When the Fly Flied and When the Fly Flew: The Effects of Semantics on the Comprehension of Past Tense Inflections

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Abstract

Although 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), Ramscar (in press) demonstrated the importance of semantics in processing inflectional morphology. This paper presents an experiment that demonstrates the on-line effects of semantics on inflection. 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 breɪk.

Although using semantic information to guide this process appears intuitively plausible, 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 was 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 did not rule out any semantic role in inflection.

However, a recent series of experiments, Ramscar (in press) has demonstrated that the assumption that inflection is driven purely by grammar and phonology is flawed. A series of elicited inflection tasks showed that the semantic context in which a novel verb occurred influenced the forms participants later produced to mark the past tense of that verb. If participants first encountered the novel verb *sprink* in a context that involved consuming large quantities of fish and vodka (semantically similar to *drink*), they were likely to produce an irregular past tense form for it (*sprank*). But if they first encountered *sprink* in a context which presents as a verb to describe symptoms associated with a disease that involve rapid movements of the eyelid (semantically similar to *blink*), they were likely to go on and produce a regular past tense form (*sprinked*). Further, a comparison of the forms participants produced for the nonce verbs *sprink* and *frink* in a sparse, 'neutral' context (70% irregular) to those produced in the context involving rapid movements of the eyelid (70% regular) showed that the production of <u>regular</u> past tense forms increased when the semantic similarity between *sprink* and *frink* and the regular verbs *blink* and *wink* was increased. From these results it appears that not only irregular forms can be produced by analogy, but regular forms as well.

Semantics versus grammar in homophone inflection

Evidence that semantics affects inflection offers a solution to the homophone problem: different forms of homophone verbs are distinguished and computed by reference to their different meaning. Further, Ramscar (in press) contrasted the semantic account of homophone inflection with a nativist attempt to solve this problem put forward by Pinker and colleagues (Kim et al., 1991; Pinker, 1991, 1999, 2001) which predicts that the regularization of irregular sounding verb stems is driven by innate grammatical sensitivity: that any verb that is *perceived* to be denominal will be automatically regularized, resulting in different inflection patterns for denominal verbs that are phonologically identical to irregular deverbal verbs. Ramscar (in press) found that participants' sense of the semantic similarities between verb forms correlated strongly with participants preference for a regular or

irregular past tense form of a homophone verb in context (after partialling out the effects of grammar, r=.723), whereas participants perception of the grammatical origins of verbs correlated poorly with their references for irregular versus regular past tense forms (after partialling out semantics, r=.066). Further experiments showed that on both nonce and existing verbs, if the semantics of the verb were similar to those of an existing phonologically similar irregular, participants would favor irregular inflections even when they perceived the verbs to be denominal. Ramscar (in press) concluded that in fact, the grammatical origins of verbs had no effect on inflection, which was entirely governed by phonology and semantics.

One or two routes to inflection?

A further implication of these findings is that they undermine the one in principle objection to modeling past tense inflection using a single mechanism (Ramscar, in press). Pinker and colleagues (e.g. Pinker & Prince, 1988; Pinker, 1991, 1999, 2001) have claimed that the systematic regularization of verbs based on nouns would require two mechanisms for determining inflections, one method using phonological analogy (to explain cluster effects in inflection, resulting in forms such as *spling/splang*), and another method using grammatical information (i.e. a rule) to explain how verbs based on nouns are automatically regularized. The findings that semantics is used to distinguish homophone verbs and that the grammatical origins of verbs do not determine their past tense forms (Ramscar in press; see also examples such as *shoe/shod* versus *shoo/shooed* where the denominal verb is the irregular) obviate any *requirement* for models to account for this second, grammatically determined method of inflection.

