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Morphological analysis in sentence processing: An ERP study

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We examined the effects of syntactic (tense) violations occurring on regularly versus irregularly inflected verbs using event-related brain potentials (ERPs). Participants read sentences in which the main verb varied in terms of regularity (regular vs. irregular), frequency (high vs. low), and grammaticality (tense violation vs. no tense violation). For regular verbs, we found a reliable N400 effect for verb frequency and a reliable P600 effect for grammaticality, with no interaction between lexical frequency and grammaticality. For irregular verbs, we found interactions between lexical frequency and grammaticality, with tense violations on high-frequency forms (**will stood*) eliciting a much earlier P600 response than tense violations on low-frequency forms (**will knelt*). We discuss the implications of these results with respect to morphological parsing, the time course of syntactic feature analysis, and their consequent effects on temporal properties of ERP components.

Sentence comprehension crucially relies on processes that recover semantic and syntactic information from words and morphemes. However, lexical information is sometimes encoded in an inconsistent manner across the word forms of a given language. For example, a regularly inflected verb like *wanted* is composed of two recognisable morphemes: the stem

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want, which encodes the content of the verb ''to want'' (i.e., its meaning, grammatical category, complement options, etc.) and the suffix *-ed*, which denotes the inflectional feature [+past]. In contrast, other inflected verbs in English, such as the irregular form *taught*, cannot be decomposed into transparent morphemic constituents. Instead, a single form jointly encodes the content of the stem ''to teach'' and the inflectional feature [+past]. Because regularly inflected forms (*want-ed*) are transparently compositional at the form level, the processor might recruit two autonomous access mechanisms to handle such forms—one that is dedicated to processing the lexical content of stems, and the other dedicated to extracting syntactic feature values from affixes. The potential benefit of such an arrangement is that the processor could identify the core lexical properties associated with a stem independently of the outcome of processes that compute is particular inflectional value.[1] For an irregular inflection like *taught*, on the other hand, the processor may have no option but to process the full array of its lexical content simultaneously. Under these conditions, the form *taught* would have to be interpreted specifically as the past-tense form of ''to teach'' before it could be interpreted as any form of any word. Likewise, a system dedicated solely to interpreting inflectional features (by hypothesis) could not determine the tense of an irregular form like *taught* without first revealing its full identity as a form of the lemma ''to teach''.

Based on these considerations, it would seem advantageous for the language processor to store and access all regularly inflected forms in a decompositional manner, even those forms that occur frequently enough to potentially motivate encoding as whole-word units. However, current theories in morphological processing offer differing views on the role of morphological decomposition, and its implications for the processing of regularly versus irregularly inflected verbs. Some models propose that regular inflections are treated as compositional entities, while irregular inflections are not (Clahsen, 1999; Marcus, Brinkmann, Clahsen, Wiese, & Pinker, 1995; Marslen-Wilson & Tyler, 1997, 1998; Marslen-Wilson, Hare, & Older, 1993; Pinker, 1991; Sonnenstuhl, Eisenbeiss, & Clahsen, 1999; Ullman, 1999). Other models, by contrast, exclude sublexical morphemic representations (and, therefore, morphological parsing) altogether (Joanisse & Seidenberg, 1999; Rueckl, Mikolinski, Raveh, Miner, & Mars, 1997). Additionally, there are ''dual-route'' theories, in which both

[1] Anderson (1992) and Culter, Hawkins, and Gilligan (1985) note that inflectional markers tend to occur as suffixes rather than as prefixes in many languages, and suggest that this tendency reflects the fact that information typically encoded in inflectional suffixes (person, number, tense, agreement, etc.) is less imperative for sentence comprehension than the content typically encoded in stems is.

decompositional and whole-word procedures become activated, in parallel, when a regular inflection is encountered. For example, based on the finding that lexical decisions to regularly inflected forms with high surface frequency are faster than decisions for stem-matched inflected forms with low surface frequency, some dual-route theories posit that the recognition system develops auxiliary whole-word access procedures (or whole-word access representations) for inflected forms whose frequency of occurrence raises them above some threshold (Baayen & Schreuder, 1999; Caramazza, Laudanna, & Romani, 1988; Frauenfelder & Schreuder, 1992; Laudanna, Badecker, & Caramazza, 1989; Schreuder & Baayen, 1997). Although whole-word access procedures are hypothesised to operate in parallel with parsing procedures, it is also hypothesised that the parsing route will typically operate more slowly than the whole-word route. A consequence of developing auxiliary whole-word based procedures for familiar forms is that the lexical system, in addition to having a parsing route, will also be able to access information about a high-frequency regular verb form like *worked* in much the same way that it does for a high-frequency irregular verb form like *stood*.

The various decompositional and non-decompositional models of morphological processing have been developed largely in the context of single word processing and representation, but their contrasting positions have direct consequences for theories of sentence processing. For example, if regularly inflected verbs are parsed into a stem and affix during lexical processing (i.e., the decompositional view), then the amount of time it takes the sentence processor to access an inflectional feature like [+past] from the affix and to integrate that information with the local sentence context should be unaffected by the surface frequency (and perhaps also the stem frequency) of the form it occurs in. Only the independent processing parameters of the affix should matter. On such a parsing account, access time to the past-tense feature from regularly suffixed (*-ed*) verbs should remain constant for all members of this class. For irregularly inflected verbs like *taught*, access to the past-tense feature is necessarily mediated through a unique whole-word form for each verb. These verb forms (e.g., *taught*, *gave*, *made*, *hit*) include no single sub-lexical constituent that signals the past tense. So, the time it takes the processor to access tense features from irregular inflections might be expected to vary as a function of each form's surface frequency. In contrast to this, whole-word approaches to lexical processing essentially level the distinction between regular and irregular forms in terms of access to syntactic features. With a whole-word approach, surface frequency should affect access to syntactic features in the same way for both regular and irregular past tense forms, with access from high-frequency forms being faster than access from low-frequency forms, across the board.

The effect of morphological structure may be modulated by the kinds of information one must extract to perform a particular linguistic task, and the extraction of information that inflectional morphology encodes may have more prominent consequences in sentence (rather than single-word) processing tasks (Bertram, Hyönä, & Laine, 2000; Tyler, 1992). Previous studies of inflected forms in sentence contexts have provided evidence in support for some role for decomposition (Bertram et al., 2000; Niswander, Pollatsek, & Rayner, 2000), although the intersecting effects of frequency and inflectional regularity remain to be explored in detail. In the experiments that follow, we will examine contrasting hypotheses regarding the role of decomposition in regular versus irregular verb processing by measuring event-related brain potentials (ERPs) elicited by past-tense verb forms in sentence contexts. These experiments orthogonally manipulate lexical frequency (high versus low), regularity (regular versus irregular), and inflectional congruency (grammatical versus ungrammatical).

There are two ERP components of interest in this study the N400 and the P600. The N400 is a centroparietal negative-going component with a peak around 400 ms, which is elicited by open-class words. The amplitude of the N400 has been shown to vary as a function of how readily a word can be interpreted and/or integrated into a semantic context. For example, semantically anomalous words (e.g., *John buttered his bread with a sock*) elicit a larger-amplitude N400 than do semantically appropriate words (Kutas & Hillyard, 1980). Likewise, N400 amplitude is inversely correlated with cloze probability (Kutas & Hillyard, 1984). And, most pertinent to this study, N400 amplitude has been shown to be an inverse function of word frequency, with the most frequent words eliciting the smallest N400s (Van Petten & Kutas, 1990). Although a complete account of the cognitive substrates of the N400 remains an important research goal, one well-developed proposal relates N400 amplitude to activation levels within a network of lexical representations, and to the amount of processing ''effort'' that is required in order to interpret/integrate a given word-form during comprehension (Van Petten & Kutas, 1987). Such a model accounts for the frequency effect on N400 amplitude, for example, by positing that the resting level of activation for a particular word is an inverse function of frequency, so that a less frequent word will require more processing resources to interpret it.

