset of the prime, the target appeared and remained on the screen until the participant responded, or until a maximum duration of 2000 ms had transpired. The inter-trial interval was 1000 ms. Participants made a lexical decision to each target on a PsyScope button box by pressing the right button (green) for words and the left button (red) for nonwords.

Results and Discussion

Three separate ANOVAs were conducted on the reaction time data for the irregular and for the regular verbs. Multilevel logistic regression analyses were conducted on the accuracy data because the dependent variable was dichotomous.¹ The primary analysis examined regulars and irregulars together, collapsed across (high versus low resonance) regulars and (nested versus irregular stem change) irregulars. Subsequent ANOVAs examined the irregular and regular verbs separately. In this and in subsequent experiments, reaction times more extreme than 3 SD from the participant’s mean were removed from the analyses (3.4%). The mean reaction time and error data are presented in Table 2. No participants or items were deleted due to high error rates.

When the data were collapsed for the 2 (Verb type: irregular vs. regular) $\times$ 2 (Relatedness: related vs. unrelated) ANOVA, the analyses revealed a main effect of verb type [$F_1(1, 47) = 44.562, p < .001$; $F_2(1, 78) = 12.973, p < .001$], indicating that participants were significantly faster to recognize regular than irregular verb targets. Here and in subsequent analyses full sets of F ratios (participants, items, minF’) based on latency data appear in Appendix B. Only significant F values are reported in the text and the 95% confidence interval from the analysis by participants is included with each difference score. The main effect of relatedness was significant [$F_1(1, 47) = 122.922, p < .001$; $F_2(1, 78) = 101.785, p < .001$], such that decision latencies to target words preceded by related primes were faster than to those preceded by unrelated prime words. Importantly, the interaction between verb type and relatedness was not significant [$F_1(1, 47) = 1.310, p = .258$]. In essence, with controls for semantic richness (resonance, mean connectivity, cue set size, family size, and neighborhood size), the +51 (± 15 ms) of facilitation for irregular verb types did not differ significantly from the +60 (± 13 ms) for regular verbs.

Multilevel logistic regression analyses collapsed over regularity with participants as a random effect revealed a main effect of relatedness and of stem type for the accuracy data [$F(1, 3837) = 6.376, p = .012$; $F(1, 3837) = 25.02, p < .001$, respectively], such that participants made more errors to unrelated items as compared to related, and to irregular as compared to regular stem type. Because irregular verbs differed on stem overlap (nested versus irregular change), whereas regular verbs differed on resonance, we also conducted separate ANOVAs on the irregular and regular response latency data.

Irregular Verbs—The results of a 2 $\times$ 2 (Stem type: nested vs. irregular change $\times$ Relatedness: related vs. unrelated) ANOVA on the irregular verbs alone revealed a main effect of stem type (nested vs. irregular change) in the analysis by participants [$F_1(1, 47) = 8.914, p = .004$], suggesting that participants recognized targets whose stem was nested in the past tense (drawn-DRAW) faster than the irregular stem change (swung-SWING) verb targets. A main effect of

relatedness also was reliable [$F_1(1, 47) = 49.668, p < .001$; $F_2(1, 38) = 47.830, p < .001$]. Most importantly, the interaction between stem type and relatedness was significant for participants [$F_1(1, 47) = 5.033, p = .03$], and marginally significant for items [$F_2(1, 38) = 3.207, p = .08$]. Accordingly, the +64 (± 21) ms priming effect for nested verbs [$t_1(47) = 5.97, p < .001$; $t_2(11) = 6.45, p < .001$], was marginally greater than the +38 (± 15) ms priming effect for irregular change [$t_1(47) = 5.13, p < .001$; $t_2(27) = 4.38, p < .001$]. For the accuracy data, multilevel logistic regression analyses revealed a main effect of relatedness and of stem type [$F(1, 1918) = 4.796, p = .029$; $F(1, 1918) = 3.847, p = .050$, respectively], indicating that there were more errors on unrelated than related pairs, and on verbs of the nested than the stem change stem type.

Regular Verbs—An additional 2×2 (Resonance: high vs. low $\times$ Relatedness) ANOVA conducted on the reaction time data for the regular verbs alone revealed a main effect of resonance [$F_1(1, 47) = 12.686, p < .001$], which as expected, showed that participants were faster to recognize the high resonance verbs than the low resonance verbs. A main effect of relatedness also was reliable [$F_1(1, 47) = 122.291, p < .001$, $F_2(1, 38) = 58.674, p < .001$]. Facilitation for both low and high resonance regular verbs was significant, with low resonance verbs producing numerically (but not statistically) greater facilitation (+65 ± 20 ms) [$t_1(47) = 6.482, p < .001$; $t_2(19) = 5.69, p < .001$], than high resonance verbs (+54 ± 16 ms) [$t_1(47) = 6.558, p < .001$; $t_2(19) = 5.13, p < .001$]. Multilevel logistic regression conducted on the error data revealed a main effect of relatedness [$F(1, 1916) = 2.992, p = .0839$], and a marginal interaction between resonance and relatedness [$F(2, 1916) = 3.005, p = .050$], such that low resonance verb targets, but not high, benefited from a morphologically related prime.

