

# The influence of semantics on past-tense inflection

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## Abstract

Previous theories of past-tense verb inflection have considered phonological and grammatical information to be the only relevant factors in the inflection process (e.g. Bybee & Moder, 1983; Rumelhart & McClelland, 1986; Kim, Pinker, Prince & Prasada, 1991). This paper presents three experiments that show that semantic information plays a decisive role in determining the inflection of both existing and novel homophone verb stems. These findings indicate that regular and irregular inflections are determined by semantic and phonological similarities in memory, and furthermore that people are not responsive to the kind of grammatical distinctions amongst verb roots that default rule theories of inflection (Pinker, 1999) presuppose.

## Introduction

In most theories -- and studies -- of past-tense verb inflection, phonological and grammatical information have been considered to be the two relevant factors in the inflection process (e.g. Bybee & Moder, 1983; Rumelhart & McClelland, 1986; Kim, Pinker, Prince & Prasada, 1991; Pinker, 1991; 1999). However, in some models of inflectional processing (MacWhinney & Leinbach, 1991; Joanisse & Seidenberg, 1999), semantic processes have been included to help explain the processing of homophone verbs (e.g. *brake/break*). Since *brake* and *break* both sound the same, phonology alone cannot distinguish which of *broke* or *braked* is to be the correct past tense form for the input *breik*.

Although using semantic information to guide this process appears intuitively plausible, it has not been supported empirically, and indeed this suggestion has been fiercely criticised by Pinker and colleagues (Kim et al, 1991; Pinker, 1999), who put forward an alternative, nativist account of homophone inflection (Pinker, 1991; 1999). This predicts that the regularisation of irregular sounding verb stems is driven by innate grammatical sensitivity: verbs that are instinctively perceived to be denominal will be automatically regularised. This account is supported by results reported by Kim et al (1991) which indicate that grammatical factors correlate better than semantic factors with people's ratings of the acceptability of past tense forms in context, although these results do not rule out any semantic role in inflection.

So do semantics have any influence on the past tense forms speakers produce? This paper seeks to clarify and directly address this question.

## Semantics and past-tense inflection

To initially test whether semantic similarity can affect the inflection of verb past tenses, Experiment 1 examines the past tense forms native English speakers produce for novel (nonce) English verbs whilst holding contexts in which the verbs are presented. The phonologically similar nonces *sprink* and *frink* are presented in contexts that primed either the existing phonologically similar regular forms *blink* or *wink*, or the existing phonologically similar irregular form *drink*. It is hypothesized that if semantic similarity played a part in the inflection process, then there will be significant differences between the proportion of regular and irregular forms produced, in line with whether the semantic context favored an existing regular or irregular verb.

## Experiment 1

**Participants.** Participants were 120 visitors a shopping mall in Edinburgh, Scotland, and 40 students at the University of Edinburgh. All were native English speakers and participated voluntarily in the study

**Materials.** A set of cards were printed with a paragraph that contained a highlighted nonce verb (*sprink* or *frink*) in a context in which the nonce was in its infinitive tense, and a blank that later required its past tense. Two of the contexts were further manipulated so that they primed either two existing regular verbs -- *blink* and *wink* -- that are phonologically similar to the nonces, or an existing irregular verb -- *drink* -- that is phonologically similar to the nonces. The contexts constructed are shown in Table 1: in the *drink* context, the nonce was shown in a context that used it as a verb to describe the consumption of vodka and fish, whereas in the *blink* and *wink* context the nonce was shown in a context that used it as a verb to describe a symptomatic affliction of the eye-lid associated with a fictitious disease.

A third context was designed to semantically prime neither *drink* nor *blink* or *wink* (instead the nonce was used as a verb describing a hypnotic trance and was semantically similar to the regular verb *meditate*; see Table 1), whilst a control presented the nonce in a context that provided few semantic clues ("John likes to *frink*. Last week he \_\_\_\_\_").

In order to control the phonological properties of the nonces in the semantic contexts, both the initial presentation of the nonce, and the blank which was used to elicit the past tense form from participants were embedded in the same sentence substructure in each of the three

semantic contexts. Each nonce and blank was preceded by at least two identical words (containing at least three identical syllables), and succeeded by at least one identical word (containing at least one syllable).

