Semantic, Phonological, and Lexical Influences on Regular and Irregular Inflection

Yi Ting Huang (huang@wjh.harvard.edu)
Department of Psychology, 33 Kirkland Street
Cambridge, MA 02138 USA

Steven Pinker (pinker@wjh.harvard.edu)
Department of Psychology, 33 Kirkland Street
Cambridge, MA 02138 USA

Abstract

Regular and irregular inflections have become an important tool for understanding mechanisms underlying human language and cognition. Regular-irregular homophones such as *rang the bell/ringed the city* challenge connectionist models in which phonological information is the only input to the inflection process. Models of language that differentiate between lexicon and grammar attribute these inflectional differences to distinct lexical or morphological representations while connectionist models distinguish them by semantic features. Ramscar (2002) argued for the semantic account by showing that people extend irregular inflection to novel words similar in sound and meaning to existing irregulars, however generalizations may have been based on analogy to those exact words rather than overlap of semantic features. We presented people with novel words that independently varied in phonological and semantic similarity to existing irregulars and found that semantics only had an effect when the level of similarity was high and when it was accompanied by high phonological similarity—the combination that evokes a particular existing verb. Results are problematic for a model that appeals both to semantic and phonological similarity and supports theories that posit distinct lexical representations.

Introduction

The English past tense has become a battleground for the nature of cognitive representations and processes. The Words and Rules (WR) theory (Pinker & Ullman, 2002; Ulman, 1999; Pinker, 1991) holds that irregular past tense forms (*sing-sung*) are stored in associative memory, whereas most regular past tense forms (*walk-walked*) are generated by an operation concatenating a suffix with a stem. The Single Pattern Associator (SPA) theory (Ramscar, 2002; MacWhinney & Leinbach, 1991; Rumelhart & McClelland, 1986) holds both regular and irregular forms are generated in a pattern associator network in which weighted connections associate phonological and semantic features of stems with phonological and semantic features of their past-tense forms.

The stakes of this debate encompass not only linguistic theory but also cognition in general. The WR account asserts that the distinction between regular and irregular verbs reflects the two ways language is represented and processed in the mind. Irregular past tense forms are stored in the lexicon, a subdivision of associative memory, and as a result, demonstrate strong effects of word frequency and phonological similarity. Regular past tense forms, in general, are relatively insensitive to these variables because they may be assembled by a productive suffixing rule, which in this case adds *–ed* to the stem. The rule applies when memory fails to retrieve an irregular form, such as in the case of novel or low-frequency verbs. These rules belong to a grammatical system responsible for the construction of complex words and sentences. This theory contrasts with an account where both kinds of past tense forms are generated by weighted connections in a connectionist pattern associator (Rumelhart & McClelland, 1986). All processing is accounted for using weighted phonological units (e.g. *–ing* to *–ung* for *sing*, *–k* to *–kt* for *walk*) that are strengthened with exposure and shared across phonologically similar stems, resulting in automatic generalization by similarity. This model contains no lexical entries or grammatical representations.

Empirically, these two theories make different predictions in the case of homophonous verbs (e.g. *rang* the bell versus *ringed* the city, *broke* the vase versus *braked* the car). Since phonological input units remain identical, these cases are problematic for an SPA model that incorporates only phonological features (e.g. Rumelhart & McClelland, 1986), because two items with identical input representations must be systematically mapped onto distinct output representations. In WR and other theories in which words have representations apart from their sounds, homophones with distinct past-tense forms are unproblematic because the irregular past tense form is associated with a word and not simply a set of sounds. Moreover, novel verbs that are homophonous with irregular forms can receive a regular form as well whenever they are derived from a noun (e.g., *ringed the city*) or adjective (e.g., *righted the boat*), because every irregular verb form is stored with a verb root, not with a set of verb sounds, and a verb based on a noun is not represented as having the same root as its homophonous pure verb (Pinker & Prince, 1988; Kim et al, 1991; Marcus et al., 1995).