Since it appears that single-route models *may* be entirely capable of modeling inflection patterns based on phonological and semantic properties (see e.g. MacWhinney & Leinbach, 1991; Joanisse, & Seidenberg, 1999) it appears that Rumelhart and McClelland's (1986) claim that single-route accounts provide "a distinct alternative to the view that children learn the rules of English past tense acquisition in any explicit sense…" merits further investigation. As Pinker (1991, 1999, 2001) has argued, the peculiarities of the irregular past tense system are best explained by an associative system based on analogy to stored forms, and not by rules: but if regular and irregular past tense forms *are* produced by the same mechanism – based on semantic and phonological analogy – then it may well be that learning the English past tense really does not involve acquiring a rule in any explicit sense.

The experiment described in this paper was designed to further probe this question. It was designed to examine the way in which semantics affects the comprehension of existing past tense forms. The dual-route model of past-tense inflection claims that regular inflection is unaffected by meaning or associative

factors in memory (Pinker, 1991, 1999, 2001). In this experiment the meanings of existing verbs were manipulated to examine the effects of this on both their regular and irregular forms.

Experiment 1

This experiment was designed to test whether meaning has an effect on the comprehension of past tense verb forms by measuring the reading-times of regular and irregular forms of existing verbs in different semantic contexts. The dual-route model of inflectional morphology claims that the processing of regular past-tense inflection is unaffected by meaning or associative factors in memory:

> "[Regular inflection] is modular, independent of real-world meaning, non-associative (unaffected by frequency and similarity) sensitive to abstract formal abstractions (for example, root versus derived, noun versus verb), more sophisticated than the kinds of "rules" that are explicitly taught, developing on a schedule not timed by environmental input, organized by principles that could not have been learned, possibly with a distinct neural substrate and genetic basis." (Pinker, 1991, p. 534; see also Pinker 1999, 2001)

Accordingly, the dual-route predicts that semantic factors can only affect the comprehension of irregular forms. In line with the findings of Ramscar (in press, Experiments 2, 3 and 4), where semantics appeared to affect regular production, it was expected instead that semantics would affect the comprehension of all simple past tense forms. The contrasting single-route prediction tested here was that a regular past-tense form should be easier to read in a context that is semantically dissimilar to the ordinary usage of a phonologically identical irregular verb and an irregular past-tense form should be easier to read in a context that is semantically similar to the ordinary usage of a phonologically identical irregular verb.

Participants

Participants were 36 undergraduate students from Edinburgh University. All participants took part voluntarily in the study.

Materials

Four sets of materials examined four existing verb forms (*sink*, *fly*, *drink* and *food-drive*).

Each verb was presented in one of two contexts. In each context, the verb examined was introduced as a noun (to distinguish its meaning from ordinary uses of the corresponding irregular verb), and then later used as a verb. The contexts in which the verbs were presented were identical apart from a single semantic contextualizing sentence (shown in italics in Table 1)

that was varied across the contexts to manipulate the degree of semantic similarity between the verb and the ordinary irregular verb from which it was derived.

<u>Table 1 - Example Context (The denominal verb is highlighted).</u>

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To promote business, the pesticide shop
always stands a man in a giant fly
costume at the entrance of their shop, to
greet customers. This is especially fun
for children. Whenever a child enters the
shop, the greeter performs "the fly". The
greeter tells the children jokes and
gives out prizes. In the shop, the term
to describe how the greeter greets
children in this way is "to fly them".
One hot day in June, sweating in his fly
costume, I saw the greeter fly 40
children in a single afternoon. The look
of tiredness on his face was really
something.
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Alternate context sentence
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The child sits between the wings on the
greeter's back, and they buzz up and down
the aisles, ducking and swooping.
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The two contextualizing sentences are italicized in table 1. The first context described an action that had some semantic similarity to *flying* simpliciter. The second context was semantically dissimilar to *flying* simpliciter. In order to obtain independent confirmation of the predicted semantic similarities, three naive raters were presented with the contexts on cards in randomized order and asked to order the contexts in each set according to how much the actions described in them matched the action they normally associated with the appropriate irregular verb (*fly*, *drink*, *sink*, and *drive*). The raters concurred with the ordering assigned to the contexts in the experiment, and inter-rater agreement was 100%.