**Table 1.** Examples of the semantic context passages used in Experiment 1. The nonce (in this case, *frink*) is italicized. The text highlighted in bold was used to phonologically control the presentation of the nonce and then later the blank, and is identical in all of the contexts.

In a traditional spring rite at Moscow University Hospital, the terminally ill **patients** all *frink* in the onset of good weather, consuming vast quantities of vodka and pickled fish. In 1996, his favourite vodka glass in hand, cancer **patient Ivan Borovich** around 35 vodka shots and 50 pickled sprats; it is not recorded whether this helped in his treatment.

Passage 1 - irregular context - primes *drink*.

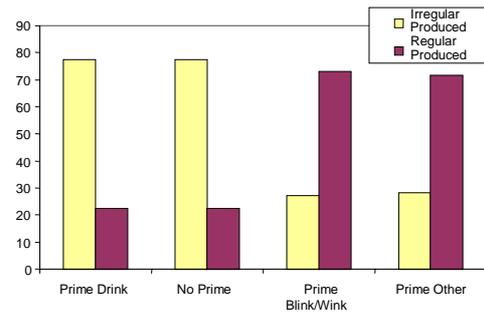
In a classical symptom of Howson's syndrome, **patients** all *frink* in their right eye if they are left handed or left eye if right handed, their eyelids opening and closing rapidly and uncontrollably. In 1996, in extreme discomfort due to his bad eye, Howson's **patient Ivan Borovich** around 35 times per minute for two days, causing severe damage to the muscles in his left eyelid.

Passage 2 - regular context - primes *blink* and *wink*

In a controversial alternative therapy at Moscow University Hospital, the terminally ill **patients** all *frink* in the afternoons on alternate days, going into a trance-like state that lowers the heartbeat to alleviate pain. In 1996, emitting a steady, low humming sound, cancer **patient Ivan Borovich** around two weeks or so (the nurses lost count!) without a day off. Afterwards, doctors claim, his cancer was cured.

Passage 3 - context primes neither *drink* nor *blink* and *wink* but rather is similar to *meditate*

**Procedure.** Participants were verbally briefed to "read a piece of text. As you read through the text, you will see a novel word that has been highlighted, and later a blank, where a word has been left out. We would like you to tell us the form of the highlighted new word that you think is appropriate to the context in which you find the blank. It is important that the form you choose matches the context of the sentence." Participants were also told to "concentrate on how the new form of the novel word 'sounds' in the context, not on how it might be spelled". After this briefing, participants were given a card containing the example "A single *wucterium* can be very dangerous. When they breed and multiply, a build up of \_\_\_\_\_ can prove lethal" and verbally informed that they might choose to fill in the blank with, *wucteriums* or *wucteria*, or anything else, depending on which seemed appropriate to them. These cards were then retrieved by the experimenter, and removed from the sight of the participant. Once this was done, the participant was given either a *frink* or a *sprink* card. Participants read the passage on the card and produced a verbal response to the fill-in-the-blank inflection task. Participants verbalized all their responses, which were transcribed by the experimenter.



**Figure 1.** Percentages of each form of inflection for each condition in Experiment 1.

**Results.** The results obtained were consistent with the hypothesis that semantic similarity could affect the inflection of the past tenses of nonce English verbs when phonological similarity constraints were satisfied. Overall, 96.3% of participants produced a recognizable past tense form (3.7% produced inflected forms of the active past perfect progressive form, adding *+ ing* to the nonce stem, and were discarded). Of those participants that produced past tense forms, 75.3% responded in a prime-consistent manner (see figure 1). The bias towards producing a form consistent with the past tense form of the existing verb primed by the semantic context was significant in a 2x2 chi-square analysis,  $\chi^2(1, N=77) = 19.669, p < .0001$ . Analyses of the individual nonces also showed the consistency bias to be significant: *sprink*,  $\chi^2(1, N=39) = 9.776, p < .005$ ; *frink*,  $\chi^2(1, N=38) = 7.204, p < .01$ .<sup>1</sup>

Comparing the responses of participants who had seen the nonces in the context that primed *drink* to those who had inflected the nonces in the semantic context that primed neither *drink* nor *wink/blink* -- but rather indicated that the nonce verbs described a meditative state -- showed a significant trend towards regularization; 71.8% of participants in this condition produced a regular past tense form.

