LANGUAGE AND COGNITIVE PROCESSES
2005, 20 (1/2), 373–394

Psychology Press
Taylor & Francis Group

Changing morphological structures: The effect of sentence context on the interpretation of structurally ambiguous English trimorphemic words

Roberto G. de Almeida
Department of Psychology, Concordia University, Montreal, Canada

Gary Libben
Department of Linguistics, University of Alberta, Edmonton, Canada

Morphological parsing has often been studied with words in isolation. In this study we used sentence context to investigate how structural analyses of morphologically complex words are affected by the semantic content of their carrier sentences. Our main stimuli were trimorphemic ambiguous words such as *unlockable* (meaning either ''not able to be locked'' or ''able to be unlocked''). We treat these words as structurally ambiguous such that the meaning of the words is determined by the perceived organisation of their constituent morphemes. The effect and malleability of this structural organisation were examined in one offline rating experiment and one cross-modal priming experiment with ambiguous words embedded in sentence context. The results of the study suggest that morphologically

Correspondence should be addressed to either author. Gary Libben, Department of Linguistics, 4-36 Assiniboia Hall, University of Alberta, Edmonton, Alberta, Canada T6G 2E7. Email: gary.libben@ualberta.ca or Roberto G. de Almeida, Department of Psychology, Concordia University, 7141 Sherbrooke St. West, Montreal, QC, Canada, H4B 1R6. Email: almeida@alcor.concordia.ca

Authors are listed in alphabetical order. This research was supported by research grants from the Social Sciences and Humanities Research Council of Canada (SSHRC) and the Fonds québécois de la recherche sur la société et la culture to Roberto G. de Almeida and a Major Collaborative Research Initiative Grant from SSHRC to Gary Libben (Director) Gonia Jarema, Eva Kehayia, Bruce Derwing, and Lori Buchanan.

We would like to thank Julie Turbide for her help in the preparation of the materials and for recording the sentences for Experiment 2. We also thank our research assistants for helping with data coding and running the experiments: Julie Turbide, Heather Wilcox, and Sally Cooper. Finally, we would like to thank Harald Baayen, Jonathan Grainger, and an anonymous reviewer for many helpful comments and suggestions.

http://www.tandf.co.uk/journals/pp/01690965.html DOI: 10.1080/01690960444000232

ambiguous words do show two interpretations and that the balance of these interpretations can be affected by the semantics of the sentence in which they are embedded. We interpret the pattern of data to suggest that when structurally ambiguous words are presented in isolation, word-internal factors determine which interpretation is to be preferred. However, in strongly constraining sentence contexts, these preferred parses are modified online to be consistent with the semantics of the entire sentence structure.

Ambiguity in language has delighted poets and annoyed philosophers for centuries. Aristotle (Rhetoric, Book 3) states that ''Words of ambiguous meaning are chiefly useful to enable the Sophist to mislead his hearers''. However, it is possible that Aristotle may have failed to note the manner in which linguistic ambiguity also reveals the intricate connectedness of language levels—the connectedness that allows us to achieve communicative precision despite the widespread ambiguity that characterises the system itself.

The key to the human ability to resolve linguistic ambiguity is undoubtedly the use of higher-level contexts to resolve lower-level equivocality. By this means, the phonetic values of graphemes are resolved by their realisations within words, the ambiguities that characterise words are resolved in their sentence contexts, and ambiguous sentences are resolved by the discourse contexts within which they are embedded.

Ambiguity in human language is routine. Indeed, the title of this paper is ambiguous. The phrase *changing morphological structures* may refer to structures that have the property of changeability (under the adjectival reading of *changing*), or it may refer to structures that are changed by an unspecified subject (under the verbal reading of the word *changing*).

In the investigation that we report in this paper, it means both. We concentrate on prefixed and suffixed trimorphemic words that can change meanings by virtue of the manner in which their constituent morphemes are construed to be organised. We also investigate whether the perceptions of the morphological structure of these words can be changed by sentence context.

Our core stimuli are words such as *unlockable,* which can be interpreted either as ''not able to be locked'' or as ''able to be unlocked''. For these two interpretations to be obtained, it is necessary that the reader or hearer compute two different morphological organisations of the constituent morphemes. Thus, for the meaning ''able to be unlocked'' to be obtained, it is necessary that the word be represented such that the adjective-marking suffix *able* is attached to the morphologically complex verb *unlock* (see Figure 1a). On the other hand, for the meaning ''not able to be locked'' to be obtained, *unlockable* needs to be represented such that the prefix *un-* is attached to a morphologically complex adjective *lockable* (see Figure 1b). These alternative structural organisations within the word may

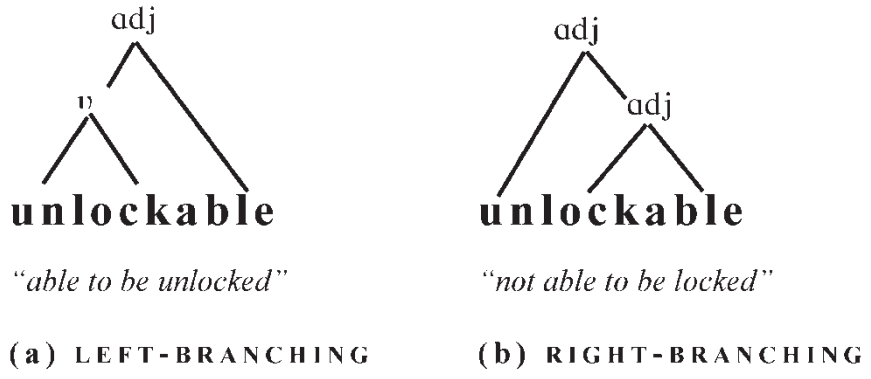

Figure 1. Two morphological trees corresponding to two interpretations of the ambiguous word *unlockable*.

be represented diagrammatically as left-branching (Figure 1a) and right-branching trees respectively (Figure 1b).

Words such as *unlockable* possess the minimum morphological complexity required to probe the psycholinguistic consequences of hierarchical morphological structure and structural ambiguity within words (Libben, 2003). They also allow us to probe the interaction (or lack thereof) between morphological parsing and sentence interpretation processes because, in order for the ambiguous trimorphemic word to be interpreted properly, the meaning that best fits the semantic context needs to be determined. For example, the sentence context (1a) biases the interpretation of *unlockable* as "able to be unlocked"—an interpretation that is consistent with the left-branching analysis presented in Figure 1a. Sentence (1b), on the other hand, biases the interpretation of the ambiguous trimorphemic word to be consistent with the right-branching structure represented in Figure 1b.