Modifications of the SPA theory have attempted to overcome the homophone problem by adding features for meaning to the input representation. For example, *break* and *brake* mean different things, and thus are represented by

different subsets of semantic features; the phonological features for the irregular past tense form *broke* become associated with the semantic features for *break* and not *brake* (MacWhinney & Leinbach, 1991). The prediction is that just as verbs tend to form families defined by shared phonological features (e.g. *throw, blow, grow*; *sing, ring, sting*), verbs should form families defined by shared semantic features: verbs with similar meanings should tend to have similar past-tense forms. Similarly, other cognitive models have tied the likelihood of irregularization to how the particular use of a verb in a context fits with its central meaning (Lakoff, 1987). As the degree of sense of extension increases, the probability of regularization increases. Both these hypotheses attempt to solve the homophone problem without positing distinct lexical entries or representations of a verb's grammatical structure.

Previous experimental evidence indicated that grammatical structure, rather than sheer semantic similarity, determines subjects' judgments of past-tense forms. Kim et al (1991) presented existing and novel verbs that are homophonous with irregulars and found that verbs derived from nouns (e.g., *to shed the tractor* = "put in the shed") were judged as requiring regular past-tense forms (*shedded the tractor*) whereas verbs that were merely metaphorically extended from their central sense did not (*to shed the tractor* = "get rid of possessions"). Although denominal verbs also happen to differ semantically from their irregular homophones, a regression analysis showed that only denominal status, not semantic similarity, predicted the degree of preference for regular or irregular forms.

Ramscar (2002) defended the SPA theory by appealing to semantic features, noting that while irregular words (*drink, shrink*, and *stink*) dominate the phonological family of words incorporating "*-ink*," the two regular exceptions—*blink* and *wink*—share not only phonological similarities but also semantic ones as well. This raises the possibility that semantics may be involved in past-tense formation after all. To examine interactions between the two kinds of features, he elicited the past-tense form of novel verbs that were semantically and phonologically similar either to a regular or an irregular verb. For example, subjects saw sentences where *frink* meant either "eyelids opening and closing rapidly and uncontrollably" (similar to *blink*) or "consuming vast quantities of vodka and pickled fish" (similar to *drink*). He found that when *frink* was introduced in the context of a semantically similar regular verb, subjects produced the regular past tense form (e.g. *frinked*), but when it was introduced in the context of a semantically similar irregular verb, subjects produced the irregular form (e.g. *frank*). Ramscar concluded that "semantic similarity could affect the inflections of the past tense of nonce English verbs when phonological similarity constraints were satisfied" (pg. 59). Furthermore, since "both regular and irregular past tense inflections can be modeled using a uniform mechanism . . . this evidence undermines both the claim that a rule is necessary to model past tense inflection and concomitant *in principle* claim that single-route models cannot account for inflection" (pg. 85). Unfortunately, Ramscar's manipulation confounded semantic similarity with lexical similarity. A lexical item, in traditional grammatical theory, is an entry in memory that links a semantic representation, a phonological representation, and a grammatical representation (e.g., information about a part-of-speech category and subcategory). Ramscar's items were so similar to existing verbs (they were nearly identical in phonology, semantics, and grammar) that subjects may have directly mapped the new lexical item to an existing lexical item, rather than being sensitive to semantic overlap. That is, they may have based their generalization on lexical entries (eschewed in pattern-associator models) rather than semantic feature overlap.

To fully explore the interaction between phonology and semantics in inflectional morphology, it is necessary to vary them independently. Ramscar examined novel verbs that displayed both high phonological and high semantic similarity to an existing verb. This likely had the effect of activating the lexical representation for that very verb, possibly leading to the unwarranted conclusion that semantics itself plays a major role in the generalization of past tense. However, in order to resolve whether verb meaning plays a direct role in inflection, we must also examine the effect of semantic similarity in cases where there is low and moderate phonological similarity between novel verbs and the existing verbs to which they are similar. By expanding comparisons to cases in which both phonological and semantic similarities are manipulated, one can see whether semantic similarity elicits a generalization gradient analogous to the generalization gradient already known to exist for phonological similarity (e.g., Bybee & Moder, 1983; Prasada & Pinker, 1993).