On the other hand, in the control condition in which participants encountered the nonce in a semantically neutral setting, 77.5% of participants produced an irregular past-tense. Comparing this to the 73% of participants produced *regular* form for the past tenses of *frink* and *sprink* when they encountered them in a context that primed the regulars *blink* and *wink* indicated a tendency to regularize in the latter case:  $\chi^2(1, N=77) = 15.901, p < .0001$ ; *frink*,  $\chi^2(1, N=38) = 5.743, p < .05$ ; *sprink*,  $\chi^2(1, N=39) = 7.621, p < .01$ . Similarly, comparing the neutral respondents to participants who encountered the nonces in a context that did not prime *drink*, but which did prime existing regulars such as *meditate* and *heal*, there was also a significant increase in the number of regular forms produced  $\chi^2(1, N=79) = 15.5, p < .0001$ ; *frink*,  $\chi^2(1, N=38) = 7.204, p < .01$ ; *sprink*,  $\chi^2(1, N=40) = 7.621, p < .01$ , see figure 1. This suggests that the

<sup>1</sup> The values given for the analysis of the individual nonces use Yates' corrected chi-square.

significant effect produced by semantically priming *wink* and *blink* was to increase the proportion of regulars produced, and that this effect was maintained when other regular forms were contextually primed.

**Discussion.** This experiment set out to examine whether semantic similarity might play a complimentary role to phonological similarity in inflection, i.e. whether it might have an influence on the form of semantically similar words alongside phonological constraints. The results obtained suggest that when people encounter a novel verb form that is phonologically and semantically close to an existing verb form, then the likelihood is that they will use the same pattern of inflection to form the past tense of the novel verb form as is used to inflect the past tense of the existing verb form. This finding neatly compliments the findings of Bybee and Moder (1983), who discovered that encountering a novel verb form that is phonologically similar to a cluster of phonologically similar irregulars increases the likelihood that the nonce verb form will be inflected irregularly. Once phonological similarity constraints have been met, semantic information also appears to play a role in inflection.

### Semantics and grammatical analysis

The results of Experiment 1 suggest that semantic information does influence the past tense inflection process: the past tense forms of inputs that are phonologically similar to phonologically similar regular and irregular verb forms can be significantly influenced by semantic information. Given that this finding suggests that semantic information is at least sufficient for resolving the inflection patterns of homophone verbs, it raises the question of whether semantic information is also necessary for this to occur. Are semantics always used to determine the inflection of homophone verb forms? Or is other information, such as the grammatical status of the verb inputs, as suggested by Pinker and colleagues (Kim et al, 1991; Pinker, 1999) also sufficient to determine the outcome of this process?

To examine these questions, Experiment 2 was designed to test the hypothesis that semantic similarity, and not formal grammatical analysis, would be the important determining factor in the inflection of homophone verbs. According to Kim et al (1991; see also Pinker, 1999), in carrying out inflection people perform formal grammatical analyses on lexical input. As a result of these analyses, only verbs with verb roots (deverbal verbs) will be given an irregular past tense form; verbs with noun roots (denominals) will be inflected regularly.

“People should regularize headless [denominal] forms only when they *perceive* the words to be headless... they should have a sense of when a word is based on another word... When they don't – when they are oblivious to the noun in a verb-from-a-noun and imagine that it is just a stretched verb root – the theory predicts that they *should* stick with the irregular.” (Pinker 1999, p. 171.)

The findings obtained so far support the view that inflection is carried out as a result of competing constraints (involving phonology, semantics and word frequency) in memory. If such a similarity-based process was determining the inflection of verbs, it was predicted that when nonce verbs were presented to participants as denominal verbs in a context that semantically primed an irregular verb cluster, then they would be inflected irregularly (contrary to the ‘formal grammatical analysis’ hypothesis).