Finally, *t* tests with pair-specific error terms to evaluate magnitudes of facilitation (nested stem, irregular stem change, regular low resonance, and regular high resonance) revealed that the +64 (± 21) ms priming effect for the nested irregular verbs did not differ from either the +54 (± 16) ms or the +65 (± 20) ms effect for the regular verbs, although, as noted above, it did differ from the +38 (± 15) ms effect for the irregular change verbs. Collectively, results indicate that greater form overlap between morphological relatives (*viz.*, nested and regular verbs) significantly increased the magnitude of facilitation relative to the irregular stem change verbs.

Overall, in Experiment 1 we observed significant magnitudes of facilitation for all four types of past-present verb pairs. Recognition latencies for regular verbs matched on frequency revealed that resonance did influence overall decision latencies, such that high resonance verbs (preceded by either a related or an unrelated prime) were recognized faster than low resonance verbs. Even though the overall response latencies for semantically elaborated, relative to reduced words, were decreased, magnitudes of facilitation were similar, suggesting that a related prime benefits both types similarly. More importantly, when irregular and regular verbs were matched on multiple measures of semantic richness, magnitudes of facilitation were significant and did not differ. The outcome of Experiment 1 fails to provide evidence that different mechanisms underlie the processing of regular and irregular types of verbs. Rather, semantic differences between the regular and irregular verbs may have contributed to earlier reports of regularity-derived differences in facilitation.

With regards to the irregular verbs, more facilitation for stem nested (*i.e.*, drawn-DRAW) than for stem change (*i.e.*, swung-SWING) type verbs supports the claim that form overlap enhances facilitation. The finding extends that of Allen and Badecker (2002) who showed that form effects can arise in the cross-modal priming task in that we observed greater facilitation when the stems were nested within verb targets so as to retain greater similarity with their morphologically related primes than for typical (stem change) irregulars. As outlined in the methods section, however, our irregular stimuli differed from those of Allen and Badecker (2002) in that we included both irregular stem change and nested stem irregular verbs, whereas

their dissimilar and similar irregular verbs were both of the irregular stem change type. Further, the irregular change verbs in our study contained both similar and dissimilar verbs according to their classification. Finally, targets in the present study were of lower frequency, therefore larger effects may reflect the greater potential for facilitation for slower words. Collectively, any direct comparison between the two experiments must be made with caution.

Experiment 2

In Experiments 2a & 2b, we examined the processing of irregular and regular verbs in individuals who were non-native speakers of English (Serbian-English bilinguals and Chinese-English bilinguals, respectively). If lexical structures are less elaborated in second language (L2) associative memory structures as a result of diminished experience in the L2, then rule-based processes should dominate in recognition. As a result, changes in L2 proficiency should influence irregular facilitation more than regular facilitation. Alternatively, if irregulars and regulars are processed by a common mechanism based on similarity of form and meaning, even if lexical structures are less elaborated in non-native than in native speakers, magnitudes of facilitation should not differ as a function of regularity (as long as verb types are matched on form and semantic similarity). However, in bilingual processing, there is evidence that form similarity may assume greater prominence when semantics are less well developed (Talamas et al., 1999). As a result, one might expect L2 recognition of irregular verbs, specifically those with low form overlap, to be more impaired than in first language (L1) processing.

Obviously, general performance in a second language depends on vocabulary size in the L2, but more interestingly, reliance on form similarity among words in the L2 may depend on the correspondence between orthographic and phonological structure (viz., alphabetic, syllabic) in the L1 (Taft, 2002), as well as the similarity of phonological patterning in the L1 and L2. When structural overlap is high between first and second language, an advantage accrues whereas “difficulties are likely to arise if the skills used in the first language are inadequate or inappropriate for the second language” (Holm & Dodd, 1996, p. 121). As one example, the structure of the L2 learners’ first language was an important determinant of performance on a gender agreement task (Sabourin, Stowe & de Haan, 2006). Similarly, it has been suggested that the differing prominence of inflectional morphology in speakers whose L1 is Finnish as compared to Swedish, accounts for the differing tendency for morphological analysis (Lehtonen, Niska, Wande, Niemi, & Laine, 2006; Lehtonen & Laine, 2003).

The Serbian and Chinese languages are of particular value to demonstrate the influence of one’s first language on mastery of a second language because they represent two very different structures. Serbian maintains a regular mapping between letter and phoneme and is a highly inflected language as compared to English. These L1 characteristics allow one to focus on how native speakers of a language that invites both phonological and morphological analysis transfer that processing style to English verb forms. In contrast, the Chinese language uses characters that represent syllables and morphemes and has little in the way of inflectional morphology. Notably, Chinese characters that are similar in form do not necessarily have similar phonology or similar semantics; therefore, we expected that Chinese-English bilinguals would be less influenced by the formal similarity between English present and past tense verb forms. These L1 characteristics allow one to examine transfer from a L1 whose structure discourages both phonological and morphological analysis.

To determine whether recognition of English L2 verbs varied with first language, two bilingual populations performed the same task with the same materials. We anticipated that 1) the bilingual participants would recognize the high resonance regular verbs faster than the low resonance regular verbs because the verbs are more semantically elaborated, and that 2) form

similarity (orthographic and phonological) might play a pivotal role within levels of irregularity as well as across regular and irregular verb targets.