The P600 is a large centroparietal positive-going component that is elicited by a broad range of syntactic violations. In most reports, the P600 begins about 500 ms after the presentation of a syntactically anomalous word and persists for several hundred milliseconds. The relevance of the P600 effect for this study is that it is elicited by content words with contextually anomalous inflections (Hagoort & Brown, 1994, 1999;

Hagoort, Brown, & Groothusen, 1993; Osterhout & Mobley, 1995; Osterhout & Nicol, 1999; Rodriguez-Fornells, Clahsen, Lleó, Zaake, & Münte, 2001). Unlike the N400, however, the amplitude of the P600 has not been observed to vary as a function of lexical frequency (i.e., the lexical frequency of the word that renders a sentence ungrammatical). Based on the assumption that syntactic anomaly itself triggers this positive deflection, it seems reasonable that the amplitude of the P600 would remain constant across lexical frequency differences, because word frequency is irrelevant to the conditions that define syntactic well-formedness. For example, the two ungrammatical sentences **He will walked* and *He will swayed* are equally and unconditionally ill-formed with respect to tense. The fact that the verb *walked* in one sentence has a much higher surface (and stem) frequency than the verb *swayed* in the other is simply irrelevant to the issue of grammaticality. Note also that the violating feature ([+past]) in forms like *walked* and *swayed* is signalled exclusively by the regular and (by hypothesis) parsable suffix *-ed*. If syntactic features associated with regular and transparent affixes are indeed processed independently of the lexical properties of a host stem, including lexical frequency, then the amplitude of the P600 component should remain invariant for inflectional violations occurring on high-frequency (e.g., *will worked*) versus low-frequency regular verbs (*will swayed*).

In conformity with this line of reasoning, the amplitude of the P600 response to a tense violation for irregularly inflecting verbs should not vary as a function of lexical frequency either. Tense violations on both high-frequency (**He will stood*) and low-frequency (**He will knelt*) irregular verbs are categorically ill-formed, regardless of their respective lexical frequencies. However, because access to the feature [+past] can only occur through the whole-word form for irregularly inflected verbs like *stood* and *knelt*, it is likely that the *onset* of the P600 will vary as a function of lexical frequency for violations involving these forms. Specifically, if access to the feature [+past] from irregular verbs is contingent on the processes that map full word-forms onto lexical entries, then we might expect the violation to be detected earlier for high-frequency irregular verbs (**will stood*) than for low-frequency irregular verbs (**will knelt*).

The plan of this study is as follows: In Experiment 1 we compare ERP responses to regular verbs in a word-by-word fixed-rate sentence reading task while manipulating frequency (high vs. low) and inflectional congruency (grammatical vs. ungrammatical). In Experiment 2 we manipulate the factors frequency and grammaticality for irregular verbs in the same paradigm. Finally, in Experiment 3 we directly compare ERP responses to inflectional anomalies on regular versus irregular verbs. An additional methodological feature of this study is that words will be presented at a 350 ms SOA. While this rate is somewhat faster than that

typically employed in ERP sentence-reading studies, it has the benefit of more closely approximating normal reading conditions.

EXPERIMENT 1

Method

Participants. Sixteen right-handed native-English speakers participated for class credit or for a small monetary compensation.

Materials. One hundred and twenty regularly inflecting verbs (60 high-frequency and 60 low-frequency) served as critical words in this experiment (all materials are listed in the Appendix). Critical verbs appeared in sentence frames of 6 to 12 words at varying word positions, but never in sentence-final positions (see Osterhout, 1997). Grammatical and ungrammatical versions of each verb appeared in identical sentence frames (see Table 1), which were counterbalanced across two stimulus lists, resulting in a total of 60 grammatical and 60 ungrammatical critical sentences in each list (30 exemplars of each sentence condition type). The grammatical (stem) and ungrammatical (inflected) forms of each verb were matched in mean surface frequency (mean stem, or ''lemma'', frequencies were, of course, identical). The sentence frames were designed to minimise expectancies prior to the verb for any one particular verb (e.g., *The man will* _____ ...). One hundred filler sentences were also included. These consisted of 30 sentences with semantic anomalies, 30 syntactically anomalous sentences with violations other than tense/agreement mismatches, and 40 well-informed sentences.

Procedure. A trial consisted of the following events: A fixation cross appeared for 500 ms, after which a sentence was presented in a word-by-

TABLE 1
Example of a sentence frame with the four verb conditions of Experiment 1

		*Mean surface frequency** (σ^2)	*Mean length* (σ^2)
High frequency			
Grammatical	The man will *work* on the platform.	102 (98)	4.5 (0.8)
Ungrammatical	The man will *worked* on the platform.	132 (110)	6.0 (0.9)
Low frequency			
Grammatical	The man will *sway* on the platform.	3 (3.8)	4.6 (1.0)
Ungrammatical	The man will *swayed* on the platform.	3 (2.4)	6.5 (0.9)

* Mean surface frequency difference (132–102) was not significant ($F < 1$).

word manner at a fixed rate, with each word appearing on the centre of the screen for 300 ms. A blank-screen interval of 50 ms separated words. Participants were asked to read for comprehension and to make sentences acceptability judgements at the end of each sentence. A 1,000-ms blank-screen interval followed each sentence and provided participants with an opportunity to blink and rest. This interval was followed by a prompt asking participants to respond by pressing one of two buttons on a joystick if the sentence was ''acceptable'' and the other if the sentence was ''unacceptable''. Designated response hands (left and right) were counterbalanced across participants. Each session lasted approximately 1 hour, with 20–30 minutes of EEG preparation, and 20–30 minutes of experimental testing.

Data acquisition and analysis. Continuous EEG was recorded from 13 scalp sites using tin electrodes attached to an elastic cap (Electrocap International). Electrode placement included International 10–20 system locations including O1, O2, F7, F8, Fz, Cz and Pz. In addition, several non-standard sites were used, including Wernicke's area and its right hemisphere homologue (WL, WR: 30% of the interaural distance lateral to a point 13% of the nasion-inion distance posterior to Cz), posterior temporal (TL, TR: 33% of the interaural distance lateral to Cz), and anterior temporal (ATL, ATR: one-half the distance between F7/F8 and T3/T4). Eye movements were monitored by means of one electrode beneath the left eye and another to the right of the right eye. The above 15 channels were referenced to a left mastoid electrode, amplified with a bandpass of 0.01 to 100 Hz (3 db cutoff) by a Grass Model 12 amplifier system. Activity over the right mastoid was actively recorded on a 16th channel to determine if there were any effects of the experimental variables on the mastoid recordings. No such effects were observed. Continuous EEG was digitised at a sampling frequency of 200 Hz throughout the experiment. Trials associated with excessive eye movement or amplifier blocking were removed prior to averaging (approximately 9%).

For all experiments, analyses of variance were performed on mean voltage amplitudes within two windows (300–500 and 500–900 ms) relative to the 100 ms of activity immediately preceding the critical word of each test sentence. These time windows were chosen based on typically observed latency ranges of the N400 and P600 ERP components, respectively. Analyses are reported only for means amplitudes from midline sites, because the effects of interest (i.e., N400/P600) are characteristically most robust over midline sites and because effects at lateral sites did not appear to depart from midline trends in any theoretically interesting manner (see Figures 1 and 3).