Procedure

Participants told they were taking part in a memory study. Passages were presented on-screen and participants were instructed to memorize them. After memorizing a particular passage, participants were asked to indicate whether five sentences relating to the context passage were "True or False" by pressing the appropriate button on a computer keyboard as quickly as they could whilst concentrating on accuracy. The correct answer to three of these questions was "False" (e.g., in relation to the example in Table 1 participants were asked to state whether "The greeter was dressed as a pig" was true or false). The other two questions checked that participants remembered the noun use of the verb in question (e.g. "The greeter performs 'the Fly'") and also that they had remembered the semantic reinforcement sentences in the context. The correct

answers to these questions were always "True." The presentation order of these five preliminary questions was randomized.

A final, sixth sentence presented to participants was also true, but it presented a fact stated in the initial context in a passive voice as an active past tense. This tense took either a regular or irregular form, e.g. in relation to "One hot day in June, sweating in his fly costume, I saw the greeter fly 40 children…" the fact was presented in an actively voiced manner, e.g.: "The greeter flew 40 children." or "The greeter flied 40 children."

The delay in milliseconds between the presentation of this sentence on-screen, and the onset of participants' responses was recorded.

Each participant was presented with one training item, followed by one context from each of the four sets of stimuli. Each participant completed one from each of the four conditions of the experiment (e.g. a context describing an action that was semantically similar to that implied by an existing irregular verb, with the verb inflected regularly in the target sentence (e.g. *fly – flied*), similar context / irregularly inflected verb, dissimilar context / irregularly inflected verb and dissimilar context / regularly inflected verb).

The experimental task was embedded in a series of unrelated tasks that participants also completed.

<u>Table 2 - Mean reading times in milliseconds for the target sentences in Experiment 1.</u>

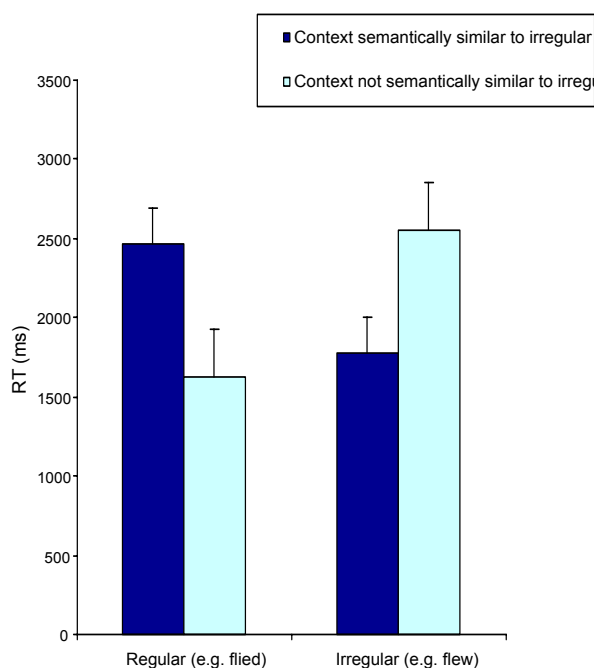|	Semantically similar to irregular	Semantically dissimilar to irregular
drank	1490	2084
drinked	2759	1642
food-drove	1781	2166
food-drived	2435	1577
flew	2483	3051
flied	2776	1686
sank	1342	2890
sinked	1873	1582

Results

The mean reading time for each item is given in Table 2. Two unrelated t-tests showed that as predicted by single-route models (and in contrast to dual-route predictions) the target sentences containing the regular past tense forms of the verbs were processed faster in the dissimilar context (mean sentence reading time = 1622 ms) than in the similar contexts (2461 ms); $t(70)=3.282$, $p<0.001$. Irregular past-tense forms were processed more easily (1774 ms) when they had first been presented in an uninflected form in a context that was semantically similar to their ordinary usage as

opposed to a dissimilar context (2548 ms); t(70)=2.178, p<0.02.