Method

Participants—In Experiment 2a, 44 Serbian-English bilingual students from the Philosophy Faculty, University of Belgrade, Republic of Serbia and Montenegro participated. In Experiment 2b, 44 Chinese-English bilingual students from Beijing Normal University participated. No participant had a known reading or speech disorder and all had normal or corrected-to-normal vision.

Participants were screened for proficiency with a picture naming/translation task (Snodgrass & Vanderwart, 1980, normed for L2 by Sholl, Sankaranarayanan & Kroll, 1995) and a sentence grammaticality judgment task (Johnson & Newport, 1989). In the picture-naming task, participants saw 80 pictures on the computer screen and gave the English name for what appeared in the line drawing. It was intended to measure command of English vocabulary. In the sentence judgment task, participants viewed sentences and pressed one of two keys to indicate if the sentence contained correct or incorrect English grammar. The later was intended to measure syntactic proficiency. Incorrect sentences entailed violations of subject-verb agreement, verb tense, omitting determiners, and using incorrect pronouns and possessive adjectives. Initially, 66 Serbian-English bilinguals and 60 Chinese-English bilinguals participated in Experiments 2a and 2b respectively. To equate the two groups on proficiency, the Serbian and Chinese bilinguals were matched based on picture naming accuracy [$t(43) = 1.840, p > .05$]. This resulted in a sample size of 44 for each group.²

Participants also completed a questionnaire about their language history where they rated (from one (non-native) to ten (native-like)) their speaking comprehension, reading, and conversational abilities in both Serbian and English. Data from these proficiency measures are summarized in Table 3. A comparison of the proficiency ratings from the Chinese bilinguals revealed that they did not rate their spoken comprehension [$t(43) = 1.824, p > .05$], speaking [$t(43) = 1.036, p > .05$], or reading [$t(43) = 1.386, p > .05$] skills in English as being significantly different from the Serbian-English bilinguals.

Materials—The materials were identical to those used in Experiment 1.

Procedure—The experimental design and procedure were the same as Experiment 1, with the addition of the picture naming, sentence judgment, and language history questionnaire tasks, which were administered in a second experimental session.

Experiment 2a: Results and Discussion

Consistent with Experiment 1, ANOVAs were conducted on the reaction time, as well as on the error data for both the irregular and regular verbs. Data from participants and items whose performance fell below the 60% accuracy criterion were removed from the analyses. Accordingly, data from no participants, but from three items (*dig*, *sew*, and *bind*) were deleted. The mean reaction time and error data are presented in Table 4.

The ANOVA for participants whose first language was Serbian on regulars and irregulars collapsed across resonance (high vs. low) and stem type (irregular vs. regular) revealed a main effect of relatedness [$F_1(1,43) = 73.478, p < .001$; $F_2(1,75) = 83.019, p < .001$]. The interaction between verb type (regular vs. irregular) and relatedness also was significant [$F_1(1,43) = 15.30, p < .001$; $F_2(1,75) = 15.802, p < .001$]. In essence, the (+84 ± 16 ms) Facilitation For the regular verbs [$t_1(43) = 10.00, p < .001$; $t_2(39) = 11.486, p < .001$] was significantly greater than the

(+48 ± 12 ms) Facilitation [t_1 (43) = 5.057, $p < .001$; t_2 (36) = 3.065, $p < .05$] for irregular verb types.

Multilevel logistic regression on the collapsed error data revealed a main effect of verb type [F (1, 3516) = 13.594, $p < .001$], indicating that participants made more errors on irregular verbs, as well as on unrelated trials as compared to related. Lastly, the interaction between verb type and relatedness was significant [F (2, 3516) = 8.143, $p < .001$].

Irregular Verbs—The results from a separate ANOVA conducted on the irregular verbs revealed a main effect of relatedness [F_1 (1, 43) = 25.578, $p < .001$; F_2 (1, 35) = 20.147, $p < .001$]. The interaction between stem type (nested vs. change) and relatedness also was significant [F_1 (1, 43) = 21.459, $p < .001$; F_2 (1, 35) = 10.761, $p < .05$]. Specifically, the +85 ± 26 ms priming effect for nested verbs [t_1 (43) = 6.277, $p < .001$; t_2 (10) = 4.178, $p = .02$] differed significantly from the nonsignificant +11 ± 22 ms priming effect for irregular change verbs [t_1 (43) = .985, $p = .330$; t_2 (25) = 1.163, $p = .256$]. Analyses conducted on the error data revealed no significant differences between any of the conditions.

Regular Verbs—An ANOVA conducted only on the reaction time data for the regular verbs revealed a main effect of resonance [F_1 (1, 43) = 9.324, $p < .05$]. Evidently, participants recognized high resonance verbs faster than low resonance verbs, replicating the finding with native speakers of English in Experiment 1. Again, there was a main effect of relatedness [F_1 (1, 43) = 100.060, $p < .001$; F_2 (1, 38) = 128.578, $p < .001$]. The magnitudes of facilitation for both verb types (+80 (± 28) ms for low resonance verbs and +86 (± 23) ms for high resonance verbs) were significant [t_1 (43) = 5.875, $p < .001$; t_2 (19) = 7.877, $p < .001$; t_1 (43) = 7.630, $p < .001$; t_2 (19) = 8.163, $p < .001$, respectively], however, the absence of an interaction indicated that they did not differ significantly. Multilevel logistic regression conducted on the error data for the regular verbs revealed a main effect of resonance [F (1, 1757) = 25.963, $p < .001$], and of relatedness [F (1, 1757) = 17.397, $p < .001$].