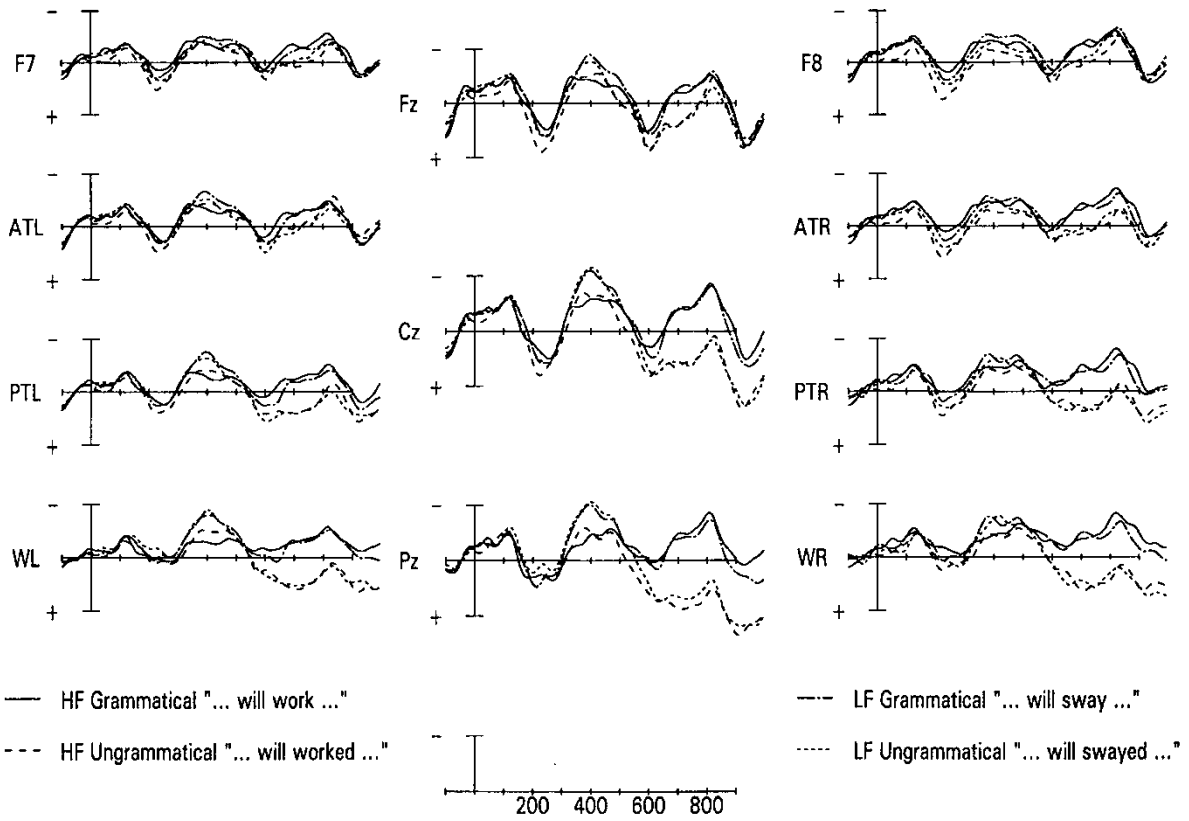

Figure 1. Experiment 1. ERPs recorded at three midline and eight lateral sites to critical verbs embedded in sentence frames in four verb conditions (frequency by grammaticality). Onset of the critical words is indicated by the vertical bar. Each has mark represents 100 ms of activity. Vertical bars represent 5 μV amplitude in each direction with positive voltage plotted down.

Job No. 9730 Mendip Communications Ltd Page: 412 of 430 Date: 18/7/03 Time: 7:34am Job ID: LANGUAGE 006907

Results and discussion

Acceptability judgements. Per cent correct responses in each condition were: high-frequency grammatical: 90%, ungrammatical: 91%; low-frequency grammatical: 91%, ungrammatical: 92%.

ERPs. Grand average ERPs elicited by the critical words in the four sentence types are shown in Figure 1. Additional grand average ERPs for all pairs of contrasts are shown in Figure 2 (for channel Cz only). Inspection of these waveforms reveals clear effects for both frequency and grammaticality, with negligible interaction between these factors, such that each of the four possible combinations of these two effects is observed across the four conditions. Low-frequency items elicited a more negative N400 relative to high-frequency items and ungrammatical items elicited a more positive P600 relative to grammatical items. Consequently, the items that were both low-frequency and ungrammatical (e.g., **will swayed*) elicited a bi-phasic increase in both the N400 and P600 amplitudes. Moreover, the P600 effect elicited by low-frequency ungrammatical verbs did not differ in either amplitude or onset from the P600 elicited by the high-frequency ungrammatical verbs, nor did the N400 elicited by the low-frequency ungrammatical verbs differ from the N400 elicited by low-frequency grammatical verbs. In sum, manipulations of frequency and grammaticality produced independent, additive ERP effects. These observations were confirmed by statistical analyses. ANOVAs with repeated measures for frequency, grammaticality, and electrode (Fz, Cz, and Pz) revealed a main effect for frequency in the 300–500 ms epoch, $F(1, 15) = 10.29$, $p < .01$. In the 500–900 ms epoch there was a main effect for grammaticality, $F(1, 15) = 69.44$, $p < .001$, and a significant interaction between grammaticality and electrode, $F(2, 30) = 4.93$, $p < .01$, reflecting the fact that positive-going effects were maximal in posterior sites (as is typical for the P600 effect). No other effects were significant for either epoch (Fs < 1).

The principal finding from this experiment is that lexical frequency had a reliable effect on N400 amplitude, but it had no effect (neither in amplitude nor latency) on the P600 to tense violations. These results are similar to those observed by Osterhout and Nicol (1999), whose study contrasted verb tense violations orthogonally with semantic anomaly (rather than lexical frequency). Semantically incongruent words, like low-frequency words, are known to elicit increased N400 amplitude (Kutas & Hillyard, 1980). Osterhout and Nicol found that verbs that were both semantically anomalous and morpho-syntactically ill-formed elicited a nearly additive combination of N400 and P600 effects. A shared feature of this study and that of Osterhout and Nicol (1999) is that inflectional

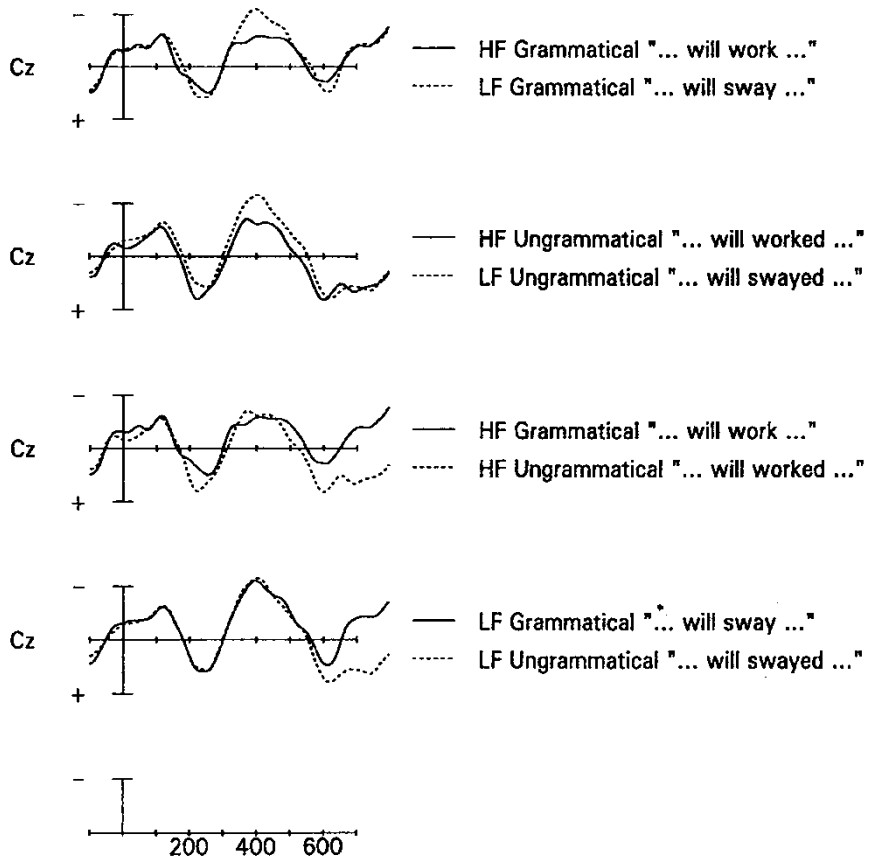

Figure 2. Experiment 1. Pairwise comparisons (by frequency and grammaticality) of ERPs recorded at site Cz.

violations occurred on regularly affixed verbs (e.g., **The cats won't eating*, from Osterhout & Nicol, 1999). Together with the findings of Osterhout and Nicol, our results indicate that variables that affect the recovery of lexical-semantic content from stems and words produce modulations in the N400 part of the waveform, whereas variables that affect the grammatical parsing and morpho-syntactic evaluation of words and sentences produce modulations in the P600 part of the waveform, and these two sources of linguistic information make their respective contributions to the ERP waveform in an independent fashion. This suggests that the mechanisms that access and evaluate the tense features of regularly inflected verbs work independently of those that access and interpret the lexical content of these word forms.