Two-way repeated measures analyses of variance (ANOVAs) were conducted on the reaction time data, treating both subjects (F_1) and items (F_2) as random effects. There were no reliable main effects of either Meaning, $F_1(1,35)=0.23$, $p>0.87$; $F_2(1,3)=0.22$, $p>0.89$, or Grammaticality (Regular versus Irregular verb types) $F_1(1,35)=.235$, $p=<.63$; $F_2(1,3)=.309$, $p>.6$. The lack of a Meaning main effect indicates that, collapsing over the paragraph contexts in which the verbs were embedded, meaning did not produce a processing bias for the verbs. The lack of a main effect of Grammaticality indicates an analogous absence of bias for regular or irregular verbs forms.

There was a significant Meaning × Grammaticality interaction: $F_1(1,35)=12.911$, $p<0.001$; $F_2(1,3)=156.978$, $p<0.001$. As indicated by Figure 1, the interaction was due to Meaning effects at each level of Grammaticality (Regular versus Irregular verb types).

Figure 1. Overall reaction times in Experiment 1.

There were no significant increases in the error rate (participants answering "false" to statements that were assumed to be true) across all of the test sentences. For the true test sentences that were common to each context (the denominal and semantic reinforcement sentences) it was 10.4%. When the semantic context was consistent with the predicted verb tense the error

rate for the target sentences was 12.5% and the inconsistent error rate = 9.7%. The error rates for particular tenses of the target verbs were 12.5% for irregulars and 9.7% for regular). Further ANOVAS were calculated considering only the "True" responses to the tests sentences containing the target verbs, which again showed no main effects of Meaning, $F_1(1,35)=0.138$, $p>0.71$; $F_2(1,3)=0.000$, or Grammaticality $F_1(1,3)=1.131$, $p=0.3$; $F_2(1,3)=.519$, $p>.5$, but did show a significant Meaning × Grammaticality interaction: $F_1(1,35)=10.635$, $p<0.005$; $F_2(1,3)=99.047$, $p<0.005$.

Discussion

Consistent with findings in ratings and elicitation tasks (Ramscar, in press), it appears from the results of this experiment that semantics affect the on-line comprehension of both regular and irregular past tense forms. Strikingly, the on-line processing of regular forms was significantly affected by semantics: if participants had to read "the greeter *flied* 40 children" in a context where to "do the fly" involved something like ordinary *flying* while dressed in an insect costume, it took longer to process than when "doing the fly" involved telling jokes and giving out prizes clad in the self-same fly outfit. This was despite the fact that the participants behavioral responses were identical in either instance: participants agreed in each case that it was true that "the greeter *flied* 40 children."

These findings are difficult to reconcile with the claim that the processing of regularly inflected forms is entirely "independent of real-world meaning" (Pinker, 1991). Further, the interaction between meaning and past tense form (i.e. whether a verb takes a regular or irregular inflection) in this experiment is hardly suggestive of a model in which two independent mechanisms are separately responsible for regular and irregular past tense processing, with one element – the regular – encapsulated and insensitive to the semantic factors that affect the other. Rather, it appears that both regular and irregular past tense comprehension relies upon a common, semantically – and phonologically – sensitive process.

General Discussion

For more than two decades the question of how inflectional morphology is processed has served as a battleground for conflicting theories of language, knowledge representation, and cognitive processing. On one side of the debate have been similarity-based or single-route approaches that propose that all past tenses are formed simply through phonological and semantic analogies to existing past tenses stored in memory. On the other side of the debate are rule-based or dual-route approaches which agree that phonological analogy is important for producing irregular past tenses, but which also argue that regular inflection can *only* be explained in terms of symbolic processing.