In Experiment 2a with Serbian L1 participants, irregular stem change verbs failed to facilitate, but nested verbs did. This pattern resembles that of native English speakers in Experiment 1, insofar as magnitudes of irregular facilitation increased when form overlap was high. The pattern of facilitation for the irregular verbs types, namely a significant nested effect and a nonsignificant stem change effect, also replicates a previous finding from the same population of non-native English speakers. Feldman, Kostić, and Pastizzo (under review) had Serbian-English bilinguals make lexical decisions to irregular and regular verbs under forward masked (Experiment 1a) and cross-modal priming conditions (Experiments 1b). They observed significant magnitudes of cross-modal facilitation for regular verbs (hatched-HATCH) and for irregular verbs of the fell-FALL type, but not for the taught-TEACH type irregulars. Likewise, in the present cross-modal study with Serbian-English bilinguals, the degree of form overlap between the present and past tense forms of the verb influenced the magnitude of facilitation. One interpretation of equivalent regular and nested facilitation is that the linguistic background of the Serbian bilinguals, specifically the highly inflected nature of their native language (i.e., many inflectional case forms) relative to the English language, accounts for their tendency to rely extensively on the internal structure of words in a recognition task. Stated succinctly, words in Serbian that look and sound alike will tend to have similar meanings because they are related by morphology, therefore, Serbian readers transfer their bias for (even partial) similarity among words from L1 to L2.

Experiment 2b: Results and Discussion

In Experiment 2b, no data from Chinese L1 participants or from any items were removed because of high error rates (60% criterion). The mean reaction time and error data are presented

in Table 5. An ANOVA conducted on the latency data collapsed over both types of irregulars and both types of regulars revealed a main effect of verb in the analysis by participants [$F_1(1, 43) = 9.368, p = .004$], indicating that the bilinguals, like the monolinguals overall were faster to recognize regular verbs. A main effect of relatedness also was present [$F_1(1, 43) = 5.589, p < .05$; $F_2(1, 78) = 2.549, p < .10$], but the interaction between verb type (irregular vs. regular) and relatedness was not significant. For these second language speakers of English, the nonsignificant ($+11 \pm 26$ ms) facilitation for irregular verb types did not differ statistically from the significant ($+32 \pm 22$ ms) facilitation for the regular verbs [$t_1(43) = 2.830, p < .05$; $t_2(39) = 2.704, p < .05$].

Likewise, with the error measure collapsed, multilevel logistic regression analyses revealed a marginally significant main effect of verb type [$F(1, 3516) = 2.940, p = .086$] and a significant main effect of relatedness [$F(1, 3516) = 5.196, p = .023$], such that participants made more errors to irregular verb trials and to unrelated trials. In contrast to the analyses based on latencies, the interaction between verb type and relatedness with the accuracy measure was significant [$F(1, 3516) = 5.657, p = .017$]. Here, accuracy rates for regular verbs benefited more from the prior presentation of a morphological relative than did irregular verbs.

Irregular Verbs—The results from the ANOVA on the irregular verb latencies revealed no significant differences between the nested and irregular change verbs. Planned comparisons on the magnitudes of facilitation for the two types of irregulars showed that neither effect was significant. Multilevel logistic regression analyses on the accuracy data indicated that despite greater form similarity, the nested verbs produced significantly *more* errors than did the irregular change verbs [$F(1, 1758) = 6.607, p = .010$].

Regular Verbs—An ANOVA conducted on the latency data for regular verbs confirmed a main effect of resonance [$F_1(1, 43) = 9.057, p < .05$], a pattern analogous to that in the monolingual data, such that verbs with greater semantic richness were faster than less rich verbs. In addition, there was a main effect of relatedness [$F_1(1, 43) = 8.007, p < .05$; $F_2(1, 38) = 7.163, p < .05$]. Facilitation for both low resonance verbs ($+38 \pm 31$ ms) and for high resonance verbs ($+26 \pm 22$ ms) was significant [$t_1(43) = 2.420, p < .05$; $t_2(19) = 1.96, p = .06$; $t_1(43) = 2.377, p < .05$; $t_2(19) = 1.85, p = .08$]. The interaction between resonance and relatedness was not significant, as in the previous experiment. The logistic regression analyses conducted on the accuracy data for the regular verified a main effect of relatedness [$F(1, 1758) = 12.403, p < .001$].

In summary, significant magnitudes of morphological facilitation arose in Experiment 2b for both types of regular verbs, but not for the irregular verbs. Replicating the results from Experiments 1 and 2a, the Chinese-English bilinguals responded faster to the high resonance verbs than to the low resonance verbs, indicating that semantic richness influenced overall recognition speed. Notably, the pattern for the irregular verbs differed from that in Experiments 1 and 2a. To elaborate, the native English speakers produced facilitation for nested (drawn-DRAW) and irregular change (swung-SWING) verbs, the Serbian-English bilinguals produced facilitation only for nested irregulars, and the Chinese-English bilinguals revealed nonsignificant facilitation for both types of irregular verbs.

