The Relationship between Lexical and Syntactic Processing

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Abstract

Lexical and syntactic processes are usually regarded as separate sub-systems of the language processing system. We re-examine the autonomy of these processes, given a mental lexicon that is morphemically decomposed, in 3 self-paced reading experiments. Although inflectional affixes have a syntactic role and derivational affixes have a lexical role, there were similar patterns of processing for both types of affix (Experiments 1 and 3). This suggests that there is a common combinatorial process at both levels of the system. Using novel and established morphologically complex words, we varied word-internal factors together with sentence level constraints (Experiment 2). Both sentence-level constraints and word-internal factors had parallel effects on the processing of novel and established words. Overall, the results indicate that the relationship between lexical and syntactic processing may be non-autonomous when morphological composition is taken into consideration.

Introduction

The nature of mental representations and the processes that operate on them are central issues in human cognition. Language processing has traditionally been assumed to comprise a number of discrete components, with their own representational forms and computational processes. We examine the relationship between two major components of the language processing system the mental lexicon and the syntax, in the light of an apparent incompatibility between recent models of lexical organisation and sentence processing. Through a series of three experiments, we ask: Is there a sharp distinction between the combinatorial processes within the lexicon that deal with the internal structure of a word and those at the syntactic level that build sentential representations?

Morphology and lexical structure

Words in English often have internal structure, in that they can be decomposed into smaller units, morphemes, that have their own (abstract) meaning. Inflectional affixes are added to stems (e.g.*happi-er:* comparative adjective; *watch-ed:* past tense) to highlight a word's syntactic role. Therefore, combining stems and inflectional affixes is generally taken to be a syntactic process. Derivational affixes are added to stems to form new words (*happy - happiness; tomb -entomb*) and this form of morphological combination is taken to be a lexical process. Linguistically, syntax is assumed to be blind to word-internal structure (Carstairs-MacCarthy, 1992). Inflectional processes are paradigmatic, they are extremely regular and applied by rule. Derivational processes, on the other hand, are much less regular. Some affixes are added ubiquitously (e.g. nominal *-er* to verbs), while others are rarely used in new word forms (e.g. *-th*).

Recognition of the complexity of the internal structure of words is currently central to an appreciation of the organisation of the mental lexicon. Models that assume that the lexicon lists only whole-word forms (Butterworth, 1983) are now in the minority. We assume here a model in which the lexicon is organised morphemically around stems and affixes. Morphologically complex words are decomposed into their constituent morphemes when the relationship between stem and affix is semantically transparent (Marslen-Wilson, Tyler, Waksler & Older 1994; Marslen-Wilson, Ford, Older & Zhou, 1996). Empirical support for this comes from a series of cross-modal priming studies, suggesting that the mental lexicon has the following features. Stems are free-standing words (*happi-ness* primes *happy*), although underlying stem representations can be abstracted away from surface phonological forms (*conclusive* primes *conclude*). The relationship between stem and affix is semantically transparent (*department* does not prime *depart*). When affixes are productive (used in new word formation), they have independent representation as morphemes (*toughness* primes *darkness* as strongly as *happiness* primes *happy*). Unproductive affixes (no longer used in new word formation) seem less likely to be independently represented (*government* only weakly primes *punishment*). Finally, inflections are not represented in the lexicon (*watched* does not prime *jumped*).

Models of sentence processing

The nature of lexical organisation has important ramifications for models of sentence processing (Hudson, 1990). In parallel with developments in linguistic theory, psychological models of syntactic processing now place a great emphasis on the role of the lexicon. Regardless of the architecture of the model (modular or interactive), lexically represented information is vital to the successful construction of sentential representations. It is assumed that syntactically relevant information is stored as part of the lexical entry for each word a person knows and that it becomes available immediately a word is recognised. However, both interactive and modular models of sentence processing make little reference to the nature of lexical organisation. In the most detailed modular model, Frazier's Garden Path model (Frazier, 1987), the lexicon and syntax are separate sub-systems. The lexicon is mostly a list of whole-word forms and any morphological assembly is strictly intra-lexical (Frazier, Flores D'Arcais, & Coolen, 1993). In the interactive tradition, the constraint satisfaction model (MacDonald, Pearlmutter & Seidenberg, 1994) assumes that the lexicon is a store of all the words a person knows, including inflections.