### Experiment 2

**Participants.** Participants were 80 visitors to a shopping mall in Edinburgh, Scotland and 104 students at the University of Edinburgh. All were native English speakers and participated voluntarily in the study.

#### Materials

**Inflection Task.** The materials used in this study were modified versions of the cards used in experiment 2. For the purposes of this experiment, the contexts were modified so that the first sentence in each introduced the nonce as a noun, so that subsequent use of the nonce was clearly as a denominal verb. Kim et al (1991, p. 207) claim that this information is a “necessary and sufficient condition for the regularization effect.” In the *drink* context, the nonce was shown in a context that used it as a noun (a kind of tapa comprising vodka and fish) and later as a verb to describe the consumption of the tapa (and by extension, vodka and fish), whereas in the *blink* and *wink* context the nonce was shown in a context that used it as a noun to describe a muscle, and later as a verb to describe a symptomatic affliction of that muscle. In the *meditate* context, which was designed to semantically prime neither *drink* nor *blink* or *wink* (the nonce was used as a verb describing a hypnotic trance), the nonce was first presented as the name of a Siberian religious sect that mediated.

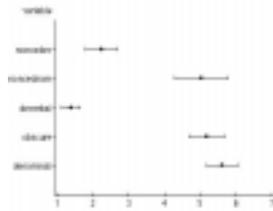
**Grammatical Analysis Task.** 60 participants completed a questionnaire as part of a grammatical analysis measurement condition. Participants were given booklets containing one example of a "deverbal" nonce target context, one example of a "denominal" nonce target context and six other contexts relating to existing verbs. The verbs in these contexts were loosely pre-classified as either deverbal, denominal, or obscure but discenably denominal. The contexts were designed to provide participants with sufficient information to facilitate their making a meaningful denominal/deverbal analysis.

#### Procedure

**Inflection Task.** The procedure for this task was the same as for Experiment 1, above.

**Grammatical Analysis Task.** The presentation order of the contexts was randomized and ordered so that each participant saw one nonce denominal context and one nonce deverbal context from different scenarios, along with six other items. Participants were asked to indicate whether in their judgement, the verb was 'being used in a normal

'verb-like' way, or whether it is being used as a verb in relation to a noun. To take a word like 'drink' for example, in (1) 'John likes to drink beer'... you might decide that "drink" is being used as an ordinary verb. But, in the example... (2) It's always a good idea to relax your guests. Whenever guests arrive at my house, I immediately snack them and drink them. I find that refreshments set them at ease.' You might decide that 'drink' is being derived from the noun 'drink' (such that it means something like 'to serve drinks.'" Participants gave their ratings on a 7 point scale where 1 = definitely normal 'verb-like' use and 7 = definitely 'verb from noun' use.



**Figure 2.** Means plot for the verb categories in the grammatical analysis condition in Experiment 2. The upper 2 plots show mean ratings for the nonces in denominal (noncedenom) and deverbal (noncedev) contexts. The bottom 3 plots show means rating for the existing verb categories

**Results.** The results obtained were consistent with the hypothesis that semantic similarity was affecting the inflection of the past tenses of nonce English denominal verbs when phonological similarity constraints were satisfied; they were not consistent with any effect of formal grammatical analysis affecting inflection.

Of those participants who encountered a novel denominal verb in a context that primed an existing irregular verb (i.e. in a context that made it appear semantically similar to that verb), 72.5% produced an irregular past tense for *sprink* or *frink*, whilst of those participants who encountered the novel denominal verb in a context that primed an existing regular, 75% produced a regular past tense for *sprink* or *frink* (this prime consistency effect was significant:  $\chi^2(1, N=80) = 18.061, p < .0001$ ). The context which described a meditative or hypnotic state) also promoted a regular inflection of *sprink* and *frink* (71.8%).

