University of Alberta

Structural Ambiguity in Trimorphemic English Words: Morphological Processing and Lexical Access in Structurally Ambiguous Words Presented in Isolation

by

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Abstract

This thesis investigates the on-line processing and lexical access of structurally ambiguous trimorphemic English words (e.g., *unlockable*). It is argued that these words can have two interpretations, as their morphological constituency can yield two hierarchical structures. My goal is to test whether and to what extent ambiguity at the structural level (e.g., [[un-][lockable]] vs. [[unlock] [-able]]) triggers ambiguity at the semantic level (e.g., "not able to be locked"- right-branching meaning vs. "able to be unlocked" - left-branching meaning).

Libben (2003) found that, unlike their non-ambiguous counterparts (e.g., *unreachable, disconnectable*), structurally ambiguous words show no parsing directionality preference in on-line processing. de Almeida & Libben (2004) found that both meanings of structurally ambiguous words are available in neutral sentence contexts. These results predict the existence of a competition for access between the two possible meanings of these words when they are presented in isolation. The goal of the present thesis is to test this prediction experimentally.

To Leo,
my best friend,
and to Christina,
my biggest fan of all.

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Chapter 1

Introduction

1.1 The goal of the thesis

The goal of this thesis is a psycholinguistic investigation of *structurally ambiguous* trimorphemic English words (e.g., *unlockable*). The morphological constituency of these complex words can be represented by two hierarchical structures, each of which licenses a different meaning (details will be provided in section 1.2). I am interested in finding out if and to what extent structural ambiguity (i.e., ambiguity between the structures (1) [[un-][*lockable*]] and (2) [[*unlock*][-able]]) triggers semantic ambiguity (i.e., ambiguity between the meanings (1) *"not able to be locked"* and (2) *"able to be unlocked"*).

The present thesis is targeted at the following conceptual question: Are structurally ambiguous words *consciously* perceived as ambiguous? This is a tip-of-the-iceberg question, and a complete understanding of its answer can be achieved only in the context of answers to fundamental questions such as: (1) how are multimorphemic words processed in the mind?; (2) is there any psychological reality to the hierarchical organization of constituent morphemes as proposed by the word syntax theories?; (3) how does hierarchical organization of morphemes influence whole-word processing?; and (4) how does structural ambiguity (i.e., ambiguity at the level of morpheme organization) influence whole-word processing? These questions have been addressed in the literature and the main findings will be discussed in section 1.3.

In the present thesis, I explore the relationship among morphological structure, on-line morphological processing and meaning access in structurally ambiguous words (e.g., *unlockable*). The hypotheses that I test are based on predictions that derive from Libben (2003) and de Almeida & Libben (2004).

Libben (2003) investigated the lexical processing of structurally ambiguous words in isolation (i.e., in a visual lexical decision task) and found that they show no parsing directionality preference in on-line processing, suggesting that both possible parses are perceived as valid. This result predicts the existence of a competition for access between the corresponding two meanings of structurally ambiguous words, which means that these words should be perceived as ambiguous when presented in isolation.

de Almeida & Libben (2004) investigated structurally ambiguous words in sentence contexts and they found that the two possible meanings of such words were available in both biased and non-biased contexts. Under the assumption that structurally ambiguous words are processed similarly when presented in non-biased contexts and in isolation, this result predicts that structurally ambiguous words should be consciously perceived as ambiguous when presented in isolation. This prediction has not been tested yet and the goal of the present thesis is to fill the gap, by examining meaning access in structurally ambiguous words presented in isolation.

I report on a series of five experiments that investigated the morphological processing and lexical access in structurally ambiguous English words (e.g., *unlockable*) presented in isolation. Each experiment was tailored to answer one the following questions: (1) Are structurally ambiguous words *consciously* perceived as ambiguous when presented in isolation?; (2) Do structurally ambiguous words license two meanings?; (3) Are both meanings equally frequent/plausible?; (4) If not, can the unbalance be due to a semantic bias within the *un-* prefix?, and (5) Can it be due to a computational bias?

1.2 Morphological structure in trimorphemic English words

Structural ambiguity is a linguistic phenomenon that can occur both at the word level (see, for example, Libben, in press; de Almeida & Libben, 2004) and at the sentence level (see, for example, Frazier & Rayner, 1982). A sentence such as "*Mary saw the man with the binoculars.*" can be interpreted in two ways: (1) Mary saw the man while using the binoculars, according to the structure "[[Mary]$_{NP}$ [saw]$_{VP}$ [the man]$_{NP}$ [with the binoculars.]$_{PP}$]"[1] or (2) Mary saw the man who had the binoculars, according to the structure "[[Mary]$_{NP}$ [saw]$_{VP}$ [the man [with the binoculars]$_{PP}$]$_{NP}$]". Similarly, a word such as *unlockable* ca be interpreted in two ways: (1) "*not able to be locked*", according to the structure [[*un-*][lockable]] or (2) *"able to be unlocked"*, according to the structure [[unlock][*-able*]].