First language (L1) comparisons—The data from the Chinese bilinguals were analyzed along with that of the Serbian bilinguals, where first language (L1) served as a between subject factor and participants were matched on proficiency. For the combined analysis, there was a main effect of verb type [$F_1(1, 86) = 5.034, p < .05$] and of relatedness [$F_1(1, 86) = 53.610, p < .01$; $F_2(1, 153) = 36.011, p < .001$]. There also was a significant interaction between relatedness and L1 [$F_1(1, 86) = 13.693, p < .01$; $F_2(1, 153) = 10.500, p < .001$] and between verb type and relatedness [$F_1(1, 86) = 8.298, p < .01$; $F_2(1, 153) = 11.832, p < .001$]. The

interaction between verb type and L1 was marginally significant for participants only [$F_1(1, 86) = 3.817, p = .54$]. We return to the influence of L1 on irregular facilitation in the General Discussion.

For the irregular verbs, the results revealed a significant interaction between relatedness and L1 [$F_1(1, 86) = 5.048, p = .027$; $F_2(1, 73) = 5.063, p < .05$], so that overall magnitudes of facilitation for the Serbian bilinguals were significantly larger than for the Chinese bilinguals. A significant interaction between irregular stem type and relatedness also emerged [$F_1(1, 86) = 10.203, p < .01$]. Most interestingly, the triple interaction between relatedness, stem type and L1 was significant for both items and participants [$F_1(1, 86) = 9.705, p < .01$; $F_2(1, 73) = 3.859, p = .05$].

For the regular verbs, there was a main effect of resonance [$F_1(1, 86) = 18.132, p < .001$; $F_2 = 2.54, p = .11$], and of relatedness [$F_1(1, 86) = 67.632, p < .001$; $F_2(1, 76) = 62.468, p < .001$]. The interaction between relatedness and L1 was significant [$F_1(1, 86) = 13.499, p < .001$; $F_2(1, 76) = 10.510, p < .01$], confirming that the magnitude of facilitation for regular verbs was significantly larger in the Serbian than in the Chinese group.

Planned comparisons further supported claims for a difference in facilitation across the two groups of bilinguals, with irregular nested [$t(43) = 3.098, p < .01$; 73 (± 43) ms difference], low resonance regulars [$t(43) = 2.093, p < .05$; 42 (± 32) ms difference], and high resonance [$t(43) = 3.872, p < .01$, 60 (± 31) ms difference] verbs all producing significantly larger effects for the Serbian bilinguals as compared to the Chinese. While moderately prolonged unrelated baselines may have contributed to the generally larger magnitudes of facilitation for Serbian L1, it is irrefutable that cannot account for the absence of nested irregular facilitation for Chinese L1.

General Discussion

In three cross-modal priming experiments, we examined the processing of regular and irregular verbs in native and non-native speakers of English. The critical stimuli consisted of two types of irregular verbs (nested stem and stem change) and two types of regular verbs (high and low resonance). In Experiment 1, native English speakers produced significant magnitudes of facilitation for all four verb sets. In Experiment 2a, Serbian-English bilinguals revealed significant facilitation for both types of regulars and for the nested irregulars. In Experiment 2b, Chinese-English bilinguals produced significant levels of facilitation for both types of regulars, but no facilitation for the irregular verbs.

When measures of target semantic richness (i.e., resonance, mean connectivity, cue set size, and morphological family size), as well as from orthographic neighborhood size, were matched across regular and irregular verbs, the magnitudes of inflected facilitation by native speakers did not differ for regulars and irregulars. Patterns of facilitation suggest that native speakers of English process the irregular and regular verbs in a similar manner. The outcome of Experiment 1 has important implications for the dual route account of regular and irregular verb processing. That is, purported regularity effects reported in earlier priming studies may reflect, at least in part, unmatched levels of semantic richness. Extending the insights of Baayen and Moscoso del Prado Martín (2005) based on analyses of corpora, the outcome of Experiment 1 with native speakers indicates that although regulars and irregulars typically differ on many semantic measures, when those properties are controlled, there are no reliable differences in inflected morphological facilitation that can be attributed to regularity.

Overall native, as well as non-native, participants produced faster decision latencies to the higher resonance regular verbs than to the lower resonance verbs, regardless of whether the target word was preceded by a related or unrelated prime word. This outcome is consistent

with the claim that greater semantic richness enhances the efficiency with which words are processed. However, because the magnitudes of facilitation for both the high and low resonance verbs did not differ, it suggests that semantic richness influences unprimed recognition latencies but that alone it cannot provide an adequate account of morphological facilitation (see Feldman, Basnight-Brown, & Pastizzo, 2006). The present demonstration of baseline differences due to semantic richness of the target points to a potential problem interpreting magnitudes of facilitation without considering baselines in designs where targets as well as the relation between prime and target differ.