(1) a. *When the zookeeper tried to unlock the birdcage he noticed that the birdcage was unlockable.*
b. *When the zookeeper tried to lock the birdcage he noticed that the birdcage was unlockable.*

The potential interaction between the morphological structure of ambiguous words such as *unlockable* and the semantics of sentences such as (1a) and (1b) may be best understood as a question of time course. Although it is clear that at some point in time the proper meaning of the ambiguous word is selected, it is of fundamental importance to understand when this interpretation is achieved. As is summarised in Table 1, one possibility (Option A) is that the very process of establishing a constituent

TABLE 1
Three alternatives for the influence of sentence context on the morphological structure of ambiguous trimorphemic words

	Option A	*Option B*	*Option C*
Step 1.	Decompose strings into morphemes, but do not produce a morphological structure	Produce two morphological structures	Produce a single morphological structure
Step 2.	Create a morphological structure on the basis of sentence context	Use the appropriate morphological structure on the basis of sentence context	Revise that structure if required by the sentence context

structure for the trimorphemic word is a process influenced by the semantics of its carrier sentence. This would mean that the morphological system is not autonomous, but rather is influenced by the semantic or conceptual system during its computations, thus constituting evidence against the view that morphological processes are encapsulated. Two other possibilities, however, can be taken as evidence that the morphological system is in fact encapsulated. One (Option B) is that the system produces outputs that are consistent with its two constituent structures. That is, given an ambiguous input, the output of the system would be two parsing trees with the proper one then selected by the demands of the context. A third possibility (Option C) is that the system produces only one output which is independent of the contextually appropriate interpretation. This would mean that the morphological system produces its own preferred parsing analysis—which could be determined by the frequency of a given analysis or by the morphological system's own principles of analysis of morphologically complex strings.

These views regarding the nature of the workings of the morphological system find parallels in the sentence parsing literature. While there are researchers who believe that the parsing mechanism interacts freely with processes of semantic interpretation (e.g., MacDonald, Perlmutter, & Seidenberg, 1994; Trueswell & Tanenhaus, 1994), others believe that sentence parsing is relatively isolated from semantic interpretation. Proponents of the multiple-output parsing analyses (e.g., Gibson, 1998), for instance, claim that all possible syntactic analyses of a given phrase or sentence are made available for selection by semantic and pragmatic systems. Proponents of single-output parsing analyses (e.g., Frazier & Clifton, 1996) claim that the sentence parsing system commits itself to one analysis—usually the simplest in terms of parsing nodes—for later revising if the analysis is incongruent with the semantic context of the sentence.

It is also important to note that these views on syntactic analysis have been at the forefront of disputes regarding the nature of the cognitive architecture of the language system. In the last two decades or so, a great deal of psycholinguistic work has investigated the hypothesis that the language system and some of its subcomponents are computationally encapsulated or modular (Fodor, 1983; Chomsky, 1984). Many of the studies supporting or refuting the modularity hypothesis have also investigated the influence of semantic context in the process of lexical access. Thus, for instance, in the study conducted by Swinney (1979), in sentence contexts biasing towards one meaning of an ambiguous prime word such as *bug*, priming was obtained for targets related to both meanings of the ambiguous word (e.g., *spy* and *ant*) when these targets were presented for lexical decision at the offset of the prime. When the targets were presented three syllables after the offset of the prime, however, only the contextually relevant target word was primed. Tanenhaus, Leiman, and Seidenberg's (1979) study produced a similar effect, suggesting that the process of accessing the meaning of an ambiguous word is relatively immune to the demands of the sentence context, with all meanings being initially accessed in parallel (or ordered by frequency; see Onifer & Swinney, 1981) with the selection of the appropriate meaning by the context coming a few hundred milliseconds later. However, in a study similar to that of Swinney (1979), Tabossi (1988) found that contextual information affected the proper interpretation of the ambiguous word. Tabossi varied the strength of the semantic contexts of her sentences and obtained priming effects only for the appropriate meaning of ambiguous words when contexts were strong (i.e., when sentence contexts were created based on ''features'' of one meaning of the ambiguous word) and priming for targets related to both meanings when contexts were weak. Tanenhaus, Dell, and Carlson (1987) proposed that the strength of the context (couched in terms of feedback from higher to lower levels of processing) should be predictive of the nature of the lexical access process, with weak contexts (or words in isolation) producing representations consistent with both meanings of an ambiguous word—thus, compatible with the encapsulation assumption—and strong contexts producing selective outputs—thus, compatible with an interactive view of the language system. In a meta-analysis of the influence of context on lexical ambiguity resolution, Lucas (1999) found that the evidence weighs in favour of the interactive, non-modular view of the lexical access process. The picture that emerges from these studies is that the strength of the semantic context may determine the nature of the lexical access process—with weaker contexts leading to the production of multiple interpretations for the ambiguous word to be activated and stronger contexts pre-selecting the proper semantic interpretation.

The present study, then, can be seen as an investigation of the nature of the architecture of the lexical processing system and how it interacts with semantic representations built during sentence comprehension. We reasoned that if morphological computations were influenced by the demands of the sentential-semantic context, then they would produce contextually appropriate parsing trees for morphologically ambiguous items. If, by contrast, the morphological system produces a parsing tree that is initially *incompatible* with the context of the sentence, then this could be taken as evidence for the encapsulation of the lexicon.

EXPERIMENT 1: SEMANTIC PLAUSIBILITY RATINGS

The first step in this study was to investigate whether putatively ambiguous trimorphemic strings such as *unlockable* can indeed receive two interpretations and whether sentences can be constructed that effectively bias toward one interpretation or the other. In this initial experiment, these questions were addressed by examining semantic plausibility rating as the dependent variable and by manipulating sentence context with both ambiguous trimorphemic words and their paraphrases. We reasoned that if ambiguous words such as *unlockable* could indeed be assigned two interpretations, they would show roughly equal plausibility when embedded in sentences such as (1), repeated as (2a) and (2b) below.

(2) a. *When the zookeeper tried to unlock the birdcage he noticed that the birdcage was unlockable.*
b. *When the zookeeper tried to lock the birdcage he noticed that the birdcage was unlockable.*

Crucially, we reasoned that sentences with *lock* would bias toward the right-branching interpretation of *unlockable* (i.e., ''not able to be locked'') whereas sentences with *unlock* would bias toward the left-branching interpretation of *unlockable* (i.e., ''able to be unlocked''). In order to test whether the contexts were indeed semantically biasing in this manner, we replaced the trimorphemic words with exactly those corresponding paraphrases, as in examples (3a) and (3b) below.