Figure 1: Predicted pattern for WR theory
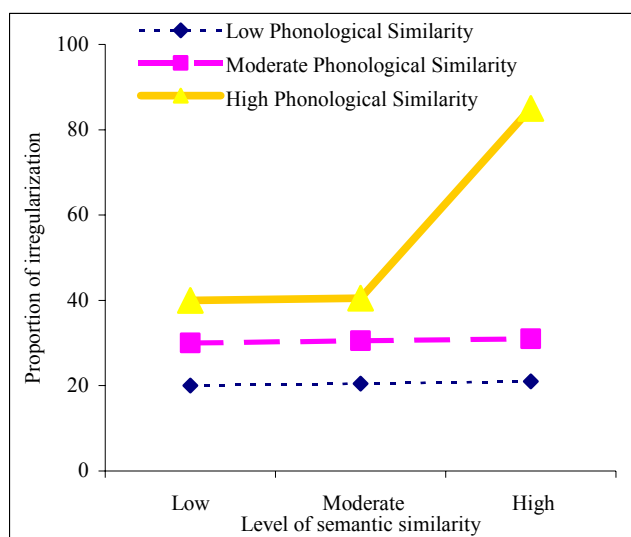
The Words-and-Rules theory predicts that when people are asked to generate past tense forms of novel verbs that vary in similarity to existing verbs, semantic similarities

should have limited consequence on generalization of irregular past tense patterns (e.g. *-ing* → *-ung*) in cases of low and moderate phonological similarity, and only lead to greater generalization in the case of high phonological similarity, where the combination of phonological and semantic similarity evokes a particular existing verb (see Figure 1). Conversely, the Single Pattern Associator Theory predicts that increases in semantic similarity would lead to greater generalization of an irregular past tense across all levels of phonological similarity.

Methods

We presented 72 native English-speaking Harvard undergraduates with sentences containing novel verbs that systematically varied in phonological and semantic similarity to existing irregular verbs. The novel verbs were based on eight known verbs (e.g. *swing, sink, lead, blow, bear, throw, read, cling*) and varied across three levels of phonological and semantic similarities (i.e. low, moderate, and high) to create nine different trial types (see table 1 for an example). These were divided among three counterbalanced conditions to ensure that each subject only saw each novel verb in a single combination of conditions. The materials were compiled in a web-survey accessible at http://pinker.wjh.harvard.edu/research/yi_ting_survey/main page/index.html.

Table 1: Example of semantic similarity

Level of Similarity (to "throw")		
Low	**Moderate**	**High**
Mike loved to **froe** elaborate meals for the most ordinary occasions.	The star goalie could **froe** the puck with any part of his body	Sam spent the whole summer practicing how to **froe** a baseball.

Subjects read sentences introducing the meaning of each novel verb (e.g. *spling*) and subsequently asked to rate the acceptability of regular (*splinged*) and irregular (*splung*) past tense forms (see table 2). Each item was judged using a scale of 1 to 7, where 1 means 'very unnatural' and 7 means 'very natural.' Subjects were told to focus on both "the way the new verb is used in the example and on the way it sounds."

After subjects completed all the sentence ratings, they were asked to go back and indicate the basis by which they formed their judgments. They were told to select among four multiple-choice items and/or indicate their own strategy (see table 3). These justifications provided a means to test our hypothesis that subjects in the condition corresponding to Ramscar's experiment (high semantic/high phonological similarity) literally thought of the exact verb with that meaning and with an equivalent sound to the test item, and simply analogized the known verb to the test item.

Table 2: Example of the novel verb rating

Introduction: Professional golfers can **spling** a golf club up to 50 miles per hour when teeing off. Of course, when they are putting, they **spling** the club much more gently.

a. Test (Irregular): Yesterday, Tiger Woods broke the record when he **splung** his club at 60 miles per hour

b. Test (Regular): Yesterday, Tiger Woods broke the record when he **splinged** his club at 60 miles per hour

Table 3: Example of the judgment strategy

Target Sentence: Yesterday, Tiger Woods broke the record when he **splung** his club at 60 miles per hour.

a. The novel word reminded of a specific word I already knew, so I simply borrowed the past-tense form from that verb. If so, please indicate which verb you had in mind.

b. The meaning of the novel word made one form seem better than the other.

c. The sound of the novel word made one form seem better than the other.