The view of the mental lexicon from the sentence processing perspective is at odds with the view from the perspective of lexical processing. Given the central role of lexical information, it is crucial that models of sentence processing recognise the dimensions of lexical organisation that are emerging from work in that field. Research at both levels also needs to address how syntactically relevant information, distributed in a morphemic lexicon, can be available for the construction of sentential representations.

Sentence processing within the context of a morphemic lexicon

To examine these issues, we decided to look at sentence processing, while taking into account the morphological complexity of words, working with the approach to lexical organisation we described above. To do this, we used the self-paced reading task, which is sensitive to both lexical and syntactic aspects of language processing. We examined the processing of morphologically complex derived and inflected words in sentential contexts as well as the relationship between contextual constraints and derived words. If the lexicon is morphemically organised, there should be differences in the processing of morphologically simple and complex words. Where we see one word, HAPPINESS, the language comprehension system, at some level, has to process two morphemes HAPPY+NESS. If separately represented stems and affixes are involved in combinatorial operations at a syntactic level, we should find evidence of interaction with contextual constraints. Such evidence is a necessary, though not sufficient, step in questioning the traditionally-drawn distinctions between lexical and syntactic processing.

Experiment 1

Before we could investigate the autonomous or interactive nature of lexical processing, we needed to demonstrate that effects of morphological complexity show up in a task that involves sentences rather than single words. We chose the self-paced reading task. As polymorphemic words are involved in more combinatorial operations than monomorphemic words, we would expect to be able to detect this extra processing in slower reading times for sentences with morphologically complex words, compared to those with simple words. If morphological decomposition is a general feature of lexical organisation, rather than specific to low frequency or novel items, reading times should be elevated to the same degree for low and high frequency complex words. To be sure that we were detecting effects of lexical processing, we used complex derived words with productive affixes. Therefore, to establish that, in general, morphological effects can be detected within sentences, we co-varied the morphological complexity and frequency of words in identical sentential environments.

We assembled 40 sets of 4 words, where we manipulated the variables of morphological complexity (simple v complex) and frequency (high v low) (see Table 1). The complex words in each set had the same productive affix. Productive affixes are those currently used in new word formation (cf. Marchand, 1969 and Bauer, 1983) and should be most strongly represented in a decomposed lexicon.

Our target words were embedded in pairs of sentences. The first sentence provided a general context. The second sentence contained the target word and was read word-by-word using the moving window technique (see (1) below: a=context sentence, b=word by word sentence).

(1) a Tom was caught pinching sweets from the shop.
b He had a SILLY/DAFT/FOOLISH/OAFISH look on his face as he handed them back.

Table 1: Details of the target words used in Experiment 1.

Morph.	Freq	LogFreq (mean)	Example
Simple	High	1.98	SILLY
	Low	0.60	DAFT
Complex	High	1.57	FOOLISH
	Low	0.30	OAFISH

In the word-by-word sentences, the target word appeared at least three words into the sentence and no fewer than six words from the end. The experimental sentences in each version were identical apart from the target word. Each sentence fitted on to a single line on the computer monitor. We pretested the predictability of the target words in the experimental sentences. Participants were given the context sentence and the word-by-word sentence, up to, but excluding, the target word and completed the sentence. If participants continued a sentence with one target word more often than the others, the sentences were altered.

Participants were tested on computers using DMASTR software. Participants read the context sentence. Then a series of dashes and spaces appeared, representing the words of the second sentence. The participants pressed the 'yes' button on a response box to read the sentence word by word. After 40% of items, participants answered a comprehension question. Reading times were collected from two words before to four words after the target.