(3) a. *When the zookeeper tried to lock the birdcage he noticed that the birdcage was not able to be locked.*
b. *When the zookeeper tried to lock the birdcage he noticed that the birdcage was able to be unlocked.*

Thus, if indeed the sentence contexts were semantically constraining, we expected to find sentence (3a) to be judged as more plausible than sentence (3b).

Method

Participants. Forty-two native speakers of English, all students at Concordia University, participated in this study. They either received course credit or $7 for participation in this and other unrelated experiments in a one-hour session. They were all naïve as to the main hypotheses under investigation.

Design and materials. Twenty-four ambiguous trimorphemic words were used in this experiment. Twenty-three of these were taken from Libben's (2003) study of lexical ambiguity, to which one stimulus item (*uninstallable*) was added.

For each word, six sentences were constructed (see Appendix). Two of these sentences biased the ambiguous trimorphemic word to be interpreted either as ''able to un-*X*'' or ''unable to *X*''. Thus, for instance, for the word *unlockable*, two contexts were created (as in (2) above): one biasing towards the right-branching analysis of the trimorphemic word (e.g., *When the zookeeper tried to lock the birdcage he noticed that the birdcage was unlockable*) and one biasing towards its left-branching analysis (e.g., *When the zookeeper tried to unlock the birdcage he noticed that the birdcage was unlockable*). In addition, there were four other sentences corresponding to each of the 24 trimorphemic words. These sentences were created with periphrastic versions of the two possible interpretations of the trimorphemic words. Thus, for instance, for sentences that contained the word *unlockable*, two other sentences were created with the expression *able to be unlocked* (e.g., *When the zookeeper tried to lock/unlock the birdcage he noticed that the birdcage was able to be unlocked*) and two sentences were created with the expression *not able to be locked* replacing the ambiguous word (e.g., *When the zookeeper tried to lock/unlock the birdcage he noticed that the birdcage was not able to be locked*). This way, two semantically consistent (*lock ... not able to be locked*, *unlock ... able to be unlocked*) and two semantically inconsistent (*lock ... able to be unlocked*, *unlock ... not able to be locked*) sentences were created from each one of the sentences with the trimorphemic words, forming six sentence types. In the present study, we refer to the periphrastic sentences that contain the root form of the verb in the first clause (e.g., *lock*) as *positive* and those that contain the *un-* prefixed form (e.g., *unlock*) as *negative*.

Thus, in summary, stimulus sentences had two types of first clauses—(1) those with a positive critical stimulus (e.g., *lock*) and (2) those with a negative critical stimulus (e.g., *unlock*). These were crossed with three types of second clauses—(a) those with an ambiguous trimorphemic stimulus (e.g., *unlockable*), (b) those with a paraphrase of the left-

branching interpretation of the trimorphemic stimulus (e.g., *able to be unlocked*) and (c) those with a paraphrase of the right-branching interpretation of the trimorphemic word (e.g., *not able to be locked*). As is shown in Table 2, if indeed the presence of the positive and negative stimuli in the first clause constrains the interpretation of the sentence as a whole, then half of the second-clause paraphrases would be inconsistent with the meaning of the first clause.

Materials were counterbalanced across six booklets, with each booklet containing 24 sentences, four of each of the six types, and with only one sentence corresponding to one of the 24 trimorphemic words in each booklet.

Procedure. Participants were given one of each of the six booklets and asked to rate how plausible each sentence was using a scale between 1 (*not plausible at all*) and 5 (*completely plausible*). They were instructed to rely on their first instinct and not to revise their ratings, proceeding from start to finish as quickly as they could.

Results and discussion

Figure 2 presents the mean plausibility ratings and standard errors for all sentence types. A 2 (first-clause word type: positive vs. negative) $\times$ 2

TABLE 2
Conditions and sample materials employed in Experiment 1

First clause word type	*Second clause word/expression*	*Semantic consistency*	*Sample sentence*
(1) Root (*positive*)	(a) Trimorphemic	consistent	*When the zookeeper tried to lock the birdcage he noticed that the birdcage was unlockable*
	(b) Periphrastic (*left-branching*)	inconsistent	*When the zookeeper tried to lock the birdcage he noticed that the birdcage was able to be unlocked.*
	(c) Periphrastic (*right-branching*)	consistent	*When the zookeeper tried to lock the birdcage he noticed that the birdcage was not able to be locked*
(2) Un + Root (*negative*)	(a) Trimorphemic	consistent	*When the zookeeper tried to unlock the birdcage he noticed that the birdcage was unlockable*
	(b) Periphrastic (*left-branching*)	consistent	*When the zookeeper tried to unlock the birdcage he noticed that the birdcage was able to be unlocked*
	(c) Periphrastic (*right-branching*)	inconsistent	*When the zookeeper tried to unlock the birdcage he noticed that the birdcage was not able to be locked*

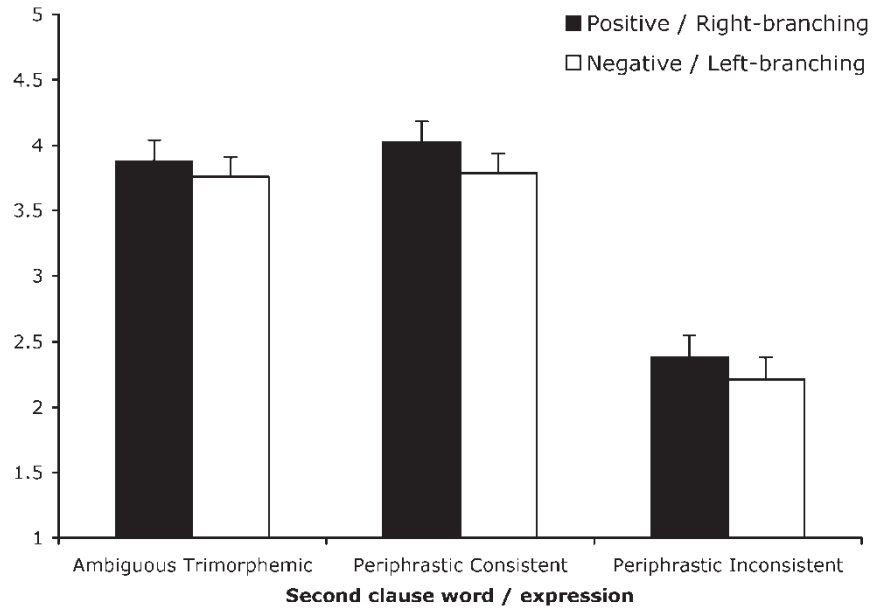

Figure 2. Mean plausibility judgements for sentences as a function of first clause context word (positive/right-branching: *root*; negative/left-branching: *un* + *root*) and second clause word or expression (trimorphemic or periphrastic). 1 = not plausible; 5 = completely plausible.