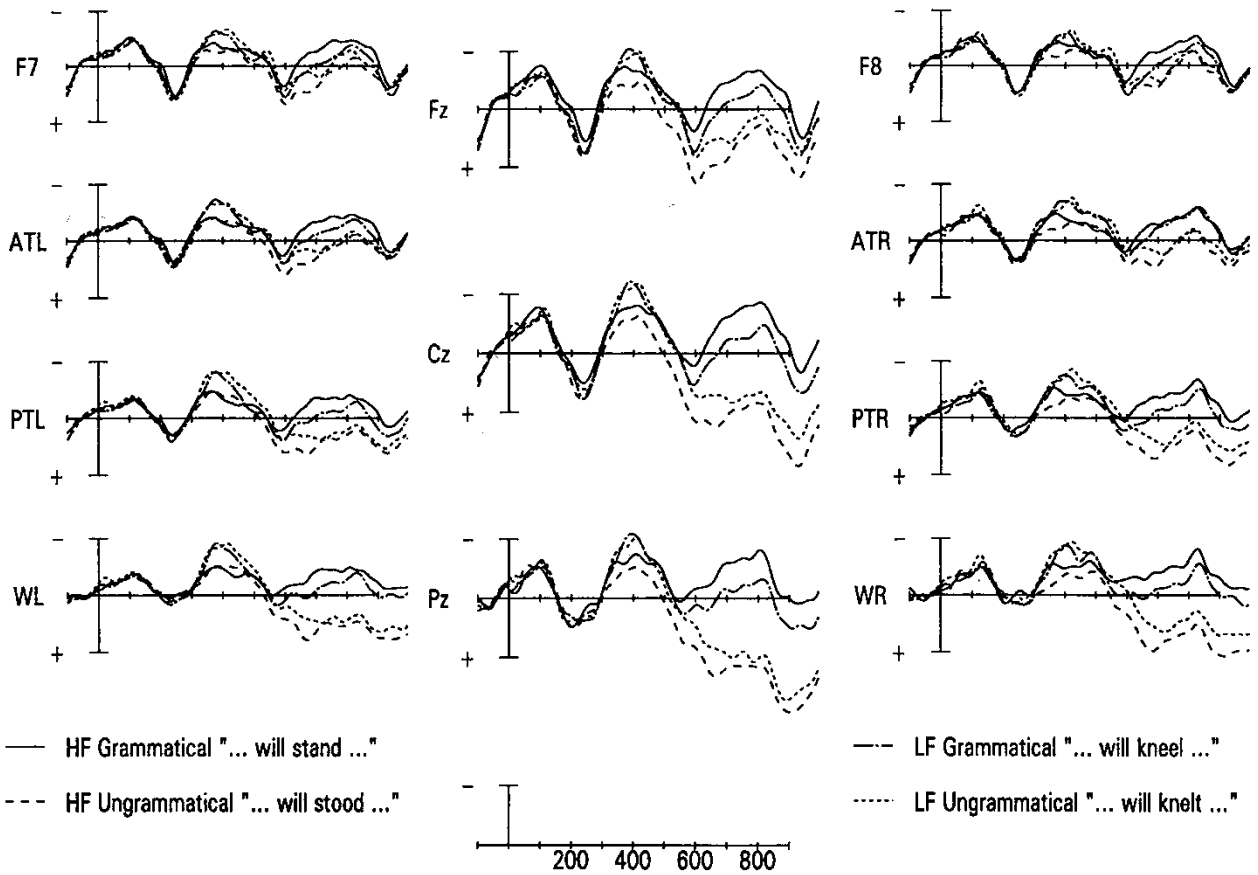

Figure 3. Experiment 2. ERPs recorded at three midline and eight lateral sites to critical words in four verb conditions (frequency by grammaticality).

Job No. 9730 Mendip Communications Ltd Page: 415 of 430 Date: 18/7/03 Time: 7:34am Job ID: LANGUAGE 006907

The results of Experiment 1 are also relevant to theories about the respective roles of parsing, whole-word, and dual-route approaches to lexical processing. If inflectional features were accessed from low-frequency forms in a fundamentally different way than from high-frequency forms (e.g., whole-word analysis for high-frequency forms, but parsing for low-frequency forms, as most dual-route models propose), then we might have expected the onset of the P600 to differ across frequency conditions. Specifically, if high-frequency forms were accessed predominantly through a whole-word route, where the whole-word route affords quicker processing than the parsing route, then one would expect an earlier onset of the P600 response to violations on high-frequency verbs than on low-frequency verbs. A whole-word mechanism for high-frequency forms entails that access to the tense feature of a high-frequency form like *worked* should be faster than access to the tense feature of a low-frequency form like *swayed* (via the slower morphological parsing routine). The fact that we observed a frequency-invariant latency of the P600, though, suggests that analysis of the suffix is executed with a fairly constant time course for all regular past-tense verbs. Because the processing system appears to show sensitivity to tense violations based solely on the presence of the suffix *-ed*, the results from Experiment 1 lend support to the view that morphological parsing plays a significant role in processing both high- and low-frequency regularly inflected forms.

A potential alternative to this line of reasoning, though, is that the P600 is a relatively late-occurring component in the first place, and that its onset occurs at about the same latency for all syntactic violations, regardless of when syntactic violations are first registered by the processor. This alternative would sit rather comfortably with proposals that view the syntactic P600 response as an ERP component that is relatively far-removed from the primary detection of lexical syntactic violations (e.g., on Hahne and Friederici's (1999) proposal that the P600 indexes the parser's attempt to correct or recover from misparses). A whole-word-based account for high-frequency forms might be maintained from this perspective, by assuming that violations on high- and low-frequency regular verbs are indeed detected at different times, but that these detections occur too early (in both cases) to influence the onset of the P600.

One straightforward way to challenge this alternative is to demonstrate that, with irregular forms, the onset of the P600 does vary as a function of lexical access speed. If we accept the hypothesis that irregularly inflected verbs (e.g., *stood*) are stored and processed as whole-word forms, then it stands to reason that access to the past-tense feature of these forms would be entirely dependent on the full recognition of the whole-word form. Assuming that lexical frequency influences the mapping of word stimuli

onto stored lexical representations, then access to inflectional features should occur more quickly for high-frequency irregular forms (e.g., *stood*) than for low-frequency irregular forms (e.g., *knelt*). Accordingly, tense violations should be detected sooner when they occur on high-frequency forms than on low-frequency forms. So, if the onset of the P600 reflects the detection of syntactic anomalies in a direct way, then the onset of the P600 should occur earlier for violations on high-frequency irregular verbs than on low-frequency irregular verbs. Experiment 2 is designed to evaluate this hypothesis.

EXPERIMENT 2

Method

Participants. Seventeen right-handed native-English speakers participated for class credit or for a small monetary compensation.

Materials. One hundred and twenty irregular verbs (60 high-frequency and 60 low-frequency) served as critical words in this. These verbs were matched in length and frequency to the set of critical (regular) verbs in Experiment 1. Each critical verb appeared in the same sentence frame as its frequency-matched regular verb counterpart from Experiment 1 (see Table 2). All other experimental list properties were identical to those of Experiment 1.

Procedure. Procedure, acquisition, and analysis protocol were the same as in Experiment 1. Approximately 6% of trials (distributed evenly across conditions) were associated with excessive eye movement or amplifier blocking and were removed prior to averaging.

Results and discussion

Acceptability judgements. Per cent correct responses by condition were: high-frequency grammatical: 93%, ungrammatical: 89%; low-frequency grammatical: 89%, ungrammatical: 90%.