Whereas the native speakers of English showed no differences in facilitation between the regular and irregular verbs, non-native speakers of English in the present study (native speakers of Chinese and of Serbian) revealed numerical differences between the two types (statistically significant only for Serbians). Overall, the bilinguals showed more facilitation for regular as compared to irregular verbs. This finding can be interpreted as generally consistent with a dual route account of morphological processing such that the bilinguals, but not native speakers, do not reliably associate irregular past tense and present tense forms of verbs. It is possible that the learning environment in which these bilinguals acquired their L2 encouraged a version of dual route processing because second language learners who learn their L2 in a school setting often are instructed to memorize irregular verbs and to use a rule for regular verbs. Alternatively, an interpretation based on the convergence of form and semantic similarity would emphasize greater reliance on the contributions of form overlap favoring regulars over irregulars (Feldman, Rueckl, Pastizzo, Diliberto & Vellutino, 2002; Rueckl et al., 1997); an effect that would be exaggerated with impoverished semantic elaboration due to limited experience in L2.

Notably in the present study, it is the results from the irregular verbs that provide new insights into processing and a challenge to a dual route account. Specifically, when the data were analyzed separately for the nested and change type irregulars, there was an interaction between verb type and facilitation for native speakers of English and for native speakers of Serbian, albeit not for native speakers of Chinese. Stated succinctly, the magnitude of nested irregular verb inflected facilitation depended on the first language of the bilinguals. Admittedly, the irregular stem change verbs did include both past participle, as well as past tense forms, whereas the nested verbs were only (less frequently used) past participles. One interpretation for the absence of facilitation for Chinese participants in the nested condition would be that these verb forms were not as familiar to the Chinese-English bilinguals as to the Serbian-English bilinguals, but this was not the case. In fact, written frequency of those forms was matched across all verb types, and more revealingly, the irregular error rates for the Chinese tended to be lower than for the Serbs.

The influence of L1 (Serbian or Chinese) on the mastery of L2 (English)

Although both non-native groups appear to show similar patterns for regular verbs overall, an analysis restricted to the irregular verbs separated by whether or not the stem was nested in the past tense form (drawn–DRAW vs. swung–SWING) showed distinct patterns of facilitation depending on L1. The Serbian-English bilinguals produced robust facilitation (85 ms) for the nested stem but not the stem change pairs, while the Chinese-English bilinguals revealed no facilitation for either type of irregular. Research whose focus is language transfer between native Chinese speakers and native speakers of European languages has shown that early linguistic experience (including L1 structure) can influence performance in a second language.

As a generalization, native speakers of European languages tend to have better proficiency in a second language and proficiency is not as limited by age of acquisition (AoA) as for native Chinese speakers when factors that influence second language proficiency purportedly are matched across differing bilingual populations (Bialystok & Miller, 1999; Jia, Aaronson, &

Wu, 2002). To elaborate, when Asian and European bilinguals were equated on language measures such as age of acquisition of the second language (English), number of years of English language instruction, and number of years spent in the US, the Asian bilinguals performed more poorly on listening and reading tasks than did European bilinguals (Bialystok & Miller, 1999; Birdsong & Molis, 2001; Jia et al., 2002). The authors argued that differences in proficiency are due to the tendency for many European languages to use an alphabetic script, as does English, thus facilitating language transfer (Jia, 2006). As pertains to the present study, because the structure of the Chinese language does not guarantee that characters with similar form retain similar phonology, or that characters with similar phonology have similar form, it is possible that native speakers of Chinese, and other essentially logographic languages do not rely on form information in English as consistently as do native speakers of alphabetic languages (Taft, 2002). The influence of pinyin-based instruction in Chinese on performance on phonological tasks in English provides support for this claim (Holm & Dodd, 1996).

In essence, due to familiarity with a highly inflected language and with a written language that captures inflectional variation, L1 speakers of Serbian appear to be analytic with respect to form in their L2. Whether or not differences with respect to the similarity of phonological patterning within syllables in L1 and L2 influences this sensitivity, it appears that Serbs are better able to transfer their sensitivity to word structure from the L1 to the L2 so as to exploit orthographic and phonological similarities between various inflected forms. This includes those forms that have an atypical affix as occurs in nested irregular stems and those that entail affixation of *-ed*. By comparison with the Serbian speakers who appear to be orthographically and phonologically flexible with respect to the criteria for similarity presumably due to experience in their L1, the Chinese speakers tend to be less attuned to morphological relatedness overall and more rigid in their criterion for similarity so that it includes only those pairs that entail affixation of *-ed*.

One final indicator of enhanced reliance on form derives from the Serbian bilinguals' greater difficulty with the irregular stem change verbs; three of the items were eliminated due to accuracy below the 60 percent criterion. In contradistinction, the Chinese bilinguals appeared to show greater accuracy for the irregular change items and none of the items were eliminated due to low accuracy. The increased accuracy by Chinese bilinguals may reflect their non-analytic approach to verbs.

In summary, both groups of bilinguals process regular verbs similarly and like native speakers. However, patterns of facilitation with the irregular nested verbs indicate that the Chinese bilinguals were not able to exploit partial form similarity when the affix was atypical (not *-ed*), whereas the Serbian bilinguals could. Stated generally, when proficiency based on vocabulary was matched, form overlap in morphologically related word pairs with an atypical affix differentially helped those who had experience with an alphabetic writing system and a highly inflected language.