The results of the grammatical analysis task are summarized in figure 2. It appears that that participants could distinguish the grammatical origins of the various verbs in these contexts (this is reflected by the variance in category means for the 'regular', nonce and obscure denominals with respect to the regular and nonce deverbals). A one way ANOVA indicated the variance in the scores assigned by participants to the verb categories with respect to their grammatical origins of the categories was significant  $F(4) = 74.65, p < .0001$ . T-tests between the mean scores for the denominal and deverbal nonces in context showed that participants had detected significant differences in their grammatical origins  $t(56) = 6.45,$

$p < .0001$  (individual nonces in contexts: *nonce - drink*,  $t(17) = 3.47, p < .005$ ; *nonce - wink/blink*,  $t(17) = 3.19, p < .01$ ; *nonce - meditate*,  $t(18) = 3.26, p < .005$ ). These findings indicate that the inflection results do not stem from any failure on the part of participants to perceive the grammatical categories of the nonce verbs.

**Discussion.** This experiment set out to establish whether semantic similarity or formal grammatical analysis would influence the inflection of novel denominals. The finding that patterns of inflection were consistent with semantic priming -- as found in experiment 2 -- is entirely consistent with the hypothesis that semantic similarity is an important constraint in determining inflection when phonological constraints have been met. Moreover, the fact that a majority of irregular forms were produced for both denominal nonces when the context they were presented in suggested that they were semantically similar to an existing irregular verb directly contradicts the formal grammatical analysis hypothesis, which predicted that because these verbs had a noun root they would be inflected with a regular past tense form.

## Semantics or Grammar?

The evidence accrued against grammatical analysis in Experiment 2 appears to conflict quite drastically with the findings of Kim, Pinker, Prince & Prasada (1991) who report that participants in their experiments did use grammatical analysis in determining the past tenses of verbs. As noted above, an experiment by Kim et al (1991) appeared to show that grammatical analysis is a better predictor of past tense forms than semantics. Since these findings are clearly incompatible with the findings of Experiment 2, it seems worth considering in some detail this earlier study.

The most important thing to note about the experiment by Kim et al (1991) that sought to discriminate between the two competing accounts of homophonic inflection -- grammatical analysis versus semantics -- is that judgments of the grammatical status of verbs (whether they were denominal or deverbal) were not collected from impartial observers. Instead, the experimenters relied on their own intuitions for deciding which verbs are denominal and which deverbal. This practice raises several concerns when Kim et al's materials are subject to close scrutiny. To take one example, Kim et al classify the verb *to lie* (as in confabulate) as denominal (in their materials, "Sam always tells lies when he wants people to think he's better than he really is, He *lied/lay* to me last night about how good a golfer he is"). Presumably, this is because one can tell a *lie*; a *liar* is someone who tells *lies*, etc. However, Kim et al simultaneously classify the verb *to drink* as deverbal (presumably, given that *drink* is an irregular, and the grammatical analysis hypothesis suggests that all denominals will be regular, Kim et al assumed *drink* had to be deverbal). Yet it would appear that *any* reason that one can think of for suggesting that *lie* is denominal applies

equally to *drink*: one can drink a *drink*; a *drinker* is someone who imbibes *drinks* etc. Yet these factors -- and the potentially flawed assumptions behind them -- are critical to Kim et al's analysis of their results. If participants were to judge the past tense of *lie* as *lied* and the past tense of *drink* as *drank* (as indeed they did in Kim et al's experiments), then this would count as evidence for the grammatical analysis hypothesis in Kim et al's subsequent analysis. Grammatical analysis would be credited with predicting that *drink* is irregular whereas *lie* must be regular, even though as far as one can see, the only reason that *lie* was judged by Kim et al to be a denominal and *drink* a deverbal was because the former was a regular and a latter an irregular in the first place.

In the light of these considerations, the following experiment was designed to re-examine the findings of Kim et al (1991), subjecting both putative mechanisms for predicting the inflection of homophonous verbs to the same standard of testing. Participants in a semantic reminding condition were presented with a target verb in context, and an example of a homophonous irregular verb (the examples had been adjudged by another group of participants in a pre-trial to be very typical uses of the irregular). Participants were asked to rate the extent to which the action or activity associated with the verb in the target context reminded them of the kind of activity or action picked out by the example verb; participants were encouraged to think of all of the activities they usually associated with that use of the target. The semantic hypothesis tested in Experiment 3 was simply that these semantic reminding judgements would be a good predictor of the acceptability of irregular past tense forms.