(semantic consistency: consistent vs. inconsistent) repeated measures ANOVA showed a main effect of consistency, $F_1(1, 41) = 75.68$, $p < .0001$, $F_2(1, 92) = 87.33$, $p < .0001$, but not word type effect, $F_1(1, 41) = 2.38$, $p = .13$, $F_2(1, 92) = 1.17$, $p = .28$, and no interaction between these two variables, $F_1(1, 41) = 0.55$, $p = .82$, $F_2(1, 92) = 0.70$, $p = .40$. These results suggest that participants compute correctly the interaction between the meaning of the first clause word (*lock* or *unlock*) and the second-clause periphrastic expression (*not able to be locked* or *able to be unlocked*). In the analyses for sentence types with trimorphemic words in the second clause, there was no significant difference in plausibility rating, $F_1(1, 41) = 0.43$, $p = .51$, $F_2(1, 47) = 1.88$, $p = .18$, indicating that both left- and right-branching contexts did not differ in terms of plausibility. In the comparison between the two trimorphemic sentences and their respective consistent periphrastic sentences, the difference between positive contexts was non-significant in the analysis by participants, $F_1(1, 82) = 0.39$, $p = .53$, and failed to reach significance in the analysis by items, $F_2(1, 45) = 3.66$, $p = .062$. In the comparison between negative contexts, there were no significant differences by participants nor by items, $F_1(1, 82) = 0.013$, $p = .91$, $F_2(1, 48) = 1.39$, $p = .25$.

Taken together, the results of Experiment 1 indicate that the sentence contexts that we constructed were indeed sufficiently constraining so that inconsistent paraphrases of the critical ambiguous words were judged to be less plausible than their consistent counterparts. No plausibility differences, however, were found for the ambiguous words themselves. This suggests that the ambiguous words were able to shift interpretations in order to adjust to the overall meaning of the sentences. That is, the word *unlockable* was assigned a right-branching structure in sentences containing *lock*, but a left-branching structure for sentences containing *unlock* in the first clause. Did the morphological structure of the word then actually change as a result of sentence context? This question was at the core of our cross-modal priming study reported in Experiment 2 below.

EXPERIMENT 2: ON-LINE MORPHOLOGICAL PARSING IN CONTEXT

The purpose of this experiment was to test if sentential context would influence the *online* parsing of the ambiguous trimorphemic words. Although ambiguous words can acquire two interpretations in strongly biasing sentence contexts, as we have seen in Experiment 1, it is not clear how this is achieved in online processing. One possibility is that the structure of the ambiguous trimorphemic word is assigned online, at the offset of the word, if not before. This prediction is consistent with an interactive language processing system in which syntactic, morphological, semantic, and background-knowledge representations interact online during linguistic input. However, as we discussed in the introduction, we can also raise two other possible outcomes in the process of parsing and interpreting those ambiguous words: one is that interpretation may occur only after the proper morphological parsing analysis is selected, among the two activated candidate parsing trees. Another is that the language comprehension system (and more specifically, the morphological parser) may commit itself to one possible analysis, leaving the interpretation that is relevant for the context for a later stage in the language comprehension process. These two last possible outcomes are consistent with a modular language processing system which takes the computation of different linguistic components to be independent of each other and, in particular, independent of the influence of semantic or conceptual representations.

In this experiment, we used a cross-modal lexical decision task on the assumption that it would allow us to tap parsing processes as participants were listening to sentences carrying ambiguous trimorphemic words. This technique has been widely used in the investigation of lexical access, in particular with ambiguous words (e.g., Swinney, 1979; Tanenhaus et al., 1979; Tabossi, 1988). Our stimuli were built upon the sentences employed

in Experiment 1. We manipulated the priming obtained between the ambiguous trimorphemic word (the prime; e.g., *unlockable*) and a visual target composed of *root* + *able* morphemes (e.g., *lockable*). We predicted that *unlockable* would prime *lockable* regardless of sentence context because of their shared morphemes. However, we predicted that the priming between *unlockable* and *lockable* would be of a greater magnitude in the case where the context biases towards the right-branching analysis of *unlockable.* This is because the adjective *lockable* is a constituent of the right-branching negative adjective $[_{Adj}[un][_{Adj}lockable]]$ but not a constituent of $[_{Adj}[_{V}unlock][able]]$. Thus, if context determines the immediate parsing analysis of the ambiguous trimorphemic string, there should be an advantage for the target *lockable* when it is preceded by an analysis of *unlockable* in which the target behaves as a major constituent of the prime.

Method

Participants. A total of 94 Concordia University undergraduate students participated in this experiment. They were all native speakers of English and had normal or corrected-to-normal vision and no known reading or cognitive disabilities. They received either credit for a Psychology course or were paid between $6 and $7 for an hour session that included this and other unrelated experiments.

Materials and design. Our main stimuli were the 24 morphologically and semantically ambiguous trimorphemic words used in Experiment 1, all with the basic structure [un + *root* + able]. All 24 words allowed either a left- or right-branching parsing analysis, as discussed above. For each word, six sentence contexts were created, as shown in Table 3 (see Appendix for a list of materials). The sentences were similar in structure, all containing two clauses, the first with a context word and the second with the main trimorphemic prime word. In the context clause, the difference between sentences was in the presence of either the root verb (e.g., *lock*) related to the trimorphemic derived adjective (e.g., *unlockable*), the *un-* prefixed verb (e.g., *unlock*) or a neutral verb (e.g., *clean*). In the prime clause, the sentences contained either a trimorphemic prime word (e.g., *unlockable*) or another unrelated trimorphemic unambiguous word (e.g., *unapproachable*). Thus, all context-prime combinations formed six different sentences (e.g., *When the zookeeper tried to lock/unlock/clean the birdcage he noticed that the birdcage was unlockable/unapproachable*). For all these combinations, the target was composed by *root* + *able* morphemes (e.g., *lockable*) corresponding to the two last morphemes of the experimental prime (e.g., *unlockable*). Six lists of materials were

TABLE 3
Main context and prime conditions for Root + suffix targets (e.g., *lockable*) in Experiment 2