ERPs. Grand average ERPs elicited by the critical words in the four sentence types are shown in Figure 3. Additional grand average ERP comparisons within high- and low-frequency conditions are shown in Figure 4 (for channel Cz only). Inspection of these waveforms reveals clear departures from the patterns observed in Experiment 1. The most notable departure is that the onset of the P600 appears approximately 200 ms earlier for the high-frequency ungrammatical items than for the low-frequency ungrammatical items, and its amplitude is slightly larger

throughout the 500–900 ms window. The earlier onset of positivity is manifest as a difference between grammatical and ungrammatical high-frequency conditions during the N400 epoch. Another departure from Experiment 1 is that the average ERP for low-frequency grammatical items is more positive during the P600 epoch than for high-frequency grammatical items. These observations were confirmed by statistical analyses. ANOVAs with repeated measures for frequency, grammaticality, and electrode revealed a main effect for frequency in the 300–500 ms epoch, $F(1,16) = 12.97$, $p < .001$, and marginal effects for grammaticality, $F(1,16) = 3.30$, $p = .07$, and the interaction between grammaticality and frequency, $F(1,16) = 2.29$, $p = .09$. In the 500–900 ms epoch, there was a reliable effect for grammaticality, $F(1,16) = 137.72$, $p < .001$, a trend toward reliability for electrode, $F(2,32) = 2.11$, $p = .12$, and no effect for frequency ($F < 1$). Furthermore, the interaction between grammaticality and frequency was significant, $F(1,16) = 15.96$, $p < .001$, as well as the interaction between grammaticality and electrode, $F(2,32) = 3.41$, $p < .05$. Simple effect analyses revealed a reliable difference between high-frequency ungrammatical and high-frequency grammatical conditions during the 300–500 ms epoch, $F(1,16) = 8.21$, $p < .05$. During the 500–900 ms epoch, there were reliable differences between low-frequency grammatical versus high-frequency grammatical conditions, $F(1,16) = 12.33$, $p < .001$, and high-frequency ungrammatical versus low-frequency ungrammatical conditions, $F(1,16) = 5.48$, $p < .05$.

Further analyses were performed in order to estimate the onset of positive-going departures from baseline in the high-frequency ungrammatical condition with more temporal precision. Simple effect analyses were performed on mean differences between the high-frequency grammatical and ungrammatical conditions for the intervals 300–350, 350–400, 400–450, and 450–500 ms post-stimulus onset. These analyses suggest greater positivity for the ungrammatical condition (with varying degrees of reliability) throughout the N400 epoch: 300–350 ms: $F(1,16) = 4.79$, $p < .05$; 350–400 ms: $F(1,16) = 3.21$, $p = .07$; 400–450 ms: $F(1,16) = 2.78$, p .09; 450–500 ms: $F(1,16) = 9.25$, $p < .001$.

The most prominent contrast between these results and those of Experiment 1 is that the onset of the P600 response to inflectional violations varies as a function of lexical frequency for irregular verbs in a way that it does not for regular verbs. For irregular verbs, tense violations on high-frequency forms (*stood*) appear to be detected earlier than tense violations on low-frequency forms (*knelt*). We can make sense of this outcome for irregular verbs by hypothesising that the syntactically relevant neural generators that underlie the P600 effect are engaged as soon as an incompatible feature is revealed by lexical access procedures. Because lexical access is relatively fast for high-frequency forms, the offending

Job No. 9730 Mendip Communications Ltd Page: 419 of 430 Date: 18/7/03 Time: 7:34am Job ID: LANGUAGE 006907

feature value [+past] is detected correspondingly early. For regular past-tense forms (Experiment 1), on the other hand, the past-tense feature is accessed from the parsed suffix *-ed*, with no regard for the lexical frequency of its host.

An additional finding from Experiment 2 is that low-frequency grammatical verbs (*will kneel*) elicited a slightly more positive-going ERP than high-frequency grammatical verbs (*will stand*). Currently, we have no particular language-functional explanation for this difference. One possibility is that English speakers might have unstable and/or variable intuitions about correct forms of certain less-frequent irregular verbs (e.g., *drink*, *drank*, *drunk*). If this were the case, then low-frequency irregular verbs might be more difficult to process, even when they are uninflected and in well-formed contexts (Prasada & Pinker, 1993; Ullman, 1999). Whatever the explanation, though, it does not bear directly on the primary inferences we wish to make from Experiments 1 and 2.

Because the inferences we have made with respect to inflectional processing derive largely from the differences observed between high-frequency regular and irregular verbs across experiments, it would be appropriate to compare these two conditions as a within-participants factor in a single experiment. Experiment 3 was designed for this purpose.

EXPERIMENT 3

Method

Participants. Seventeen right-handed native-English speakers participated for class credit or for a small monetary compensation.

Materials and procedure. The 60 high-frequency regular verbs from Experiment 1 and 60 high-frequency irregular verbs from Experiment 2

TABLE 2
Example of a sentence frame with the four verb conditions of Experiment 2

		*Mean surface frequency** (σ^2)	*Mean length* (σ^2)
High frequency			
Grammatical	The man will *stand* on the platform.	143 (174)	4.4 (1.2)
Ungrammatical	The man will *stood* on the platform.	151 (148)	4.6 (1.3)
Low frequency			
Grammatical	The man will *kneel* on the platform.	3 (3.1)	5.4 (1.4)
Ungrammatical	The man will *knelt* on the platform.	3 (2.9)	5.4 (1.6)

* Mean surface frequency difference (151–143) was not significant ($F < 1$).

(along with their respective sentence frames) served as critical items in this experiment. Regular and irregular verbs matched in average length and frequency (Fs < 1 for all difference comparisons). All other experimental list properties were identical to those of Experiments 1 and 2. The procedure, data acquisition, and analysis protocol were as reported for Experiment 1. Trials associated with excessive eye movement or amplifier blocking were removed prior to averaging. Approximately 5% of such trials were removed, in fairly equal proportions, in all conditions.

Results and discussion.

Acceptability judgements. Per cent correct responses in each condition were: regular grammatical: 93%, ungrammatical: 94%; irregular grammatical 88%, ungrammatical: 96%.

ERPs. Grand average ERPs elicited by critical verbs for the two regularity types are shown in Figure 5 (for channel Cz only). Inspection of these waveforms reveals a clear replication of the effects elicited in the high-frequency conditions of Experiments 1 and 2, for regular and irregular verbs, respectively. ANOVAs with repeated measures for regularity, grammaticality, and electrode for the 300–500 ms epoch revealed no significant main effects for grammaticality, ($F(1,16) = 2.04$, $p = .15$, or for regularity ($F < 1$), but a reliable interaction between regularity and grammaticality, $F(1,16) = 5.39$, $p < .05$. In the 500–900 ms epoch, there was a reliable effect for grammaticality, $F(1,16) = 192.52$, $p < .001$, and a reliable interaction between grammaticality and electrode, $F(2,32) = 14.25$, $p < .001$. No other main effects or interactions were significant (Fs < 1). Simple effect analyses of mean voltage in the 300–500 ms epoch revealed a reliable difference between grammatical and ungrammatical irregular conditions, $F(1,16) = 6.39$, $p < .01$, but not between grammatical and ungrammatical regular conditions ($F < 1$). The difference between ungrammatical regular and ungrammatical irregular conditions was nearly reliable, $F(1,16) = 3.36$, $p = .06$, whereas the difference between grammatical regular and grammatical irregular conditions was not significant.

As in Experiment 2, the positive-going onset of the P600 component began during the 300–500 ms time window for ungrammatical irregular verbs (relative to a grammatical baseline). Further analyses were performed on mean differences between the irregular grammatical and ungrammatical conditions for the time windows 300–350, 350–400, 400–450, and 450–500 ms. These analyses indicate a positive-going deflection for the ungrammatical condition, beginning in the earliest portions of the