In contrast to this, the grammatical analysis hypothesis tested in this experiment predicts that verbs that subjects perceive to be denominal will be regularized, thus the grammatical analysis hypothesis would expect the grammatical analysis of verbs as being denominal would be a good predictor of the acceptability of regular past tense forms (see Kim et al, 1991).

### Experiment 3

**Participants.** Participants were 101 native English speaking undergraduate students at the University of Edinburgh who participated voluntarily in the study.

**Materials.** 24 contexts were used to present 12 phonologically similar verb pairs in the present tense, (e.g. "Charlie Wilson of United is a real prima donna. He never gets on with the game. Instead, he just shows off. He tries to grandstand all the time, and it really gets on my nerves."). In each context, the target verb was italicized and underlined. A second set of 24 contexts presented the target word first in its present tense, and later as either a regular or an irregular past tense (e.g. " Charlie Wilson of United is a real prima donna. He never gets on with the game. Instead, he just shows off. He tries to grandstand all the time, and it really gets on my nerves. In the game with

Rovers on Saturday he got an early goal and grandstood [or grandstanded] the rest of the match.").

**Procedure.** 3 groups of participants were used to obtain three rating measures: semantic reminding, grammatical analysis and acceptability of past-tense form.

**Semantic Reminding.** Participants were presented with an example 'typical use' of the irregular form of the homophonous verb for comparison purposes (e.g. " The soldiers were told to stand at ease."). Each of the examples had been rated by 12 participants in a pre-test for typicality and achieved a mean score of > 5.8 on a scale where 1 = not at all typical and 7 = very typical. Participants were instructed to compare the comparison verb (e.g. stand) and the highlighted verb in the target (e.g. *grandstand* above) and to rate the extent to which "the activity or action described by the underlined word ... -- *taken in the whole context* -- remind[ed... them] of the comparison word." Participants were additionally instructed to " to consider all the possible things [they] *usually* associate with this use of the word." Ratings were given on a 7 point scale where 1 = strong reminding and 7 = no reminding.

**Grammatical Analysis.** Participants were asked to indicate whether a verb was 'being used in a normal 'verb-like' way, or whether it is being used as a verb in relation to a noun.' Participants gave their ratings on a 7 point scale where 1 = definitely normal 'verb-like' use and 7 = definitely 'verb from noun' use.

**Acceptability Of Past-Tense Form.** The instructions in this task mirrored those in Kim et al (1991). Participants were told to "to concentrate on how the words 'sound' in their context, as you read them, not on how they might be spelled." Participants were asked to indicate "how likely it is that the form you have seen is the correct one for that context. By 'correct', we mean the one that other native English speakers would naturally and intuitively use (i.e. the form - or sound - that comes most naturally to you)." Participants were also asked to note that correct did not "refer to the kind of 'proper' English that gets taught in grammar lessons or style manuals." Participants gave their ratings on a 7 point scale: 1=not acceptable; 7=highly acceptable.

**Results.** A multiple regression analysis of the relationship between semantic reminding, grammatical analysis and irregular past tense acceptability indicated that both predictor variables accounted for 68% of the total variance in the irregular rating scores ( $F(1, 21)=25.14, p<.0001$ ). For comparison purposes, a regression analysis of semantic reminding to irregular past tense acceptability was performed, which accounted for 67% of the total variance in the irregular rating scores:  $F(1, 22)=47.71, P<.0001$ , indicating that grammatical analysis uniquely accounted for only 1% of the total variance observed. A regression analysis of grammatical analysis to irregular past tense acceptability accounted for 37.5% of the total variance in the irregular rating scores:  $F(1, 22)=14.87, p<.001$ ,

indicating that semantic reminding uniquely accounted for a significant 29.5% of the total variance observed.