Results and Discussion

The data from three participants were discarded because of overall slow or very fast reading times. Data points below

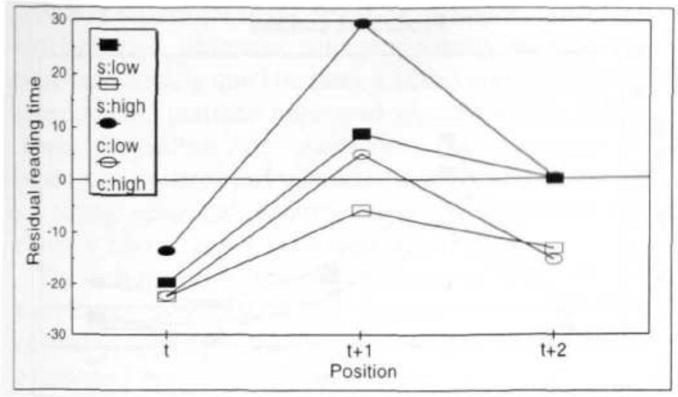

Figure 1: Mean reading times for simple (s) and complex (c) words at the target and two subsequent positions.

100ms and over 1200ms were removed (less than 0.3% of the data). As the target words varied in length, we transformed the data using a regression technique (Ferreira and Clifton, 1986) to give a residual reading time which measures difference from expected reading time (see Fig 1). Significant effects were found after the target word, rather than on the target word itself: a common feature of word-by-word reading. On the first post-target word (t+1) low frequency word sentences were read more slowly than high frequency word sentences (F1(1,36)=12.73;p=0.001:F2 (1,36)=13.82; p=0.001). Sentences with complex words were read more slowly (F1(1,36)=9.67; p=0.004: F2(1,36)=9.43; p=0.004). There was no interaction between frequency and morphological complexity (F's<1). At the second post target word (t+2) there was a frequency effect (F1(1,36)= 13.68; p=0.001:F2(1,36)=10.84;p=0.002), but not complexity (F's<1). Item means from t+1 and t+2 were analysed together with position as a within-items variable. Words at t+2 were read more quickly (F2(1,36)=33.54;p<.01). There was an effect of frequency (F2(1,36)=23.65; p<0.001) which did not interact with position (F<1) and a complexity effect (F2(1,36)=4.78; p<0.05), which did (F2 (1,36)=6.67; p=0.02). Complexity and frequency did not interact.

These results show that, as well as effects of a word's frequency, effects of its morphological composition can also be detected within sentential contexts. Furthermore, these effects are independent of one another. These results support our assumption that decomposition is a general feature of lexical organisation. Having found effects of morphological complexity in a task involving reading a sentence, we can go on to examine further the relationship between lexical and syntactic processing and a decomposed lexicon.

Experiment 2

If lexical and syntactic processes operate independently of one another and on different structures, then, even within the context of a decomposed lexicon, we would expect (1) that morphologically complex words should be assembled into complex lexical units, before they are output to syntactic processes and (2) that the process of morphological assembly should be carried out without reference to syntactic and other constraints defined at a sentence level. For the purposes of higher level processing, furthermore, the computed whole-word representation would have no internal structure. If, however, lexical and syntactic processes are not autonomous, then the syntactic and semantic environments in which a complex word occurs may be able to influence these basic processes of morphological combination.

To examine these different possibilities, we needed to use stimuli that would unequivocally require an active process of assembly from their constituent morphemes. To this end we used novel morphologically complex words (such as *nursely*) that we constructed to conform with English word-formation rules. Our basic comparison was between novel forms of this type and matched sets of existing complex forms (such as *saintly*), presented under conditions of either strong or weak pragmatic and syntactic constraint.