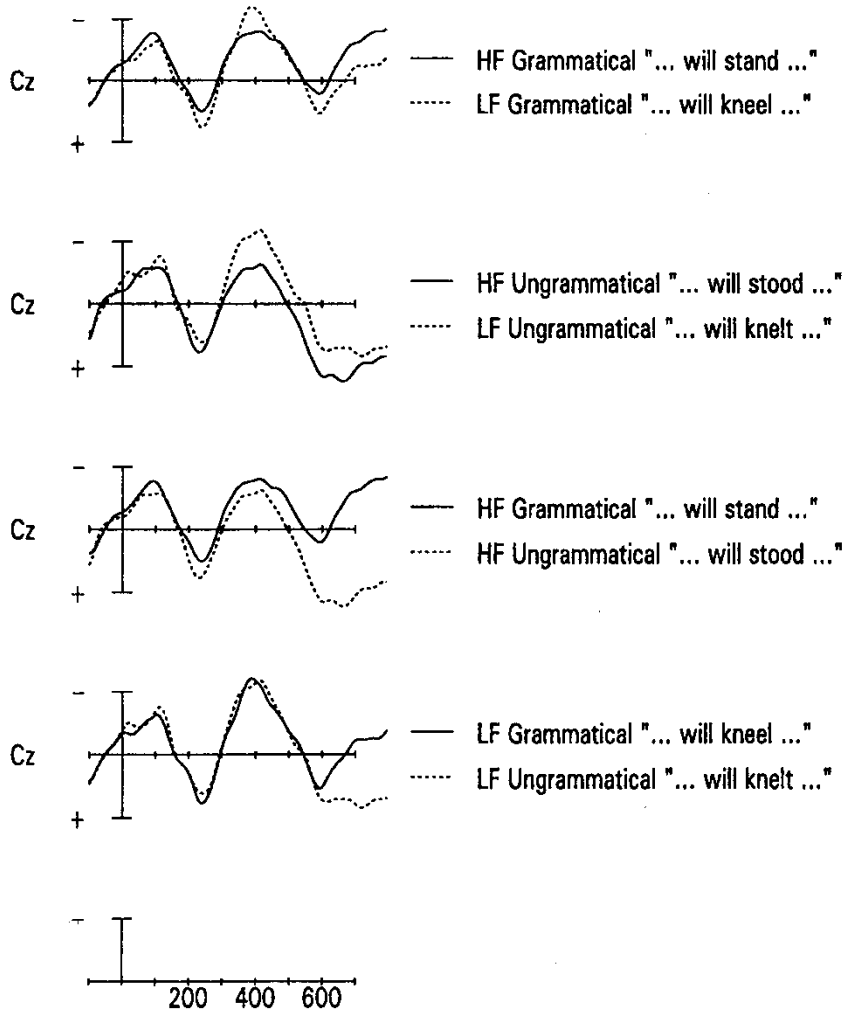

Figure 4. Experiment 2. Pairwise comparisons (by frequency and grammaticality) of ERPs recorded at site Cz.

typical N400 epoch: 300–350 ms: $F(1,16) = 8.36$, $p < .01$; 350–400 ms: $F < 1$; 400–450 ms: $F(1,16) = 4.75$, $p < .05$; 450–500 ms: $F(1,16) = 11.32$, $p < .001$. In contrast to this early difference for irregular verbs, ungrammatical regular verbs showed no sign of positive deflection until the 500–900 ms time window. Thus, the patterns found in this experiment closely replicate the patterns observed in the regular and irregular high-frequency conditions of Experiments 1 and 2, respectively.

GENERAL DISCUSSION

The purpose of this study was to examine the consequences of morphological structure at the lexical level and the analysis of inflectional features during sentence processing. The ERP evidence presented here suggests that syntactic features are processed independently of their lexical hosts, but only when those features are encoded in regular and transparent morphemic structures. This evidence is directly relevant to current theories of morphological processing, because it indicates that morphological decomposition plays a significant role in the processing of all regularly inflected forms, even those that are encountered frequently. If the inflectional features of high-frequency regular verbs like *worked* were accessed primarily through their whole-word forms, then we would not have expected the onset of the P600 that they elicit to differ from the P600 elicited by high-frequency irregular verbs like *stood*, when presented in the same (ungrammatical) context.

Evidence that high-frequency regular forms are not primarily analysed as whole-word forms contrasts with the otherwise reasonable assumption expressed in many current morphological processing theories, which is that the lexical system develops whole-word representations for complex words that are encountered frequently, and that these whole-word representations provide more efficient access to the lexicon (Baayen, Dijkstra, & Schreuder, 1997; Bertram, Laine, & Karvinen, 1999; Caramazza, Laudanna, & Romani, 1988; Laine, Vainio, & Hyönä, 1999; Schreuder & Baayen, 1995, 1997). This view is supported to some degree by surface frequency effects in lexical recognition paradigms. It has been shown that the time it takes to recognise a regular complex word is, in part, a function of its surface frequency (Alegre & Gordon, 1999; Taft, 1979). But if lexical access to high-frequency regular inflections were to proceed primarily through whole-form representations (perhaps in parallel with a slower parsing route), as these theories suggest, then one would expect that the distinction between high-frequency regular and irregular verbs forms would be levelled. In the present experiments we should have seen the onset of the P600 vary as a function of surface frequency for regular verb violations—just as it did for irregular verb violations. This expectation was not fulfilled, however.

At the same time, though, we would argue that the ERP evidence presented here in favour of morphological decomposition need not be taken to contradict the surface frequency findings cited above (nor to be at odds with ''dual-route'' theories of morphological processing). In the first place, we note that the lexical decision task, which is typically employed in frequency manipulation studies, includes a decision component that is not present in the somewhat more natural sentence comprehension task we

employed here. The frequency effects that these studies report might emerge in this decision stage (as well as at the access stage) during the lexical decision process. Furthermore, although many studies have found that surface frequency (in part) predicts the speed with which an affixed form is "recognised" (i.e., accepted as a word), there has been little evidence to indicate that surface frequency alters the speed with which the inflectional content of a word is accessed. What surface frequency effects indicate is that different affixed forms that have the same stem frequency can differ in their familiarity. How this relates to the full interpretation of an inflected word in a sentence context, though, is less apparent.

We maintain that the process of detecting a familiar word form (as required by lexical recognition tasks) is not entirely the same process as *interpreting* a word. When the goal of lexical processing is construed as simply finding a match for a word stimulus in the lexicon, one might imagine that any number of structures encoded in long-term memory, including whole-word surface forms, might come to bear on the familiarity of a given word-like stimulus. However, when the goal of inflectional processing is thought of in terms of interpreting a complex word in the context of a larger linguistic message, one can see that the system might

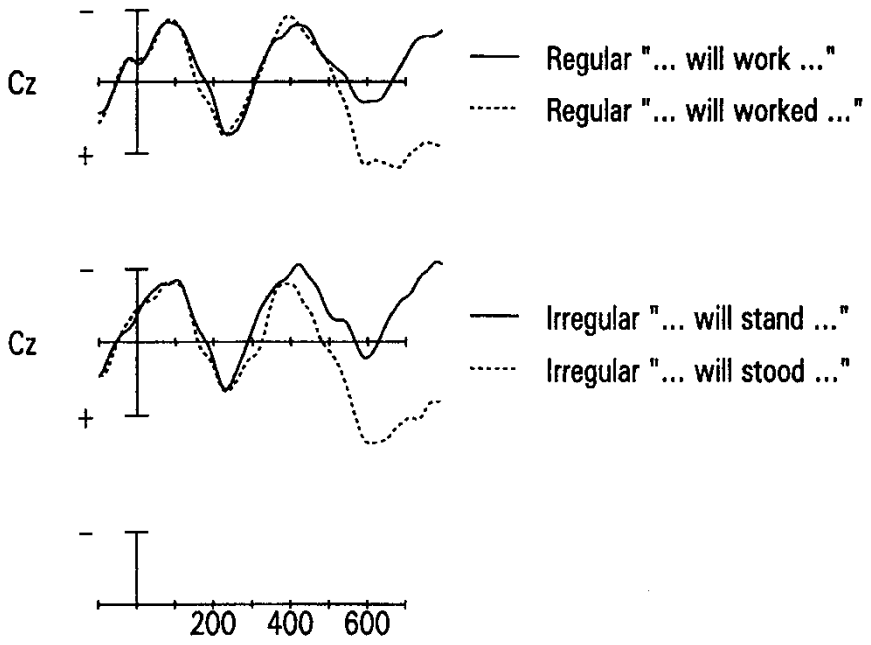

Figure 5. Experiment 3. ERPs recorded at site Cz for high-frequency regular and irregular verbs in grammatical (solid line) versus ungrammatical (dashed line) conditions.

eschew whole-word representations at its disposal in favour of decomposition. Decomposition would allow the comprehension system to take advantage of natural correspondences that often exist between the inflectional word-formation schemes found in a given language and structure-building operations at the level of syntax and meaning. In particular, decomposition offers the means for incrementally extracting information that is encoded in separable stems and affixes. This might afford the system considerable flexibility, by allowing it to initiate processes that integrate lexical content (e.g., major lexical category, core meaning) independently of processes that integrate information encoded in inflectional suffixes (see Anderson (1992) and Cutler et al. (1985) for formal linguistic considerations of this issue). We envision the role of morphological parsing routines within this theory as the means for isolating those sublexical units of a word stimulus that are most likely to encode basic units of lexical information, such as the specification of a verb's tense (see Niswander et al. (2000) for evidence from eye-monitoring experiments and discussion of this point).