Context type	*Prime type*	*Example (context and prime words in italics)*
Root (e.g., *lock*)	Related (e.g., *unlockable*)	When the zookeeper tried to *lock* the birdcage he noticed that the birdcage was *unlockable*
	Unrelated (*unapproachable*)	When the zookeeper tried to *lock* the birdcage he noticed that the birdcage was *unapproachable*
Un + root (*unlock*)	Related (*unlockable*)	When the zookeeper tried to *unlock* the birdcage he noticed that the birdcage was *unlockable*
	Unrelated (*unapproachable*)	When the zookeeper tried to *unlock* the birdcage he noticed that the birdcage was *unapproachable*
Neutral (*clean*)	Related (*unlockable*)	When the zookeeper tried to *clean* the birdcage he noticed that the birdcage was *unlockable*
	Unrelated (*unapproachable*)	When the zookeeper tried to *clean* the birdcage he noticed that the birdcage was *unapproachable*

created. The lists were counterbalanced so that all six contained an equal number of context and prime types, with one context-prime combination for each one of the main experimental trimorphemic words. In addition to the 24 experimental trials, each list contained 120 filler trials. These consisted of simple sentences (e.g., *Inactive people can get overweight*) and complex sentences (e.g., *When the skier reached the bottom of the slope, he noticed that he was the first one down*), with a mixture of morphologically simple (e.g., *load*) and complex (e.g., *repayment*) word targets. The nonword targets were also complex (e.g., *unmithable*) and simplex (e.g., *mirk*). They were constructed by changing characters or morphemes in actual English words, but preserving their phonotactic properties. There were 144 trials in total, 96 of which had word targets (*yes* responses; including the 24 experimental trials) and 48 had nonword targets (*no* responses).

Apparatus and procedure. We used a cross-modal priming with lexical decision technique. Participants sat in front of a Macintosh G3 computer which had a CMU response box and a pair of headphones attached to it. The response box had two main buttons, one labelled *yes* and the other labelled *no*. We used PsyScope 1.2.5b (Cohen, MacWhinney, Flatt, & Provost, 1993) to present the stimuli (both auditory and visual) and to collect response times.

Participants were instructed that in each trial they would hear a sentence, and that for each sentence, they would see a string of letters appearing in the middle of the computer screen. They were told that the

string of letters would appear at any time during the presentation of each sentence. They were also instructed that they had to pay attention to the sentences because after the experimental session they would be given a task in which they would have to remember some of the sentences they heard during the experiment. In addition, participants were instructed that they had to pay attention to each string of letters presented on the screen and to decide as fast and as accurately as possible whether or not it formed an English word. If the string of letters formed an English word, they had to press *yes* on the button box; otherwise they had to press *no*.

For the 24 experimental trials, the visual targets (always words) were presented 500 ms after the offset of the aurally presented final word in the sentence (always a trimorphemic prime such as *undoable*). For all the filler trials, the targets were presented at different points in the sentences, including 12 that were presented 500 ms after the offset of the sentences. Participants were run individually in a dark room. Visual stimuli (strings of letters) were presented on white Times 24 font over black background. Auditory stimuli were recorded by a female student at a normal pace and were presented at a comfortable volume over the headphones. The experimental session started with instructions presented on the screen and reinforced by the experimenter, followed by a series of 10 practice trials, a reinforcement of the instructions also presented on the screen, and the 144 main trials. The experimental session lasted about 20 min.

Results and discussion

Raw data points above 3000 ms or below 300 ms were discarded from the analyses (2.9% of all data). Two participants who committed errors (i.e., responded *no*) in all experimental trials were eliminated. In the remaining data from 92 participants, there were 29.6% errors (including data from 17 participants who committed errors in over 50% of the experimental trials).

Our analyses focused on two primary variables: context type and prime type. A 3 (context type: left-branching biasing, right-branching biasing, neutral) $\times$ 2 (prime type: trimorphemic related vs. unrelated) repeated measures ANOVA showed a main effect of context in the participants analysis only, $F_1(2, 142) = 3.07$, $p = .049$, $F_2(2, 40) = 1.39$, $p = .26$, and a main effect of prime, $F_1(1, 71) = 15.91$, $p = .0002$, $F_2(1, 20) = 5.63$, $p = .028$. There was no interaction between the two factors.

Although the overall ANOVA showed no interaction between the context and prime factors, we note that analyses taking the neutral prime and related primed conditions separately as one-way ANOVAs showed that context had an effect only when the trimorphemic prime was present in the stimulus sentence, $F_1(2, 156) = 4.17$, $p = .017$. For the unrelated prime condition, context had no effect, $F_1(2, 156) = 0.45$, $p = .65$.

TABLE 4
Target response times in milliseconds (standard errors, in parentheses) and per cent errors for each of the core conditions in Experiment 2

	Context type		
Prime type	*Root*	*Un + Root*	*Neutral*
Response Times (ms)			
Related *(un + root + able)*	835 (37)	926 (49)	925 (48)
Unrelated	964 (40)	1007 (46)	1000 (46)
Errors (%)			
Related *(un + root + able)*	24	22	24
Unrelated	35	34	39

Given the high number of errors in the dataset, we also analysed the error rates for participants and items. These analyses produced no effect of context type, $F_1(2, 180) = 1.33$, $p = .27$, $F_2(2, 40) = 1.45$, $p = .25$, but a significant effect of prime type, $F_1(1, 90) = 35.4$, $p < .0001$, $F_2(1, 20) = 20.6$, $p = .0002$. Table 4 shows RTs and error rate data for all conditions.

In summary, the results of Experiment 2 indicate that the presence of trimorphemic ambiguous words in sentence final position increased response speed to their respective bimorphemic substrings as targets. In contrast, the effect of context on target response times was weak. To the extent that it did play a role, its effect must be seen as semantic, rather than purely lexical. Target response times in the neutral and *un + root* contexts were virtually identical. It was the *root* context that resulted in reduced response times as compared to the neutral context. Because only the *root* context (e.g., *lock*) is semantically compatible with the bimorphemic target (e.g., *lockable*), we conclude that it is not simply the presence of the corresponding lexical root in the sentence context that affects response latencies to the target, but rather the meaning of the word containing that lexical root. Finally, our analyses treating the related and unrelated prime conditions separately revealed that an effect of context is only reliable when the ambiguous trimorphemic word is present as the last word of the sentence. The implication of this observation is taken up in the General Discussion below.

GENERAL DISCUSSION

This investigation has focused on the question of whether structurally ambiguous words can be disambiguated by sentence context.