Predictions of proficiency

In addition to their role as matching variables, correlational analyses were conducted on the proficiency task scores in order to determine which measures generally were good predictors of self-assessed performance (see Table 6). For both groups of bilinguals, self-reported ratings of English reading, spoken comprehension, and speaking skills appeared to be correlated positively. Errors on judgments of sentence grammaticality negatively correlated with both the Chinese and Serbian ratings of English spoken comprehension. Picture naming error rate, which reflects vocabulary knowledge, was positively correlated with AoA of English for the Chinese bilinguals. In contrast, for Serbian bilinguals there were no correlations of picture naming errors or grammaticality judgment errors with AoA of English. The differential predictive value of picture-naming and sentence grammaticality proficiency across the two L1s

is consistent with the claim that grammatical and nongrammatical aspects of language diverge developmentally, as well as functionally (Slobin, 1996).

First language speakers of Serbian and Chinese could be matched on vocabulary, but attempts to match concurrently on grammatical measures of proficiency were unsuccessful, demonstrating that the two measures did not behave identically. The picture naming and grammatical proficiency measures failed to correlate for the Chinese bilinguals. However, performance on the two measures was correlated for Serbian bilinguals. The most interesting interpretation is that the relation between various measures of L2 proficiency is not uniform across different L1s and the implication is that it is advisable to include multiple measures of L2 proficiency. Insofar as inflectional morphology often entails command of grammatical morphemes that are affixed to stems, one might expect patterns of inflectionally related morphological facilitation to be associated more strongly with performance on the sentence grammaticality than on the picture naming task, and this was the case for Chinese speakers. However, if the structure of L1 benefits processing of inflectional morphology in L2 then it is possible that magnitudes of facilitation will be large overall, but will not vary sufficiently so as to correlate with performance on the grammaticality task, and this may have been the case for Serbian speakers. In our estimation, the absence of correlations between grammatical proficiency and magnitudes of facilitation in L2 English is likely to reflect experience with a highly inflected first language. This interpretation warrants further investigation.

Correlations of magnitudes of facilitation for each of the four verb types with proficiency measures, revealed that for the Chinese bilinguals, the ability to assess grammaticality correctly in correct sentences of English (“YES” response) correlated negatively with the magnitude of nested, irregular verb change, and low resonance verb facilitation. Evidently, as error rates on the grammaticality task decrease, the magnitude of facilitation increases. Thus, bilinguals who do not associate the irregular with the regular verb forms so that they do not show facilitation to the target, are more biased to say that a grammatical sentence (e.g., *They took their children to the theater*) is not grammatical. In essence in the present study, Chinese performance on the sentence grammaticality task predicted patterns of inflected morphological facilitation, especially for irregular verb formations.

Conclusion

The current study revealed that monolingual speakers of English produce equivalent magnitudes of facilitation in the cross-modal lexical decision task when irregular and regular verbs forms are matched on measures of semantic richness. The implication is that variation in semantic properties across regular and irregular verb types that have been documented by Baayen and Moscoso del Prado Martin (2005) may have contributed to prior claims of processing differences between regulars and irregulars. In contrast, the two groups of non-native speakers of English matched on vocabulary proficiency showed differential patterns of facilitation between irregulars and regulars (statistically significant only for Serbians), as well as between nested versus irregular change irregulars. Whereas interactions of regularity and facilitation are consistent with multiple accounts, differential effects of form on irregular facilitation are more difficult to describe solely in terms of lexical activation among stored word forms. Finally form-based differences in L2 irregular facilitation that vary as a function of L1, provide compelling evidence that the orthographic, phonological, and/or morphological structure of a bilingual’s L1 can play a critical role in the mastery of L2.

To our knowledge, we are the first to examine patterns of morphological facilitation for nested verbs, and admittedly differences in the construction of materials may contribute to failures to replicate interactions of facilitation with regularity in previous studies. Future researcher may need to consider not only semantic richness and the preservation or non-preservation of the stem in prime and target, but also the variation in stem form within the verb paradigm as a

whole. One question is whether there are experimental conditions under which processing for verbs with stem changes and irregular past participles (*know-knew-known*) differs from processing for verbs with no stem change, but irregular past participles (*prove-proved-proven*). Resolution may require a less dichotomous characterization of verbs as regular or irregular and consideration of the distribution of frequencies over various inflected forms including semantic as well as form-based variation (e.g., Moscoso del Prado Martin, Kostić & Baayen, 2004). Our intuition is that graded magnitudes of inflectional facilitation will prevail as one contrasts irregular, semi-regular, and regular verbs.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1
Properties of critical stimuli (SD) for Experiments 1 & 2.