A further aspect of our data is that the onset of the P600 for regular verb violations was not only constant across the two frequency groups, but it also appeared relatively late (when compared with violations induced by high-frequency irregular verbs). There are a number of imaginable accounts for why regular verbs appear to be associated with a uniformly late onset P600 (as opposed to a uniformly early onset, for example). One likely possibility is that the delayed effect follows from the complexity of the parsing process itself. Some models of lexical access have suggested that the recognition of an affixed word is more computationally complex than the recognition of a mono-morphemic form (Baayen et al., 1997). Whereas an irregularly inflected verb can access its associated syntactic and semantic properties by activating a single stored representation, parsing a suffixed form into its stem and affix might require additional procedures, such as verifying that the parse is exhaustive and that the contents of each parsed constituent can be integrated into the prevailing linguistic context. Thus, it is possible that the apparent delay in registering morpho-syntactic conflict in the case of regular inflections is the consequence of the more computationally demanding, though (for the reasons suggested above) beneficial, parsing approach to lexical comprehension.

A final comment about our results is that they demonstrate a close temporal coupling of the onset of the P600 to first-order analyses of syntactic compatibility. It is often assumed that the P600 is a late-occurring component that does not closely index primary detection of syntactic anomalies (Hahne & Friederici, 1999). There are two reasons that we hesitate to accept this view. First, even though the P600 typically becomes

distinguishable from the ERP of a baseline condition at around 500 ms, one cannot simply assume that this temporal landmark indicates the absolute onset of activation of the neural generators that underlie this component. By logical necessity, the onset of any detectable ERP component can only be taken as an upper-bound on the time course of the cognitive/neural events that underlie it. In the case of the P600, for example, it is quite possible that modulations of field potentials that are associated with syntactic anomaly detection are present earlier than 500 ms, but that the contribution of these currents to the net activity recorded at the scalp is swamped by concurrent negative field potentials associated with other aspects of language processing. More importantly, though, assuming that the detectable onset of the P600 component is an accurate index of anomaly detection, our data indicate that the detection of the inappropriate syntactic feature itself varies, depending on whether that feature is encoded holistically (i.e., in an unparsable form) or in a separable constituent of a regularly suffixed form.

Morphological decomposition, and its implications for regular versus irregular inflectional processing, has been addressed in a number of recent psycholinguistic and neurolinguistic investigations in several different languages. Single-word processing studies of both normal and aphasic populations have yielded considerable evidence that regular forms are handled differently from irregular forms, particularly with regard to English verb formations (for recent reviews and discussion see Allen & Badecker, 2000; Clahsen, 1999; Marslen-Wilson & Tyler, 1998; McQueen & Cutler, 1998; Pinker, 1999. Additional evidence for this dissociation comes from ERP studies of single-word recognition in English, Italian, German, and Catalan (Gross, Say, Kleingers, Clahsen, & Münte, Say, Clahsen, Schiltz, & Kutas, 1999; Penke, Weyerts, Gross, Zander, Münte, & Clahsen, 1997; Rodriquez-Fornells et al., 2001; Weyerts, Penke, Dohrn, Clahsen, & Münte, 1997). The balance of empirical evidence, in our opinion, challenges the notion that both regular and irregular forms are represented and processed by entirely the same mechanisms (Rueckl et al., 1997).

Exactly what one means by a ''difference'' between regular and irregular morphology, though, might be characterised at any number of levels of representation with any number of consequences for performance factors like language acquisition, lexical memory structuring, and online production and comprehension. In this study, we have focused specifically on the consequences for the sentence processor when tense information is encoded independently in a regular affix versus when it is encoded in a composite, irregular form. Our findings provide further evidence that regular and irregular forms are represented and processed differently. Simply put, if regular forms like *worked* were represented on the model of

how irregular forms like *stood* must be, then these two types of words should have elicited the same ERP response (when factors like length and frequency are held constant). Instead, our results indicate that irregular forms provide direct access to inflectional features, whereas regular forms yield such information only after morphological parsing has been carried out on the word stimulus. While we hold open the possibility that whole-word representations for familiar regular forms like *worked* play some role in lexical access, our data suggest that access to a syntactic feature like tense depends, for the purposes of sentence or phrasal interpretation, primarily on morphological parsing. Accordingly, our data reveal specific instances in which the particular morpho-lexical processing approach that is invoked in order to deal with a given complex word directly impinges on the behaviour of interpretative mechanisms associated with higher-level linguistic units, such as phrases and sentences.

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REFERENCES

Alegre, M., & Gordon, P. (1999). Frequency effects and the representational status of regular inflections. *Journal of Memory and Language*, *40*, 41–61.

Allen, M., & Badecker, W. (2000) Morphology: the internal structure of words. In B. Rapp (Ed.), *Handbook of cognitive neuropsychology: What deficits reveal about the human mind/brain* (pp. 211–232). Hove, UK: Psychology Press.

Anderson, S. (1992). *A-morphous morphology*. Cambridge: Cambridge University Press.

Baayen, H., & Schreuder, R. (1999). War and peace: Morphemes and full forms in a noninteractive activation parallel dual-route model. *Brain and Language*, *68*, 27–32.

Baayen, H., Dijkstra, T., & Schreuder, R. (1997). Singulars and plurals in Dutch: Evidence for a parallel dual-route model. *Journal of Memory and Language*, *37*, 94–117.

Bertram, R., Hyönä, J., & Laine, M. (2000). The role of context in morphological processing: Evidence from Finnish. *Language and Cognitive Processes*, *15*, 367–388.

Bertram, R., Laine, M., & Karvinen, K. (1999). The interplay of word formation type, affixal homonymy, and productivity in lexical processing: Evidence from a morphologically rich language. *Journal of Psycholinguistic Research*, *28*, 213–226.

Caramazza, A., Laudanna, A., & Romani, C. (1988). Lexical access and inflectional morphology, *Cognition*, *28*, 297–332.

Clahsen, H. (1999). Lexical entries and rules of language: A multidisciplinary study of German inflection. *Behavioral and Brain Sciences*, *22*, 991–1060.

Cutler, A., Hawkins, J., & Gilligan, G. (1985). The suffixing preference: A processing explanation. *Linguistics*, *23*, 723–758.

Frauenfelder, U., & Schreuder, R. (1992). Constraining psycholinguistic models of morphological processing and representation: The role of productivity. In G. Booij & J. van Marle (Eds.), *Yearbook of morphology 1991* (pp. 165–183). Dordrecht: Kluwer.

Gross, M., Say, T., Kleingers, M., Münte, T., & Clahsen, H. (1998). Human brain potentials to violations in morphologically complex Italian words. *Neuroscience Letters*, *241*, 83–86.

Haggoort, P., & Brown, C. (1994). Brain responses to lexical ambiguity resolution and parsing. In C. Clifton, L. Frazier, & K. Rayner (Eds.), *Perspectives on sentence processing* (pp. 45–80). Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Haggoort, P., & Brown, C. (1999). Gender electrified: Evidence on the syntactic nature of gender processing. *Journal of Psycholinguistic Research*, *28*, 715–728.

Haggoort, P., Brown, C., & Groothusen, J. (1993). The syntactic positive shift (SPs) as an ERP measure of syntactic processing. *Language and Cognitive Processes*, *8*, 439–483.

Hahne, A., & Friederici, A. (1999). Electrophysiological evidence for two steps in syntactic analysis: Early automatic and late controlled processes. *Journal of Cognitive Neuroscience*, *11*, 193–204.

Joanisse, M., & Seidenberg, M. (1999). Impairments in verb morphology after brain injury: A connectionist model. *Proceedings of the National Academy of Sciences*, *96*, 7592–7597.