In Experiment 1, we probed the extent to which the interpretation of ambiguous trimorphemic words such as *unlockable* would be adjusted to fit the alternative meanings of sentence frames. We concluded that this was

indeed the case, based on the finding that the trimorphemic words were judged to be equally plausible in sentences that biased toward either left-branching or right-branching interpretations. The critical evidence in support of this conclusion was that, although the ambiguous words were judged to be equally plausible, their paraphrases (*able to be unlocked* or *not able to be locked*) were not judged to be equally plausible across sentence contexts. Thus, although the paraphrases showed fixed meanings that affected the plausibility of the sentence as a whole, the ambiguous words showed interpretive malleability. This malleability appears to be inconsistent with the view that their morphological structure is insulated from the effects of sentence context.

Experiment 2 probed the extent to which the pattern of metalinguistic ratings found in Experiment 1 would be manifested in a task in which morphological parsing and interpretation were implicit rather than explicit. The behavioural task in this experiment was a lexical decision on a target such as *lockable*, which is a morphological constituent of the right-branching structure *un-lockable*, but not of the left-branching structure *unlock-able*. We reasoned that if sentence context influenced the constituency structure that participants would implicitly assign to ambiguous trimorphemic words, then those effects would be evident in the magnitude of the sentence's facilitative effect on the ambiguous word's root + suffix substring.

The results of Experiment 2 bring us back to the alternative hypotheses stated at the outset of this paper. We argued that there are three main ways in which the assignment of morphological constituency within a trimorphemic word could interact with sentence semantics.

The first (Option A) is that sentence context directly affects how a morphologically ambiguous word will be structured. The second (Option B) is that a computationally encapsulated morphological parser produces two candidate parses. Finally, it may be the case (Option C) that there is an initial preferred parse that is then revised, if necessary, on the basis of sentence context.

If we accept that sentence context played some role in the related prime condition, but no role in the unrelated prime condition, then the strong modularity position (Option B) cannot be supported. This option would predict lexical priming to be completely uninfluenced by sentence context because both morphological parses are always available.

This leaves Options A and C as viable alternatives. Option A, which suggests full interactivity between syntax and morphology, would account for the effect of context in the related prime condition by claiming that when *unlockable* is preceded by the *lock* context, it becomes *un-lockable*, thus serving as a more effective prime for its morphological constituent *lockable*.

A context effect in Experiment 2, however, does not rule out the possibility that an initial parse, based solely on lexical factors is initially constructed and then revised in accordance with the semantics of sentence context (Option C). We assume that this analysis would be a right-branching one, following the findings of Libben (2003) and Popescu (2004) who found that, all other things being equal, the morphological processing system seems to prefer a right-branching analysis for prefixed and suffixed trimorphemic words presented in isolation.

This leaves us then with the following conclusion based on the results of this study. Trimorphemic ambiguous words do indeed have two potential parses and interpretations. However, in normal language processing, only one of those potential meanings appears to be used. When ambiguous words are presented in isolation, the morphological parsing system shows an overall propensity to prefer prefix-stripping (see Taft, 1981). However, in sentence context, we see strong evidence that the sentence affects the interpretation of the ambiguous word which it contains. The extent to which this change in interpretation affects the actual morphological structure of the trimorphemic word and the time course of such a structural change are less clear. Although we see some evidence in Experiment 2 that sentence context can penetrate morphological priming effects, the fact that morphological priming effects in the inappropriate semantic context (81 ms) were not less than those for the neutral sentence context (75 ms) suggests to us that there is an independent level of morphological analysis in the on-line processing of sentences that cannot be inhibited by a sentence context that biases toward an incompatible parse (e.g., *unlock-able* with respect to the target *lockable*).

It is important to also note that our data support the view that morphological decomposition is a fundamental property of the processing of words both in isolation and in sentence context. If individual morphemes were not available to the cognitive system throughout lexical processing, they could not be arranged (or rearranged) on-line in accordance with the semantics of a sentence. This brings us finally to the observation with which we began this paper—the almost ubiquitous ambiguity found in language. The results of Experiment 1 show that participants seem to effortlessly resolve this ambiguity. Elsewhere, we have also found that participants are almost completely unaware of morphological ambiguity, even under conditions in which they are asked directly whether strings such as *unlockable* can have two meanings (Popescu, 2004; Popescu, de Almeida & Libben, 2004). But, whether or not participants are aware that ambiguous strings can have two meanings, the key finding in this study is that they can *use* two meanings, and that it is the human ability to reorganise existing elements into new configurations that allows them to do so.

REFERENCES

Aristotle. (n.d.). Rhetoric, Book 3, Chapter 2. In R. Maynard (Ed.). *Great Books of the Western World* (Vol. 9, 1404–[39], p. 655). Chicago: Encyclopedia Britannica Inc. [1952].

Chomsky, N. (1984) *Modular approaches to the study of the mind*. San Diego: San Diego State University Press.

Cohen, J., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: An interactive graphic system for designing and controlling experiments in the psychology laboratory using Macintosh computers. *Behavior Research Methods, Instruments, and Computers*, *25*, 257–271.

Fodor, J. A. (1983). *The modularity of mind*. Cambridge, MA: MIT Press.

Frazier, L., & Clifton, C. Jr. (1996). *Construal*. Cambridge, MA: MIT Press.

Gibson, E. (1998). Linguistic complexity: Locality of syntactic dependencies. *Cognition*, *78*, 1–76.

Libben, G. (2003). Morphological parsing and morphological structure. In A. Egbert & D. Sandra (Eds.), *Reading complex words* (pp. 221–239). Amsterdam: Kluwer.

Lucas, M. (1999). Context effect in lexical access: A meta-analysis. *Memory and Cognition*, *27*, 385–398.

MacDonald, M. C., Pearlmutter, N. J., & Seidenberg, M. S. (1994). The lexical nature of syntactic ambiguity resolution. *Psychological Review*, *101*, 676–703.

Onifer, W., & Swinney, D. A. (1981). Accessing lexical ambiguities during sentence comprehension: Effects of frequency of meaning and contextual bias. *Memory and Cognition*, *9*, 225–236.

Popescu, A. (2004). *Structural ambiguity in trimorphemic English words: Morphological processing and lexical access in structurally ambiguous words presented in isolation*. Unpublished MSc thesis. University of Alberta, Edmonton, Canada.

Popescu, A, de Almeida, R. G., & Libben, G. (2004). *What can we learn from morphological ambiguity?* Manuscript in preparation.