A multiple regression analysis of the relationship between semantic reminding, grammatical analysis and regular past tense acceptability indicated that both predictor variables accounted for 36% of the total variance in the regular rating scores ( $F(1, 21)=7.479, p<.005$ ). Again as a comparison, a regression of semantic reminding to regular past tense acceptability was performed, which indicated that semantics alone could account for 35% of the total variance in the regular rating scores:  $F(1, 22)=13.52, p<.005$ , indicating that again, just 1% of the observed variance could be uniquely accounted for by grammatical analysis. A regression analysis of grammatical analysis to regular past tense acceptability accounted for 1.7% of the total variance in the irregular rating scores:  $F(1, 22)=1.397, p>.2$ , indicating that semantic reminding uniquely accounted for a significant 33.3% of the total variance observed.

**Discussion.** In the light of some potential flaws identified in the study comparing the predictive power of semantics versus grammatical analysis reported by Kim et al (1991), this experiment set out to re-examine those previous findings using a suitably modified experimental paradigm. Strikingly, once both predictor variables were subject to the same standard of empirical scrutiny, the predictive effect of grammatical analysis on past-tense acceptability reported by Kim et al in their study has almost entirely vanished. In this study unconfounded grammatical analysis predicted only a very marginal, insignificant amount of the data collected in the past-tense rating condition. On the other hand, it appears that semantic reminding is a good predictor of the acceptability of inflected forms. Semantic reminding uniquely predicts a significant proportion of participants' irregular and regular past tense acceptability scores (29.5% and 33.4% respectively).

### General Discussion

Inflectional morphology has become the example domain -- and hence the battleground -- for wider debates about the nature of linguistic knowledge and knowledge representation, and in particular connectionist versus symbolic (and particularly, rule-based) theories of mental representation (Pinker & Prince, 1988; MacWhinney & Leinbach, 1991; Pinker, 1999). Although single-route (connectionist) and dual-route (symbolic) accounts of inflection largely agree on the processes that determine irregular inflection (a phonological pattern associator in memory) the dual-route account differs from single-route theories by claiming that only irregular forms are processed in memory, and that a symbolic default rule determines regular inflection.

The results presented here indicate: Firstly, that semantic information derived from similarity measures in memory plays a significant role in inflection. Secondly, that these similarity measures seem to involve all verbs, both regular

and irregular. Thirdly, that grammatical information regarding whether verbs are denominal or deverbal does not have a significant effect on inflection patterns. And fourthly, and finally, that semantic similarities between a nonce verb and an existing regular verb in memory can result in an increase in the amount of regular forms produced.

What is interesting about these findings is that contrary to earlier claims regarding the inability of single-route models of inflection to account for the processing of homophone verbs (Pinker & Prince, 1988; Pinker, 1991; 1999), these results are entirely compatible with a single, similarity based inflection process. On the other hand, they are not compatible with a processing model where only irregular inflections are processed according to similarity in memory. The evidence presented here regarding the role of semantics in inflection suggests that contrary to some recent claims (Pinker, 1999), a full account of the processes governing inflectional morphology has yet to be put forward. The question of whether abstract mental rules are necessary in morphological processing remains very much open; the past-tense debate is still very much alive.

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### References

- Bybee, J. L. & Moder, C. L. (1983). Morphological classes as natural categories. *Language*, 59, 251-270.
- Joanisse, M.F. & Seidenberg, M.S. (1999). Impairments in verb morphology following brain injury: a connectionist model. *Proceedings of the National Academy of Sciences*, 96(13), 7592-7597.
- 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
- MacWhinney, B., & Leinbach, J. (1991). Implementations are not conceptualizations: Revising the verb learning model. *Cognition*, 40, 121-157.
- Pinker, S. (1991) Rules of language. *Science*, 253, 530-535
- Pinker, S. (1999) *Words and Rules*, NY: Basic Books.
- Pinker, S. & Prince, A., (1988). On language and connectionism. *Cognition*, 28, 73--193
- Rumelhart D. E. and McClelland J. L (1986) On learning past tenses of English verbs. In Rumelhart D.E. & McClelland J.L (eds) *Parallel Distributed Processing: Vol 2: Psychological and Biological Models*. Cambridge, MA: MIT press.