Kutas, M. & Hillyard, S. (1980). Event-related brain potentials to semantically inappropriate and surprisingly large words. *Biological Psychology*, *11*, 99–116.

Kutas, M. & Hillyard, S. (1984). Brain potentials during reading reflect word expectancy and semantic association. *Nature*, *307*, 161–163.

Laine, M., Vainio, S., & Hyönä, J. (1999). Lexical access routes to nouns in a morphologically rich language. *Journal of Memory and Language*, *40*, 109–135.

Laudanna, A., Badecker, W., & Caramazza, A. (1989). Priming homographic stems. *Journal of Memory and Language*, *28*, 531–546.

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

Marslen-Wilson, W., & Tyler, L. (1997). Dissociating types of mental computation. *Nature*, *387*, 592–594.

Marslen-Wilson, W., & Tyler, L. (1998). Rules, representations, and the English past tense. *Trends in Cognitive Science*, *2*, 428–435.

Marslen-Wilson, W. D., Hare, M., & Older, L. (1993). Inflectional morphology and phonological regularity in the English mental lexicon. *Proceedings of the 15th Annual Conference of the Cognitive Science Society* (pp. 693–698). Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

McQueen, J., & Cutler, A. (1998). Morphology in word recognition. In A. Zwicky & A. Spencer (Eds.), *Handbook of morphology* (pp. 406–427). Oxford: Blackwell.

Münte, T., Say, T., Clahsen, H., Schiltz, K., & Kutas, M. (1999). Decomposition of morphologically complex words in English: Evidence from event-related brain potentials. *Cognitive Brain Research*, *7*, 241–253.

Niswander, E., Pollatsek, A., & Rayner, K. (2000). The processing of derived and inflected suffixed words during reading. *Language and Cognitive Processes*, *15*, 389–420.

Osterhout, L. (1997). On the brain response to syntactic anomalies: Manipulations of word position and word class reveal individual differences. *Brain and Language*, *59*, 494–522.

Osterhout, L., & Mobley, L. (1995). Event-related brain potentials elicited by failure to agree. *Journal of Memory and Language*, *34*, 739–773.

Osterhout, L., & Nicol, J. (1999). On the distinctiveness, independence, and time course of the brain responses to syntactic and semantic anomalies. *Language and Cognitive Processes*, *14*, 283–317.

Penke, M., Weyerts, H., Gross, M., Zander, E., Münte, T., & Clahsen, H. (1997). How the brain processes complex words: An event-related potential study of German verb inflections. *Cognitive Brain Research*, *6*, 37–52.

Pinker, S. (1991). Rules of language. *Science*, *253*, 530–535.

Pinker, S. (1999). *Words and rules: the ingredients of language*. New York: Basic Books.

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

Rodriguez-Fornells, A., Clahsen, H., Lleó, C., Zaake, W., & Münte, T. (2001). Event-related brain responses to morphological violations in Catalan. *Cognitive Brain Research*, *11*, 47–58.

Rueckl, J., Mikolinski, M., Raveh, M., Miner, C., & Mars, F. (1997). Morphological priming, fragment completion, and connectionist networks. *Journal of Memory and Language*, *36*, 382–405.

Schreuder, R., & Baayen, H. (1995). Modeling morphological processing. In L. Feldman (Ed.), *Morphological aspects of language processing* (pp. 131–154). Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Schreuder, R., & Baayen, H. (1997). How complex simplex words can be. *Journal of Memory and Language*, *37*, 118–139.

Sonnenstuhl, I., Eisenbeiss, S., & Clahsen, H. (1999). Morphological priming in the German mental lexicon. *Cognition*, *72*, 203–236.

Taft, M. (1979). Recognition of affixed words and the word frequency effect. *Memory and Cognition*, *7*, 263–272.

Tyler, L. (1992). *Spoken language comprehension: An experimental approach to disordered and normal processing.* Cambridge, MA: MIT Press.

Ullman, M. (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.

Van Petten, C., & Kutas, M. (1987). Ambiguous words in context: An event-related potential analysis of the time course of meaning activation. *Journal of Memory and Cognition*, *26*, 188–208.

Van Petten, C., & Kutas, M. (1990). Interactions between sentence context and word frequency in event-related brain potentials. *Memory and Cognition*, *18*, 380–393.

Weyerts, H., Penke, M., Dohrn, U., Clahsen, H., & Münte, T. (1997). Brain potentials indicate differences between regular and irregular German noun plurals. *NeuroReport*, *8*, 957–962.

APPENDIX

Regular verbs		*Irregular verbs*	
accept-accepted	baste-basted	arise-arose	bind-bound
act-acted	bawl-bawled	become-became	bite-bit
add-added	beg-begged	begin-began	bleed-bled
agree-agreed	blare-blared	break-broke	blow-blew
allow-allowed	bless-blessed	bring-brought	breed-bred
apply-applied	blink-blinked	build-built	cling-clung
ask-asked	bog-bogged	buy-bought	creep-crept
call-called	brag-bragged	catch-caught	dig-dug
care-cared	bury-buried	choose-chose	dive-dove
carry-carried	cheat-cheated	come-came	dream-dreamt
cause-caused	chew-chewed	deal-dealt	flee-fled
change-changed	chill-chilled	draw-drew	fling-flung
cover-covered	choke-choked	drink-drank	forbid-forbade
deny-denied	chop-chopped	drive-drove	foretell-foretold
die-died	chug-chugged	eat-ate	forsake-forsook
drop-dropped	churn-churned	fall-fell	freeze-froze
enter-entered	cite-cited	feed-fed	grind-ground
exist-existed	clean-cleaned	feel-felt	hide-hid
face-faced	coax-coaxed	fight-fought	kneel-knelt
fade-faded	cook-cooked	find-found	leap-leapt
follow-followed	dance-danced	fly-flew	mislead-misled
force-forced	detain-detained	forget-forgot	mistake-mistook
form-formed	divert-diverted	forgive-forgave	overhear-overheard
help-helped	drown-drowned	give-gave	override-overrode
hope-hoped	dust-dusted	go-went	overtake-overtook
join-joined	erode-eroded	grow-grew	partake-partook
kill-killed	evade-evaded	hang-hung	plead-pled
learn-learned	expire-expired	hear-heard	ring-rang
like-liked	fade-faded	hold-held	sew-sewn
live-lived	flex-flexed	keep-kept	shine-shone
look-looked	flinch-flinched	know-knew	shrink-shrank
move-moved	flush-flushed	lead-led	slay-slew
need-needed	hoist-hoisted	leave-left	slide-slid
note-noted	juggle-juggled	lose-lost	sling-slung
offer-offered	lurk-lurked	mean-meant	slink-slunk
open-opened	melt-melted	meet-met	smite-smote
pass-passed	mug-mugged	pay-paid	speed-sped
place-placed	nag-nagged	ride-rode	spin-spun
play-played	oil-oiled	run-ran	spit-spat
prove-proved	owe-owed	see-saw	spring-sprang
reach-reached	pester-pestered	seek-sought	steal-stole
restrict-restricted	pout-pouted	sell-sold	sting-stung
save-saved	rob-robbed	send-sent	stink-stank
seem-seemed	row-rowed	shoot-shot	stride-strode
serve-served	scare-scared	sing-sang	string-strung
show-showed	scoff-scoffed	sit-sat	strive-strove
start-started	shove-shoved	sleep-slept	swear-swore

Regular verbs		*Irregular verbs*	
stay-stayed	ski-skied	speak-spoke	swell-swollen
stop-stopped	skip-skipped	spend-spent	swim-swam
talk-talked	solve-solved	stand-stood	tear-tore
try-tried	squeal-squealed	strike-struck	undergo-underwent
turn-turned	squirm-squirmed	take-took	uphold-upheld
use-used	squirt-squirted	teach-taught	wake-woke
visit-visited	stomp-stomped	tell-told	weave-wove
wait-waited	sway-swayed	think-thought	weep-wept
walk-walked	tackle-tackled	throw-threw	wind-wound
want-wanted	tamper-tampered	understand-understood	withdraw-withdrew
watch-watched	tow-towed	wear-wore	withhold-withheld
wish-wished	vow-vowed	win-won	withstand-withstood
work-worked	wilt-wilted	write-wrote	wring-wrung