The present thesis is concerned with the structural ambiguity phenomenon as it occurs at word level. I investigate the on-line processing and meaning access in structurally ambiguous trimorphemic English words obtained by *derivation.*

Derivation is a morphological process that creates new (complex) words from existing (simple) ones. A simple word contains one *morpheme* (Morphemes are the smallest units of language that can provide information about meaning, such as *water*, or about function, such as the *-s* plural in *cars*). Words that contain two or more morphemes are referred to as *morphologically complex* or *multimorphemic.* For illustration, consider the word *unlockable.* This word contains three morphemes (therefore, it is called *tri*morphemic): (1) *un-*, (2) *lock*, and (3) *-able.* The *lock* morpheme is called the root of the complex word and carries the major component of its meaning. The *un-* and *-able* morphemes are called affixes and they function as operators in the process of derivation. The morphological units that they modify during the process of derivation are referred to as their base. Affixes that precede their base are called prefixes (e.g., *un-*), and affixes that follow their base are called suffixes (e.g., *-able*).

Different languages regulate derivation in different ways. Some languages, like English, for example, use *selectional restrictions* (Pesetsky, 1985; Sproat, 1988). These are constraints upon the lexical category of the words that specific affixes can combine with in the derivation process. For instance, the

[1]NP = noun phrase; VP = verb phrase; PP = prepositional phrase.

suffix *-able* can combine only with verbs (e.g., $[[eat]_V[-able]]$ vs. $^*[[food]_N[-able]]$), while the *un-* prefix can combine with verbs, adjectives, and nouns (e.g., $[[un\text{-}][do]_V]$, $[[un][happy]_{Adj}]$, $[[un][ease]_N]$). Among the few English affixes that can modify words belonging to different lexical categories, the *un-* prefix has a special status. Unlike the *-ly* suffix, for instance, that can combine with both nouns and adjectives (e.g., $[[friend]_N[-ly]]$, $[[quick]_{Adj}[-ly]]$), and to which it contributes the same *manner* meaning, the *un-* prefix changes its meaning contribution as a function of the lexical category of the word it modifies in the derivation process. Thus, when it combines with adjectives, *un-* means "*not*" (e.g., *unhappy*), when it combines with verbs, it means "*reverse the action of the root verb*" (e.g., *unlock*), and when it combines with nouns, it means "*lack of*" (e.g., *unease*). Because the *un-* prefixation of English nouns is quite rare (only five such examples are listed in the Celex database, Baayen et al., 1995), and because the *"lack of"* meaning of the *un-* prefix plays no role in the structural ambiguity phenomenon under investigation in this thesis, I will restrict my discussion of the *un-* prefix to the other two meanings. Moreover, I will argue that, in fact, there are *two* homophonous *un-* prefixes: (1) the adjectival *un-* prefix (e.g., *unhappy*) and (2) the verbal *un-* prefix (e.g., *unlock*). As homophony (i.e., same sound pattern; e.g., *night* vs. *knight*) and homography (i.e., same spelling pattern; e.g., *bat* - *"the flying animal"* vs. *bat* - *"the baseball stick"*) are well-known sources of semantic ambiguity in monomorphemic words, I suggest that, based on the same principles, the dichotomy between the adjectival and verbal *un-* prefixes can be conceptualized as an instance of *prefix-internal semantic ambiguity.* As I will argue later on in this section, this prefix-internal ambiguity is the trigger of structural ambiguity in some *un*-verbroot-*able* words (e.g., *unlockable*), when specific selectional and semantic restrictions apply.

Below, I will discuss how these restrictions interact to determine the internal morphological structure and, thereby, the complex meanings of trimorphemic English words, in general, and of structurally ambiguous words, in particular.

Unreachable, for example, is a trimorphemic word where the root *reach* is flanked by the *un-* prefix on the left and the suffix *-able* on the right. The selectional restrictions of both affixes and the semantic restrictions of the root need to be satisfied *simultaneously* for this word to license a semantically valid meaning. Considering that the *un-* prefix can combine with both adjectives and verbs, and the suffix *-able* can combine only with verbs, the following two morphological structures can be obtained:

(a) $[un\text{-}\ [[reach]_V\text{-}able]_{Adj}]_{Adj}$ and

(b) $*[[un\text{-}[reach]_V]_V\ \text{-}able]_{Adj}$.

In structure (a), the suffix *-able* modifies a verb (i.e., *reach*) and the *un-* prefix modifies an adjective (i.e., *reachable*). In structure (b), both affixes modify verbs: the *un-* prefix modifies *reach* and the suffix *-able* modifies **unreach*. The latter is morphologically well-formed, as the *un*-prefix can combine with verbal roots, but it is semantically invalid, because the act of reaching can not be reversed. In other words, for a verb to combine successfully with the *un-* prefix, the action it expresses needs to be reversable (e.g., *lock* in *unlock*). As *reach* is not reversable, this semantic restriction is violated and so, structure (b) is invalid. Hence, the correct morphological structure for *unreachable* is (a), which licenses the meaning *"not able to be reached"*.