Verb Type	Related	Unrelated	Target
Irregular Nested	drawn	drain	DRAW
Frequency per mill	52.08(104)	51.75 (38)	78.58 (105)
Length	5.42 (.67)	5.4 (.51)	4.17 (.72)
Resonance			0.09 (.08)
Mean Connectivity			1.57 (.70)
Cue Strength			17.64 (4.9)
Family Size			4.93 (.86)
Neighborhood Size			7.18 (3.9)
Irregular Change	Swung	swept	SWING
Frequency per mill	66.60 (53)	63.40 (32)	64.46 (49)
Length	4.54 (.89)	4.6(.91)	4.32 (.86)
Resonance			0.12 (.09)
Mean Connectivity			1.65 (.56)
Cue Strength			14.41 (6.1)
Family Size			5.03 (.77)
Neighborhood Size			6.26 (4.45)
Regular Change Resonance <.10	Guided	guessed	GUIDE
Frequency per mill	65.45 (90)	63.55 (49)	75.6 (38)
Length	6.20 (.77)	6.4 (.75)	4.45 (.69)
Resonance			0.025 (.02)
Mean Connectivity			1.38 (.51)
Cue Strength			15.56 (4.9)
Family Size			5.06 (.66)
Neighborhood Size			5.1 (3.6)
Regular Change Resonance >.10	Pushed	paused	PUSH
Frequency per mill	56.30 (35)	55.30 (42)	67.3 (40)
Length	6.15 (.99)	6.3 (.92)	4.40 (.75)
Resonance			0.23 (.14)
Mean Connectivity			1.58 (.66)
Cue Strength			14.5 (4.3)
Family Size			5.52 (.59)
Neighborhood Size			6.5 (5.1)

Table 2
Mean reaction times, standard deviations, and accuracy rates (in parentheses) for native speakers of English (Experiment 1).

Verb Type	Related	Unrelated	Facilitation
Irregular			
Nested	519 (95)	583 (94)	+ 64 *
SD	91	94	
Irreg Change	552 (96)	590 (94)	+ 38 *
SD	94	116	
Regular			
Low Res	511 (99)	576 (97)	+ 65 *
SD	89	111	
High Res	502 (98)	556 (98)	+ 54 *
SD	93	100	

*
p < .05.

Table 3

Picture naming, sentence judgment, and language history questionnaire data for the Serbian-English and Chinese-English bilinguals who participated in Experiments 2 (standard deviations are presented in parentheses).

	L1 Serbian		L1 Chinese	
	SERBIAN	ENGLISH	CHINESE	ENGLISH
AoA (yrs)	1.7 (1.1)	10.0 (2.8)	1.6 (2.2)	12.1 (1.7)
Age of Reading Acquisition (yrs)	5.6 (1.1)	10.1 (2.4)	4.6 (2.3)	12.1 (1.3)
Speaking Rating	9.5 (.90)	6.3 (2.2)	9.3 (1.1)	5.9 (1.3)
Spoken Comprehension Rating	9.7 (.67)	6.8 (2.1)	9.4 (1.3)	6.0 (1.5)
Reading Rating	9.8 (.61)	6.8 (2.0)	9.0 (1.2)	7.3 (1.2)
% Error Picture Naming		45 (12)		49 (9)
% Error Rate Sentence Task				
YES response		21 (9)		40 (18)
NO response		32 (12)		56 (14)

Table 4
Mean reaction times, standard deviations, and accuracy rates (in parentheses) for Serbian speakers reading in English (Experiment 2a).

Verb Type	Related	Unrelated	Facilitation
Irregular			
Nested	674 (91)	758 (89)	+ 85 *
SD	107	123	
Irreg Change	724 (90)	735 (92)	+ 11
SD	123	104	
Regular			
Low Res	693 (95)	773 (88)	+ 80 *
SD	106	113	
High Res	667 (98)	753 (96)	+ 86 *
SD	94	123	

*
 $p < .05$.

Table 5
Mean reaction times, standard deviations, and accuracy rates (in parentheses) for Chinese speakers reading in English (Experiment 2b).

Verb Type	Related	Unrelated	Facilitation
Irregular			
Nested	680 (92)	692 (94)	+ 12
SD	172	107	
Irreg Change	687 (96)	698 (95)	+ 11
SD	130	112	
Regular			
Low Res	667 (97)	705 (94)	+ 38 *
SD	146	95	
High Res	645 (99)	671 (95)	+ 26 *
SD	116	100	

*
p < .05

Table 6
Correlations between proficiency measures and facilitation for Serbian-English and Chinese-English bilinguals.

	Sentence Gram. ERR	Sentence Gram. ERR- NO	Sentence Gram. ERR- YES	Picture Naming ERR
Serbian-English Bilinguals				
Eng Comprehension Rating			-.246 [*]	
Pic. Naming ERR	-.145	.030	-.314 [*]	
English AoA	-.10	-.164	.031	-.010
Nested fac	-.058	-.133	.084	.155
Irreg Fac	-.115	-.145	-.005	.135
Low res regular fac				
High res regular fac		-.103	.227	.216
Chinese-English Bilinguals				
Eng Comprehension Rating	-.286 [#]	-.211	-.212	-.044
Pic. Naming ERR	-.101	-.090	.056	
English AoA	.151	.132	.097	.308 [*]
Nested fac	-.301 [*]	.015	-.439 [*]	-.063
Irreg Fac	-.231	.128	-.420 [*]	-.173
Low res regular fac	-.320 [*]	-.224 [*]	-.252 [#]	-.070
High res regular fac	-.205	-.171	-.135	-.057

* $p < .05$,

$p < .10$.