This manipulation on its own would not be sufficient to distinguish between autonomous and non-autonomous accounts of the relationship between morphological and syntactic processing. Words that are output as the completed product of an autonomous lexical processor may still be read more quickly in constrained, rather than unconstrained sentences. However, any effects of context should not be influenced by morphological factors, since processes operating at the sentential level should be blind to word-internal factors. Here we manipulated the internal structure of the novel forms by varying whether they were prefixed or suffixed (as in *deconflict* and *nursely*). If sentence-level processes interact only with the completed output of morphological assembly, then the order of affixes within the word should have no effect. Conversely, if contextual factors affect processes of morphological assembly, then these may operate differentially for novel suffixed items, where the stem comes first, than for novel prefixed items. Context and order of stem and affix may interact further with the productivity of the affix another word-internal factor. Affix type (prefix or suffix) was co-varied with productivity in this experiment.

We would find evidence of processing interacting across lexical and syntactic levels, if (i) novel and established words were processed in qualitatively the same way; (ii) the processing of complex words was influenced by context; (iii) there were differences between the reading of prefixed and suffixed word sentences; and (iv) there were differences between sentences with productive and unproductive affixes.

We constructed 80 morphologically complex novel test words of which there were four types: words with productive prefixes and suffixes, and unproductive prefixes and suffixes. To be novel, words were not in the CELEX database (Baayen, Pipenbrook & Guiliker, 1995) nor in the OED, or were listed there as obsolete. The novel words were pretested by asking participants to decide whether or not they had encountered them before. Only words with a low probability of having been encountered before were used.

We matched the novel words with low frequency established words with the same affix, where these words