Swinney, D. (1979). Lexical access during sentence comprehension: (Re)consideration of context effects. *Journal of Verbal Learning and Verbal Behavior*, *18*, 645–659.

Tabossi, P. (1988). Accessing lexical ambiguity in different types of sentential contexts. *Journal of Memory and Language*, *27*, 324–340.

Taft, M. (1981). Prefix stripping revisited. *Journal of Verbal Learning and Verbal Behavior*, *20*, 289–297.

Tanenhaus, M., Leiman, J. M., & Seidenberg, M. S. (1979). Evidence for multiple stages in the processing of ambiguous words in syntactic contents. *Journal of Verbal Learning and Verbal Behavior*, *18*, 427–440.

Tanenhaus, M. K., Dell, G. S., & Carlson, G. (1987). Context effects in lexical processing: A connectionist approach to modularity. In J. L. Garfield (Ed.), *Modularity in knowledge representation and natural-language understanding* (pp. 83–108). Cambridge, MA: MIT Press.

Trueswell, J. C., & Tanenhaus, M. K. (1994). Toward a lexicalist framework of constraint-based syntactic ambiguity resolution. In C. Clifton Jr., L. Frazier, & K. Rayner (Eds.), *Perspectives on sentence processing* (pp. 155–179). Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

APPENDIX

Materials used in Experiments 1 and 2

All sentences (a) and (b) were employed in Experiment 1 together with the periphrastic versions of the ambiguous trimorphemic words. Thus, for example, for the word *unbendable,* four other sentences were formed by replacing the trimorphemic word in each sentence (a) and (b) with either *not able to be bent* or *able to be unbent.* All sentences (a) to (f) were employed in Experiment 2.

1. Unbendable
a. The painter wanted to bend the board and he was told that the board was unbendable
b. The painter wanted to unbend the board and he was told that the board was unbendable
c. The painter wanted to bend the board and he was told that the board was unremovable
d. The painter wanted to unbend the board and he was told that the board was unremovable
e. The painter wanted to take the board and he was told that the board was unremovable
f. The painter wanted to take the board and he was told that the board was unbendable

2. Unbucklable
a. When the driver tried to buckle the belt he realised that the belt was unbucklable
b. When the driver tried to unbuckle the belt he realised that the belt was unbucklable
c. When the driver tried to buckle the belt he realised that the belt was uncomfortable
d. When the driver tried to unbuckle the belt he realised that the belt was uncomfortable
e. When the driver tried to adjust the belt he realised that the belt was uncomfortable
f. When the driver tried to adjust the belt he realised that the belt was unbucklable

3. Unbuttonable
a. The shopper wanted to button the dress and realised that the dress was unbuttonable
b. The shopper wanted to unbutton the dress and realised that the dress was unbuttonable
c. The shopper wanted to button the dress and realised that the dress was unsuitable
d. The shopper wanted to unbutton the dress and realised that the dress was unsuitable
e. The shopper wanted to try on the dress and realised that the dress was unsuitable
f. The shopper wanted to try on the dress and realised that the dress was unbuttonable

4. Uncoilable
a. When the electrician tried to coil the wire he realised that the wire was uncoilable
b. When the electrician tried to uncoil the wire he realised that the wire was uncoilable
c. When the electrician tried to coil the wire he realised that the wire was unmanageable
d. When the electrician tried to uncoil the wire he realised that the wire was unmanageable
e. When the electrician tried to connect the wire he realised that the wire was unmanageable
f. When the electrician tried to connect the wire he realised that the wire was uncoilable

5. Uncorkable
a. The waitress tried to cork the bottle and realised that the bottle was uncorkable
b. The waitress tried to uncork the bottle and realised that the bottle was uncorkable
c. The waitress tried to cork the bottle and realised that the bottle was unusable
d. The waitress tried to uncork the bottle and realised that the bottle was unusable
e. The waitress tried to recycle the bottle and realised that the bottle was unusable
f. The waitress tried to recycle the bottle and realised that the bottle was uncorkable

6. Undoable
a. The clerk that attempted to do the job was convinced that the job was undoable
b. The clerk that attempted to undo the job was convinced that the job was undoable
c. The clerk that attempted to do the job was convinced that the job was unchangeable
d. The clerk that attempted to undo the job was convinced that the job was unchangeable
e. The clerk that attempted to evaluate the job was convinced that the job was unchangeable
f. The clerk that attempted to evaluate the job was convinced that the job was undoable

7. Undressable
a. When the child wanted to dress the doll she realised that the doll was undressable
b. When the child wanted to undress the doll she realised that the doll was undressable
c. When the child wanted to dress the doll she realised that the doll was uncontortable
d. When the child wanted to undress the doll she realised that the doll was uncontortable
e. When the child wanted to play with the doll she realised that the doll was uncontortable
f. When the child wanted to play with the doll she realised that the doll was undressable

8. Unfastenable
a. When the jeweler tried to fasten the brooch, the jeweler realised the brooch was unfastenable
b. When the jeweler tried to unfasten the brooch, the jeweler realised the brooch was unfastenable
c. When the jeweler tried to fasten the brooch, the jeweler realised the brooch was unfashionable
d. When the jeweler tried to unfasten the brooch, the jeweler realised the brooch was unfashionable
e. When the jeweler tried to appraise the brooch, the jeweler realised the brooch was unfashionable
f. When the jeweler tried to appraise the brooch, the jeweler realised the brooch was unfastenable

9. Unfoldable
a. When the janitor tried to fold the table, he saw that the table was unfoldable
b. When the janitor tried to unfold the table, he saw that the table was unfoldable
c. When the janitor tried to fold the table, he saw that the table was unstable
d. When the janitor tried to unfold the table, he saw that the table was unstable
e. When the janitor tried to paint the table, he saw that the table was unstable
f. When the janitor tried to paint the table, he saw that the table was unfoldable

10. Unhookable
a. The fisherman tried to hook the bait and he realised that the bait was unhookable
b. The fisherman tried to unhook the bait and he realised that the bait was unhookable
c. The fisherman tried to hook the bait and he realised that the bait was unpiercable
d. The fisherman tried to unhook the bait and he realised that the bait was unpiercable
e. The fisherman tried to use the bait and he realised that the bait was unpiercable
f. The fisherman tried to use the bait and he realised that the bait was unhookable

11. Unloadable
a. The courier wanted to load the packages by hand and was told that the packages were unloadable
b. The courier wanted to unload the packages by hand and was told that the packages were unloadable

c. The courier wanted to load the packages by hand and was told that the packages were unavailable
d. The courier wanted to unload the packages by hand and was told that the packages were unavailable
e. The courier wanted to deliver the packages by hand and was told that the packages were unavailable
f. The courier wanted to deliver the packages by hand and was told that the packages were unloadable