d. I didn't really think of any particular strategy or reason for my choice: one of the past-tense forms just seemed better than the other

e. Other

Results

Results are shown in Figure 2. A 3 x 3 analysis of variance (ANOVA) testing the effects of phonological and semantic similarity (i.e. low, moderate, high) on naturalness ratings of irregular past tense patterns revealed a significant main effect of phonological similarity ($F(2, 206) = 81.04$, $p < .001$), replicating Bybee and Moder (1983) and Prasada and Pinker (1993). Subjects demonstrated a strong monotonic increase in naturalness rating of an irregular past tense as phonological similarities increased. Post-hoc analysis revealed that differences were significant between all three levels of phonological similarity (p's < .001, Bonferonni corrected). There was also a main effect of semantic similarity, $F(2, 207) = 9.317$, $p < .001$. However, post-hoc analyses revealed that while verbs with high similarity were significantly different from verbs with moderate similarity ($p < .01$), neither group was significantly different from verbs with low semantic similarity ($p > .05$).

While the interaction between the two variables failed to be significant ($p > .05$), planned comparisons revealed a difference between the effects of semantic similarity on subjects' ratings in the low and moderate phonological similarity groups compared to the high phonological similarity group. In both the low and moderate phonological similarity groups, there was no significant difference in ratings between the low versus moderate semantic similarity groups ($p > .05$) and the moderate versus high semantic similarity groups ($p > .05$). However, in the high phonological similarity group, despite no significant difference in ratings between the low versus moderate

semantic similarity groups (p > .05), there was a significant difference between the moderate versus high semantic similarity group (p < .01).

Figure 2: Effects of similarity on Irregular past tense ratings
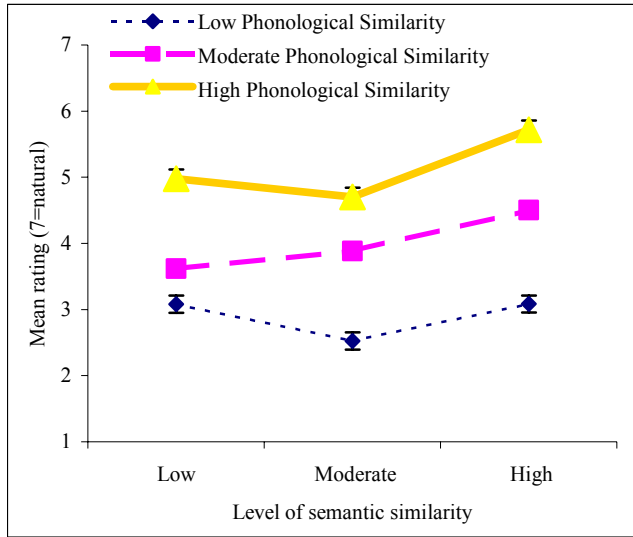
To summarize, the results from the phonological manipulation suggest that subjects' tendency to accept an irregular past tense increased as similarities to known irregular verbs increased. Results from the semantic manipulation suggest that subjects' tendency to accept an irregular past tense remained resistant to variation in semantic similarity unless the meaning of novel verbs highly resembled that of known irregular verbs (figure 3).

Figure 3: Effects of similarity on Irregular past tense
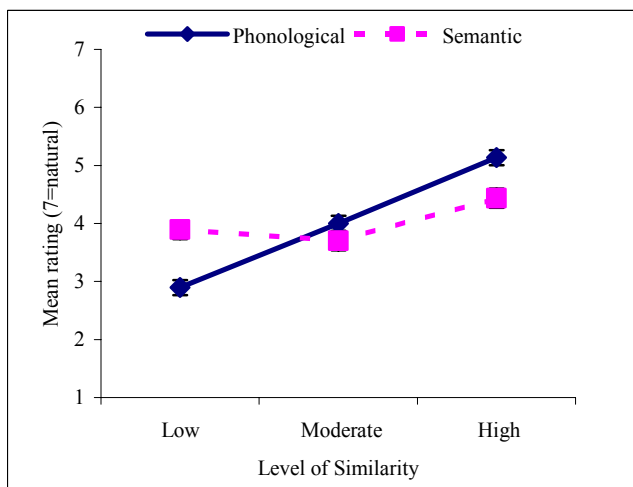
Subjects' *regular* past tense judgments demonstrated parallel effects (though with the sign reversed)—ratings *decreased* as novel verbs increased in phonological, but not semantic, similarities to known irregular verbs (figure 4). A