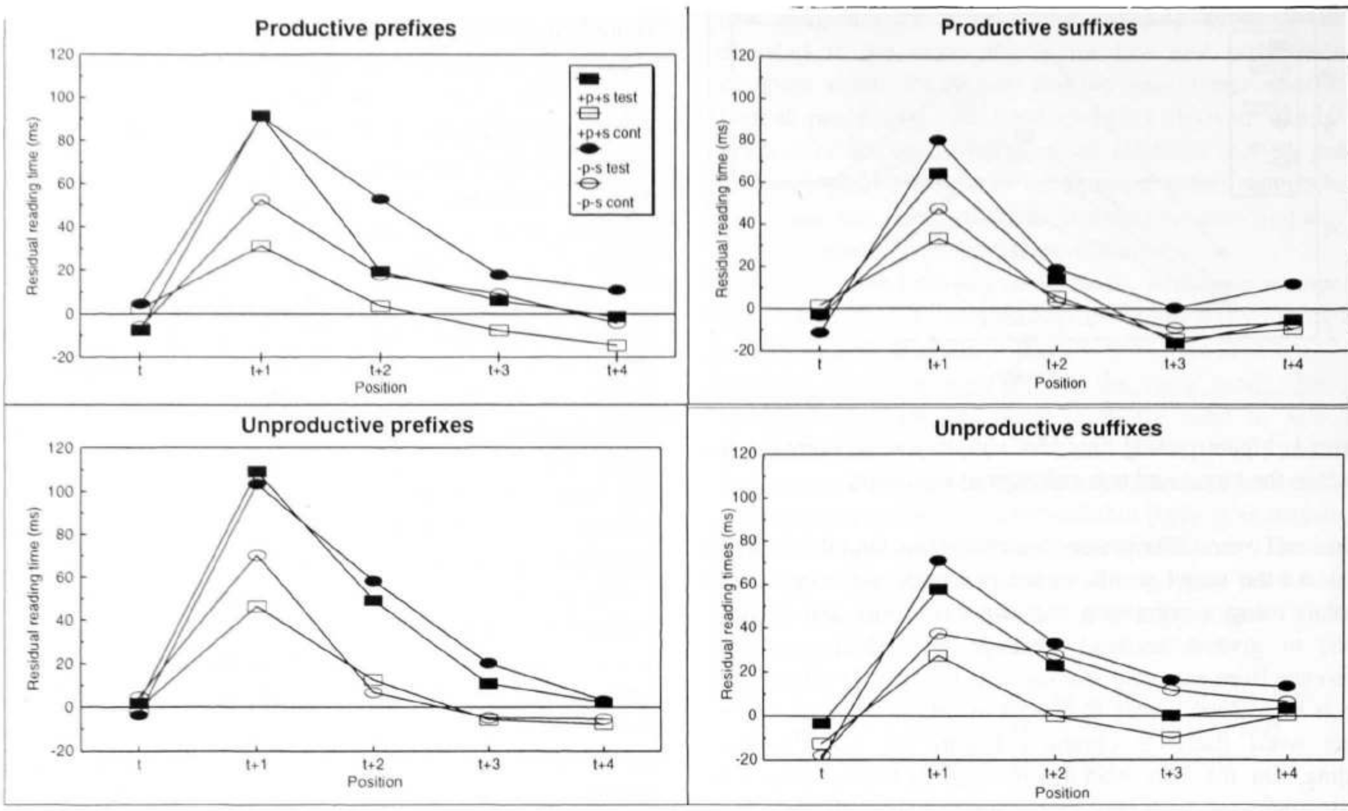

Figure 2: The mean reading times each type of affixed word (+p+s = strongly constrained; -p-s = weakly constrained).

could be substituted into the same sentential environments as the novel forms. As in Experiment 1, we used a context sentence followed by a sentence with the target word to be read word-by-word. We constructed the sentential constraints preceding the target word so that in one condition there were strong pragmatic constraints on the interpretation of the critical complex form, and where the syntactic class of the target was also strongly constrained. In the second condition, we kept the pragmatic and syntactic constraints as weak as possible. We confirmed these constraints in a pretest. Participants were given the experimental pairs of sentences, up to, but excluding, the target word and completed the second sentence. The results show that for constrained sentences, 53% of continuations were related pragmatically to the target word, and 97% of continuations had the same syntactic class. The corresponding results for the unconstrained sentences were 7% and 41% respectively. Examples of the sentences are shown in (2) and (3) (a=context; b=word-by-word sentence). The procedure was the same as Experiment 1.

(2) Strong pragmatic and syntactic constraint:

a. John's speech to the conference was filled with point after point.

b. He began some tedious and LISTY/WORDY demands for better working conditions.

(3) Weak pragmatic and syntactic constraint:

a. John decided it was time to make the strength of his feelings clear

b. He began some LISTY/WORDY demands for better working conditions.

Results and discussion

The data from three participants and less than 0.3% of other data were excluded (as per Experiment 1). There were no significant effects on the target word (see Fig 2). At subsequent positions, novel words caused significant disruption (t+1-t+4:F2(1,64)=58.15; p<0.001)[1]. Constrained sentences were read significantly more quickly than unconstrained (t+1-t+4:F2(1,64)=22.71; p<0.001), but there was no interaction between the target words and constraint (F2<1). On the first two post-target words, prefixed word sentences were read more slowly than suffixed word sentences[2]. At t+2 there was no difference in the average reading time for established words (Prefix: 10ms; Suffix: 9ms), but there was a difference for novel words (Prefix: 33ms; Suffix 22ms) - a significant target by affix interaction (F1(1,36)=6.63; p<0.02: F2 (1,64)=5.94: p<0.02). Here sentences with unproductive affixes were read significantly more slowly by participants than those with productive affixes (F1(1,36)=6.23:p<0.02;F1(1,64)= 1.18: p>0.2). The three-way interaction between productivity, constraint and

[1] When main effects occur over two or more post-target words, we report the results of an analysis that we conducted on the item means only with position as a within-item variable

[2] (t+1:F1(1,36)= 21.34: p<0.001; F2(1,64)=2.96: p=0.09; t+2:F1(1,36)=8.60:p<0.01;F2(1,64)=1.81:p >0.1)

affix was significant ($F1(1,36)=7.51$: $p<0.01$:$F2(1,64)=9.63$: $p<0.01$). Both sentences with productively suffixed words were read equally quickly, (9ms v 10ms) and sentences with unproductive prefixes were read equally slowly (31ms v 32ms), regardless of constraint. For sentences with productive prefixes and unproductive suffixes, the presence of strong sentential constraints had a facilitatory effect (11ms v 35ms; 12ms v 31ms respectively).