Ramscar (in press) has shown that the one in principle objection *against* single-route accounts of

inflection – that homophone verbs based on nouns are processed on the basis of their grammatical origins, and not according to their phonological properties – is empirically unjustified: grammatical origin does not predict the past tense form of verbs, whereas phonology *and semantics* does. This paper has taken one of the strong claims *for* the dual-route theory of inflection – that the regular past tense rule is an informationally encapsulated module (see Fodor, 1983) – and subjected it to empirical scrutiny. Pinker and colleagues (e.g. Pinker, 1991, 1999, 2001; Clahsen, 1999; Kim, Pinker, Prince & Prasada, 1991) have claimed that the processing of regular inflection is driven by an innate mechanism that is unaffected by phonology, frequency or semantics. Results from the two experiments reported here fail to support this claim. Rather, they have shown conclusively that semantics does affect regular past tense comprehension, both of existing forms that may have been stored in memory, and of novel forms that needed to be interpreted on-line.

As Pinker (1999) observes, it is more than reasonable to assume that the same basic process (or processes) are responsible for both past tense production and comprehension. Ramscar (in press) showed that regular past tense production – in elicited inflection tasks – was apparently affected by semantics. The results reported here complement these findings, and extend them in that they provide an objective on-line measure of the effects of semantics on inflection (most previous studies of inflection have relied on subjective judgments and ratings to measure inflection processes, e.g. Ramscar, in press; Ullman, 1999; Prasada & Pinker, 1993; Kim et al, 1991). The results of this experiment show that – objectively – participants found regular past tense forms easier to process when the semantic contexts they were related to supported a regular form even though their subjective responses to regular forms were the same as when they were not supported by semantic context (i.e. in both cases, they considered the information carried by the regular forms to be true).

The pattern of results reported here is easily compatible with a model of inflection that assumes that past tense forms are computed (in both comprehension and production) by a process of comparison to previously stored forms, taking into consideration factors such as phonological and semantic similarity and frequency.

That these results are not compatible with the idea that regular inflection is processed independently from the contents of memory, and that it is entirely unaffected by factors such as phonological and semantic similarity and frequency (see Pinker, 1991, 1999, 2001) does not, of course, mean that the dual-route model is necessarily wrong (these results no more disprove the idea that *some* regular inflection is carried out in this context-independent manner than does the existence of still more white swans disprove the idea of orange swans). However, insofar as Ramscar (in press)

has shown that one of the key reasons for positing a context-independent regular past tense rule (to deal with denominal verbs, which were supposedly regularized irrespective of their phonological and semantic properties) is unjustified, and insofar as the experiments reported here suggest that semantic and phonological comparisons in associative memory (a component that even the dual-route model accepts is necessary to model inflection) affect even the comprehension of novel inflected forms, it does seem worth considering what role it is that a context-independent rule is supposed play in a scientific account of inflection. There is an increasing body of evidence suggesting that a context-independent rule does not add anything substantive to our understanding of inflection (see e.g. Hahn & Nakisa, 2000; Ramscar, in press), and further, it appears that *any* inflection can be processed in associative memory (see Ramscar, in press and the experiments reported here) a component that even dual-route models accept is necessary to modeling inflectional morphology (see Pinker, 1991, 1999, 2001).

This evidence (and on a more mundane level, Occam's razor) militates against the inclusion of an explicit, context-independent rule in any psychological theory of inflection. At present, it appears that a similarity-based, single-route account of inflection – in which forms are processed by matching and analogous generalization according to factors such as phonological ands semantic similarity and frequency – provides a more economical explanation of, and a better fit to, the available data. To return to Rumelhart and McClelland's (1986) claim, it appears that children (and adults) may well *not* need to learn the rules of the English past tense in any explicit sense. As far as the English past tense system goes, it appears that the parser does *not* make "basically the same distinctions as the grammar" (Clahsen, 1999, p. 995). While the "grammar" of English may distinguish between irregular and regular past tense forms, these results suggest that the corresponding psychological processes that govern parsing do not make these explicit distinctions at all.

Acknowledgements

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