3 x 3 ANOVA revealed a significant main effect of phonology ($F_{(2, 207)} = 43.78$, $p < .001$) and semantics ($F_{(2, 207)} = 5.04$, $p < .01$), but no significant interaction between the two ($F_{(4, 207)} = 1.392$, $p > .05$). However, closer examination of simple main effects revealed that the effect of semantics was again limited specifically to a difference between moderate and high semantic similarity in the high phonology ($p < .05$).

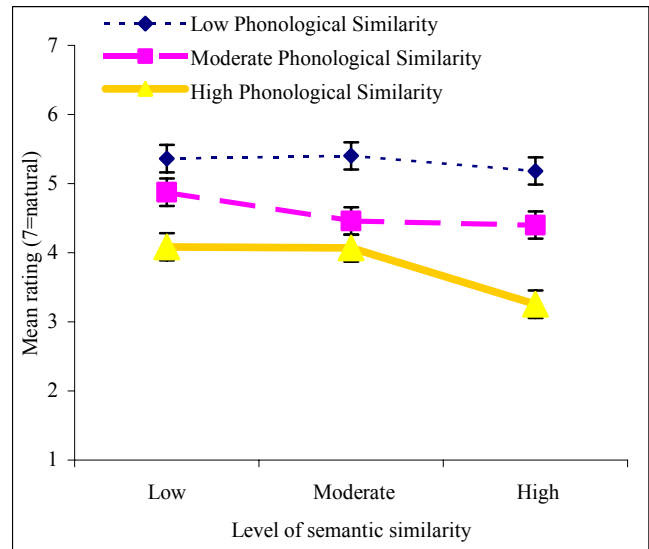Figure 4: Effects of similarity on Regular past tense

Figure 5 reports the strategies subjects recruited to form their judgments, in particular, their use of analogy to a known word. A 3 x 3 ANOVA testing the effects of phonological and semantic similarity revealed significant main effects of phonological ($p < .001$) and semantic ($p < .001$) similarity as well as a significant interaction between the two factors ($p < .001$). Tests of simple main effects revealed that while subjects failed to make reference to the known word in all levels of semantic similarity in the low phonological similarity group ($p > .05$), in both the moderate and high phonological similarity groups, there was a significant effect of moderate to high semantic similarity ($p < .01$).

The frequency with which subjects actually listed the target word we had in mind when constructing the stimuli (figure 6) reveals a similar trend: the highest counts were found in the high phonology/high semantic similarity group (N=136) and moderate phonology/high semantic similarity group (N=53). Furthermore, within this latter group, we found that subjects' reference to the correct known word differed greatly between two groups of novel words. Among the items ending in –*ing* or –*ink* (e.g. *fring, frink, ning*), subjects reported using the target word almost twice as often (n=28) than in all the other phonological families (e.g. *cleef, jare, poe, preek, zoe*) combined (n=15).

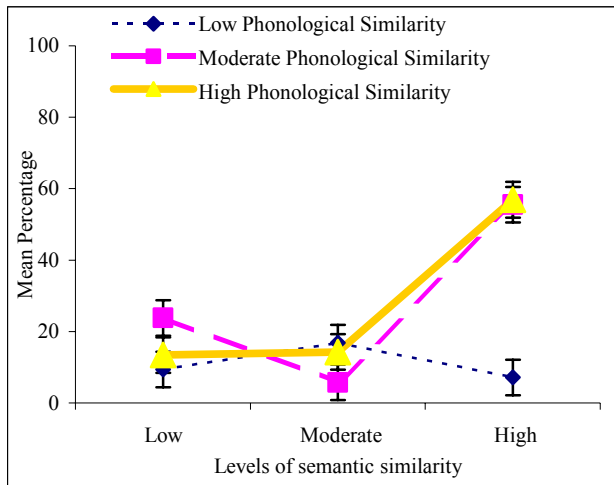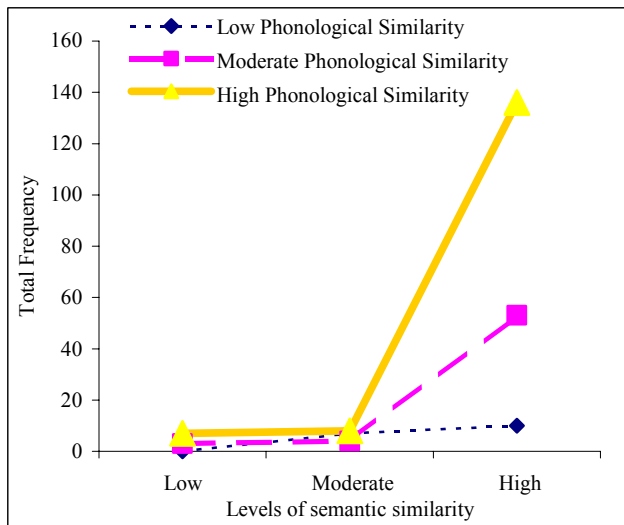Figure 5: Selection of Target Word strategy