The results show that the processing load for novel morphemic combinations is reduced by the sentential context in apparently the same way as it is when processing established words. This pattern supports our prediction that sentential contexts can influence the processing of morphologically complex words. As predicted there were differences in the way that novel prefixed and suffixed forms were processed. From this we can tentatively conclude that a word's internal structure is not lost once lexical processes have computed their output product. A word's internal structure is preserved and remains available to interact with syntactic processes.

Productivity of affix did not have a reliable effect on the processing of complex words, but the slower reading of all sentences with unproductively prefixed words is suggestive that there are differences in morphemic representations depending on how productive an affix is.

Experiment 3

In Experiment 1 we found effects of morphological composition with stems and derived affixes within what is traditionally regarded as the lexical domain, while in Experiment 2 we looked at derivational morphology in greater depth. Now we turn to the syntactic domain and combinatorial processes with inflected words to see if similar principles apply.

Syntactic processes are concerned with building sentential representations. Tense is always realised in the underlying structure of a sentence in traditional linguistic analysis, whether or not there is a clear phonological marker. The syntactic structure in sentences (4), (5) and (6) below is identical, although in (5) tense is overtly marked with the affix *-ed,* while in (4) it is not, and in (6) it changes the entire phonological form of the stem.

(4) I watch you.
(5) I watched you.
(6) I saw you.

If lexical and syntactic domains function as separate sub-systems, there should be no differences in processing different surface realisations of the same underlying syntactic structure. But if there is some commonality between combinatorial operations for derived and inflected words, we would expect the results of this experiment to be comparable with those of Experiment 1.

The past tense in English is usually formed by adding the suffix *-ed* to the verb. There are some exceptions to this rule, with about 180 irregular past tense forms (e.g. *sleep/slept; teach/taught*). Verbs with regular past tenses are undoubtedly morphologically complex and can be straightforwardly decomposed into stems and affixes. Irregular past tenses, while having the same syntactic functions, are not combinatorially complex in the same way and cannot be decomposed into a stem and affix.

We constructed 32 sets of four past tense verbs, which varied according to regularity (regular v irregular) and frequency (high v low). As many of the irregular past tenses in English are extremely frequent, the frequency matching between the regular and irregular forms was only approximate (see Table 2 and examples in (7)). The procedure was the same as Experiment 1, with pairs of pretested sentences, identical apart from the target word.

(7) a.The parish church was holding a fundraising supper.
b Mary made the starter and George
PROVIDED/FETCHED/GOT/CHOSE
the food for the main course.

Table 2: Details of target words for experiment 3.

Morph	Freq Type	Example	Mean log Freq
Regular	High	PROVIDED	1.41
	Low	FETCHED	0.30
Irregular	High	GOT	1.87
	Low	CHOSE	0.48