12. Unlockable
a. When the zookeeper tried to lock the birdcage he noticed that the birdcage was unlockable
b. When the zookeeper tried to unlock the birdcage he noticed that the birdcage was unlockable
c. When the zookeeper tried to lock the birdcage he noticed that the birdcage was unapproachable
d. When the zookeeper tried to unlock the birdcage he noticed that the birdcage was unapproachable
e. When the zookeeper tried to clean the birdcage he noticed that the birdcage was unapproachable
f. When the zookeeper tried to clean the birdcage he noticed that the birdcage was unlockable

13. Unpackable
a. When the mover asked if he could pack the furniture, he was told that the furniture was unpackable
b. When the mover asked if he could unpack the furniture, he was told that the furniture was unpackable
c. When the mover asked if he could pack the furniture, he was told that the furniture was unmovable
d. When the mover asked if he could unpack the furniture, he was told that the furniture was unmovable
e. When the mover asked if he could carry the furniture, he was told that the furniture was unmovable
f. When the mover asked if he could carry the furniture, he was told that the furniture was unpackable

14. Unpluggable
a. When the repairman attempted to plug the old appliance, he noticed that the old appliance was unpluggable
b. When the repairman attempted to unplug the old appliance, he noticed that the old appliance was unpluggable
c. When the repairman attempted to plug the old appliance, he noticed that the old appliance was unadaptable
d. When the repairman attempted to unplug the old appliance, he noticed that the old appliance was unadaptable
e. When the repairman attempted to service the old appliance, he noticed that the old appliance was unadaptable
f. When the repairman attempted to service the old appliance, he noticed that the old appliance was unpluggable

15. Unrollable
a. The architect wanted to roll the blueprints and the blueprints were unrollable
b. The architect wanted to unroll the blueprints and the blueprints were unrollable
c. The architect wanted to roll the blueprints and the blueprints were unreadable
d. The architect wanted to unroll the blueprints and the blueprints were unreadable
e. The architect wanted to copy the blueprints and the blueprints were unreadable
f. The architect wanted to copy the blueprints and the blueprints were unrollable

16. Unscrewable
a. When the carpenter tried to screw the parts, he realised the parts were unscrewable
b. When the carpenter tried to unscrew the parts, he realised the parts were unscrewable
c. When the carpenter tried to screw the parts, he realised the parts were unreliable
d. When the carpenter tried to unscrew the parts, he realised the parts were unreliable
e. When the carpenter tried to assemble the parts, he realised the parts were unreliable
f. When the carpenter tried to assemble the parts, he realised the parts were unscrewable

17. Unscramblable
a. When the hacker tried to scramble the message he noticed the message was unscramblable
b. When the hacker tried to unscramble the message he noticed the message was unscramblable
c. When the hacker tried to scramble the message he noticed the message was unavailable
d. When the hacker tried to unscramble the message he noticed the message was unavailable
e. When the hacker tried to decipher the message he noticed the message was unavailable
f. When the hacker tried to decipher the message he noticed the message was unscramblable

18. Unsealable
a. The postman wanted to seal the package and was told the package was unsealable
b. The postman wanted to unseal the package and was told the package was unsealable
c. The postman wanted to seal the package and was told the package was unalterable
d. The postman wanted to unseal the package and was told the package was unalterable
e. The postman wanted to inspect the package and was told the package was unalterable
f. The postman wanted to inspect the package and was told the package was unsealable

19. Untieable
a. When the sailor attempted to tie the knot, he noticed the knot was untieable
b. When the sailor attempted to untie the knot, he noticed the knot was untieable
c. When the sailor attempted to tie the knot, he noticed the knot was unattainable
d. When the sailor attempted to untie the knot, he noticed the knot was unattainable
e. When the sailor attempted to displace the knot, he noticed the knot was unattainable
f. When the sailor attempted to displace the knot, he noticed the knot was untieable

20. Untwistable
a. When the gardener tried to twist the hose, he noticed that the hose was untwistable
b. When the gardener tried to untwist the hose, he noticed that the hose was untwistable
c. When the gardener tried to twist the hose, he noticed that the hose was unfreeable
d. When the gardener tried to untwist the hose, he noticed that the hose was unfreeable
e. When the gardener tried to drag the hose, he noticed that the hose was unfreeable
f. When the gardener tried to drag the hose, he noticed that the hose was untwistable

21. Unwindable
a. When the clocksmith started to wind the antique watch, he realised that the antique watch was unwindable
b. When the clocksmith started to unwind the antique watch, he realised that the antique watch was unwindable
c. When the clocksmith started to wind the antique watch, he realised that the antique watch was unsaleable
d. When the clocksmith started to unwind the antique watch, he realised that the antique watch was unsaleable
e. When the clocksmith started to fix the antique watch, he realised that the antique watch was unsaleable
f. When the clocksmith started to fix the antique watch, he realised that the antique watch was unwindable

22. Unwrapable
a. When the florist tried to wrap the bouquet, she thought that the bouquet was unwrapable
b. When the florist tried to unwrap the bouquet, she thought that the bouquet was unwrapable
c. When the florist tried to wrap the bouquet, she thought that the bouquet was unbearable
d. When the florist tried to unwrap the bouquet, she thought that the bouquet was unbearable
e. When the florist tried to arrange the bouquet, she thought that the bouquet was unbearable
f. When the florist tried to arrange the bouquet, she thought that the bouquet was unwrapable

23. Unzipable
a. When the computer programmer wanted to zip the file, he realised that the file was unzipable
b. When the computer programmer wanted to unzip the file, he realised that the file was unzipable
c. When the computer programmer wanted to zip the file, he realised that the file was unfindable
d. When the computer programmer wanted to unzip the file, he realised that the file was unfindable
e. When the computer programmer wanted to the copy the file, he realised that the file was unfindable
f. When the computer programmer wanted to copy the file, he realised that the file was unzipable

24. Uninstallable
a. When the technician tried to install the program he noticed that the program was uninstallable
b. When the technician tried to uninstall the program he noticed that the program was uninstallable
c. When the technician tried to install the program he noticed that the program was unobtainable
d. When the technician tried to uninstall the program he noticed that the program was unobtainable
e. When the technician tried to transfer the program he noticed that the program was unobtainable
f. When the technician tried to transfer the program he noticed that the program was uninstallable