Figure 6: Production of Target word

This difference suggests that items we had classified as "moderate phonological similarity," which were not intended to evoke the target word, in fact were perceived as similar enough to the target word to evoke it a large percentage of the time. This motivates separating the *-ing/ink* family from the rest of the items. As noted by Pinker & Prince (1988), the *–ing/ink* family is unusual among irregulars in being dominated by irregular friends (i.e. phonologically similar irregular verbs) but very few regular enemies (i.e. phonologically similar regular verbs).

With verbs outside the *ing/ink* phonological family, a 3 x 3 ANOVA revealed a significant main effect of phonology ($p < .001$) and semantics ($p < .001$), and in addition, the predicted interaction between phonology and semantics ($p < .001$). A similar pattern emerges when the *–ing/ink* family items are reclassified from "moderate" to "high" phonological similarity (see figure 7). A 3 x 3 ANOVA here revealed a significant main effect of phonology ($p < .001$)

and semantics ($p < .001$), and the predicted interaction between the two factors ($p < .05$). This confirms that high phonological and semantic similarity to a known verb will lead subjects to analogize a novel item to that word; without this combination, semantic similarity has little or no effect.

Figure 7: Irregular past tense ratings of recoded verbs
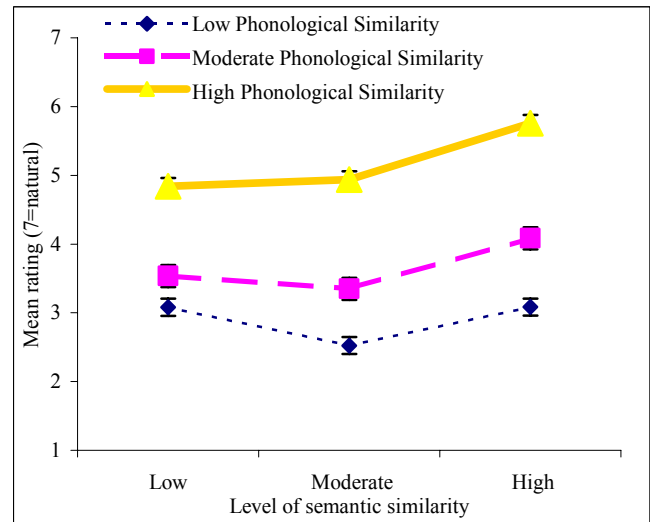
We performed a series of regression analyses to examine how well subjects' reported strategies (i.e. analogy known word, use of similarity in sound, use of similarity in meaning) predicted their likelihood to irregularize novel verbs as measured by their ratings. The regression analysis revealed that while all three variables together significantly explained 16% of unique variance ($p < .001$), only the use of a known word had a significant beta coefficient ($p < .01$). This was confirmed with individual regressions on each variable, which revealed large differences in the variance explained. Known word significantly explained 16.8% of unique variance ($p < .001$) and sound significantly explained 5.8% of unique variance ($p < .01$). However, meaning accounted for a very small (1.6%) and non-significant proportion of the variance ($p > .05$).