Results and Discussion

The data from 5 participants and other points amounting to less than 0.3% were excluded (as per Experiment 1). There were no effects on the target word (see Fig 3). At t+1 regular past tense sentences were read significantly more slowly than irregular ($F1(1,37)=6.8$;$p=0.02$;$F2(1,28)=5.91$;$p < 0.025$). There was no effect of word frequency and no interaction between word frequency and regularity (all F's<2). At t+2 high frequency word sentences were read more quickly than low frequency sentences. This effect was marginal by participants and significant by items ($F1(1,37)=2.99$; $p<0.09$: $F2(1,28)=4.59$; $p<0.04$) Here the regularity effect disappeared and there was no interaction (all F's<1). We analysed the item means only from t+1 and t+2 together, adding position as a within-item factor. There were no main effects of position or regularity, but a marginal effect of frequency ($F2(1,28)=3.76$; $p<0.07$). There was a significant interaction between position and regularity ($F2(1,28)=7.50$; $p=0.01$). There was no interaction between frequency and regularity or position (All F's<2). The results of this experiment show that sentences with morphologically complex regular past tense verbs are read more slowly than those with irregular past tense verbs. This is independent of a word's surface frequency. In Experiment 1, we kept the syntactic environment constant, while varying the lexical processing task (reading a morphologically simple or derived word). In this experiment, we kept the lexical and syntactic environments constant, while varying the

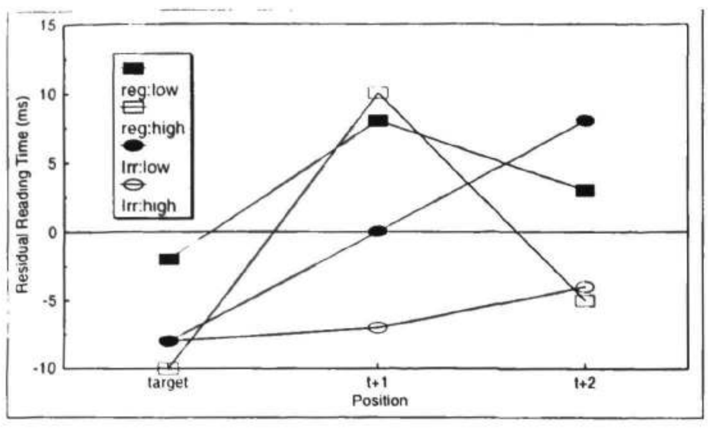

Figure 3: Mean reading times for regular and irregular part-tenses on the target word and two subsequent positions.

combinatorial complexity of the target words. Although the effects in this experiment are not so strong as in Experiment 1, the pattern of results is essentially the same. This indicates that there is some common feature to combinatorial operations at lexical and syntactic levels.

General Discussion

The experiments in this paper were set up to examine the sharp distinction conventionally made between lexical and syntactic processes, working within a framework that regards morphological combination as a central aspect of lexical organisation. A first, ground-clearing experiment was designed to investigate whether effects of morphological complexity could be detected in sentence level tasks. Accordingly, in Experiment 1, we found elevated reading times for sentences with morphologically complex words as compared to those with morphologically simple words.

In a second comparison, we found qualitatively similar effects of morphological complexity in both the lexical and syntactic domains. This is based on the parallel patterns of results for derived words and inflected words in Experiments 1 and 3, where effects of morphological combination were independent of word frequency. In a third comparison, we found that novel and existing morphologically complex words both had reduced processing load in strongly constrained sentence contexts. One interpretation of this is that higher level contextual factors can influence lexical level processes of morphemic combination.

Further evidence for this interactive, or non-autonomous account comes from the differences we found between prefixed and suffixed words. The order of morphemes in a word made a difference to how they were read, with stem + affix combinations read more quickly than affix + stem combinations. Where word-internal factors were not conducive to successful novel morphemic combination (i.e. unproductive + prefix), sentence level constraint had no influence. Similarly, when two factors (productive + suffix) combined that were maximally conducive to novel morphemic combination, contextual constraints did not bring additional benefits. However, when two intermediate word-internal factors (i.e. productive + prefix; unproductive + suffix) combined, strong constraint had a clear influence.

Overall, we can conclude that we have found sufficient evidence to continue re-examining the relationship between lexical and syntactic processes. One direction for pursuing this would be to ask whether specific syntactic constraints could be shown to determine, or pre-determine, how sets of morphemes were combined.

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