Discussion

This study examined the extent to which phonological, semantic, and lexical factors influence the way people inflect a novel past tense form. This question is relevant to the controversy over whether regular/irregular homophones such as *ring-rang, wring-wrung,* and *ring-ringed* are differentiated by differences in meaning, as claimed by advocates of models consisting of a single connectionist pattern associator, or by having distinct lexical entries, as claimed by advocates of models distinguishing lexicon from grammar. Both theories can account for the monotonic increase in the acceptability of irregulars as a function of phonological similarity to existing irregulars, because both acknowledge that words are stored in a memory system that generalizes the phonological relationships in past-tense

forms (e.g., *i-u*) according to phonological similarity (Bybee & Moder, 1983; Pinker & Prince, 1988; Prasada & Pinker, 1993).

These two theories make different predictions, however, on the role of semantic similarity in generalization. In a SPA model, distributed semantic and phonological representations play a similar role in generalization and are the only kinds of information represented. In contrast, models positing lexical entries containing grammatical (as well as semantic and phonological) information can distinguish words that have distinct grammatical properties (such as irregular inflection) without requiring such differences to track gradations in semantic features. Replicating Ramscar (2002), we found that people extend an irregular inflection to a word that sounds like and means the same as an existing irregular verb. However, we found that this extension was limited to cases where the new verb was a near-doppelganger of an existing one (i.e., being similar to it both in sound and in meaning), which leads people to treat the new verb as the existing one in disguise. Mere semantic similarity, unless it was both extreme in magnitude and accompanied by high phonological similarity, was not enough to evoke the stored irregular patterns.

Our results extend previous research demonstrating strong influence of phonological similarity in irregular past tense formation of novel verbs, but little or no direct influence of semantic similarity (Kim et al., 1991; Marcus et al., 1995). Subjects' patterns of ratings and strategies suggest that unlike phonological features, which have distributed representations across families of verbs, semantic information is encapsulated at the lexical level when it comes to inflectional morphology. As a result, semantic similarity has an impact on irregular past tense formation only to the extent that these similarities cause subjects to believe that a novel verb is in fact a variant of a known irregular verb. This confirms the traditional characterization of language as consisting of a lexicon of entries and a set of operations that combine them.

Acknowledgements

References

Bybee, J. L., & Moder, C. L. (1983). Morphological classes as natural categories. *Language*, 59, 251-270.

Kim, J. J., Pinker, S., Prince, A., & Prasada, S. (1991). Why no mere mortal has ever flown out to center field. *Cognitive Science, 15,* 173-218.

Lakoff, G. (1987). Connectionist explanations in linguistics: Some thoughts on recent anti-connectionist papers. Unpublished electronic manuscript, ARPAnet, University of California, Berkeley.

MacWhinney, B., & Leinbach, J. (1991). Implementations are not conceptualizations: Revising the verb learning model. *Cognition, 40,* 121-157.

Marcus, G. F., Brinkmann, U., Clahsen, H., Wiese, R., and Pinker, S. (1995). German inflection: The exception that proves the rule. *Cognitive Psychology*, 29, 189-256.

Pinker, S. & Ullman, M. T. (2002). The past and future of the past tense. *Trends in Cognitive Science,* 6, 456-463.

Pinker, S. (1991). Words and rules. New York: Basic Books.

Pinker, S. & Prince, A. (1988). On language and connectionism: analysis of a parallel distributed processing model of language acquisition. *Cognition, 28,* 73-193.

Prasada, S., & Pinker, S. (1993). Generalization of regular and irregular morphological patterns. *Language and Cognitive Processes, 8,* 1-56.

Ramscar, M. (2002). The role of meaning in inflection: Why the past tense does not require a rule. *Cognitive Psychology, 45,* 45-94.

Rumelhart, D. E., & McClelland, J. L. (1986). On learning past tenses of English verbs. In D. E. Rumelhart, & J. L. McClelland (Eds.), *Parallel distributed processing. Vol 2: psychological and biological models.* MIT Press: Cambridge, MA.

Ullman, M. T. (1999). Acceptability ratings of regular and irregular past tense forms: Evidence for a dual-system model of language from word frequency and phonological neighborhood effects. *Language and Cognitive Processes, 14,* 47-67.