The morphological structure of complex words can also be represented graphically by *morphological trees.* The morphological trees capture the idea that derivation is an incremental process and so, it is best represented hierarchically. The *hierachical approach* (Selkirk, 1982) claims that multimorphemic words possess internal substructures formed by binary trees, where one branch is the head and its semantic properties percolate to the node above it. The branching directionality of morphological trees are determined by the morphological hierarchical structures, which in turn, are determined by the selectional and semantic restrictions of individual affixes.

Figure 1.1 presents the morphological tree for *unreachable.* This hierarchical structure is also referred to as the *right-branching* structure, as it is the affix at the right of the root (i.e., the suffix *-able*) that initiates the two-step derivation process of the complex word. As shown above, the *un-* prefix can not combine with the verb root *reach*, because it does not express a reversible action, thereby violating a semantic restriction. Therefore, the derivation process starts with the suffix *-able*, which attaches to the verb *reach* and forms the complex adjective *reachable.* Then, the prefix *un-* attaches to *reachable* and forms *unreachable.*

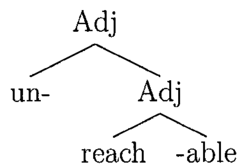

Figure 1.1: Right-branching morphological tree.

Similarly, the morphological structure of trimorphemic words where the derivation process is initiated by the affix at the left of the root (i.e., the prefix) can be represented by *left-branching* morphological trees. *Disconnectable* is a left-branching word. The prefix *dis-* can attach to the root verb *connect*, as both selectional and semantic restrictions are satisfied. Thus, the complex verb *disconnect* is formed. Then, the suffix *-able* attaches to the verb *disconnect* and forms the adjective *disconnectable.* This trimorphemic adjective licenses the meaning *"able to be disconnected"*. Figure 1.2 presents the morphological tree for *disconnectable.*

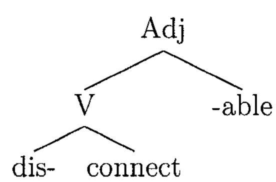

Figure 1.2: Left-branching morphological tree.

As discussed above, the complex meanings of *prefix*-root-*suffix* words are determined by their hierarchical structures, which, in turn, are determined by the interaction between selectional and semantic restrictions of affixes. Most often, these restrictions constrain the possible morpheme combinations to a single structure, that can be either left-branching (e.g., *disconnect-able*) or right-branching(*un-reachable*).

However, there are trimorphemic words where these restrictions can *not* limit the morpheme combinations to one structure, thus allowing for both right-branching and left-branching structures. This ability of complex words to organize their constituent morphemes in more than one way, and thereby yield more than one interpretation, is known as *structural ambiguity.* The words that have this ability are referred to as *structurally ambiguous* words. *Unlockable* is such an example. Considering that the *un-* prefix can combine with both adjectives and verbs, and the suffix *-able* can combine only with verbs, the following two morphological structures can be obtained:

(a) $[un\text{-}[lockable]_{Adj}]_{Adj}$

(b) $[[unlock]_{V}\text{-}able]_{Adj}$.

The morphological trees that correspond to these structures are presented in Figure 1.3.

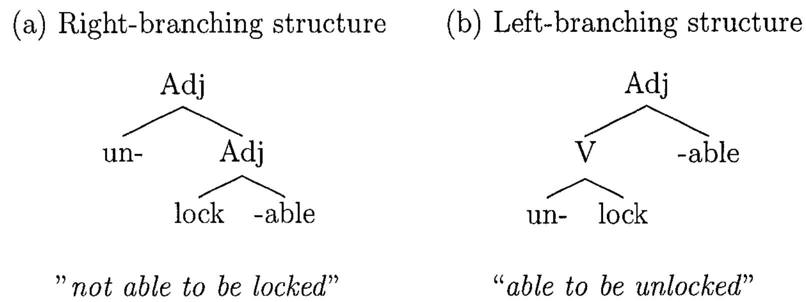

Figure 1.3: Right-branching and left-branching morphological trees for *unlockable.*

In Figure 1.3 (a), which corresponds to structure (a), the derivation starts at the right of the root. The suffix *-able* attaches to the verb root *lock* and forms the complex adjective *lockable.* Then, the *un-* prefix attaches to the newly formed adjective and the trimorphemic word *unlockable* is obtained. As the *un-* prefix contributes its adjectival meaning (i.e., *"not"*), this structure licenses the meaning *"not able to be locked"*. This meaning is also referred to as the right-branching meaning.

In Figure 1.3 (b), which corresponds to structure (b), the derivation process is initiated at the left of the root. The *un-* prefix attaches to the root *lock* and forms the complex verb *unlock*. As the root of this verb expresses a reversible action (compare with **unreach* in *unreachable*), the *un-* prefix successfully contributes its verbal meaning (i.e., *"reverse the action of the root"*) and so the resulting verb is semantically valid. Then, the suffix *-able* attaches to the complex verb *unlock* and forms the trimorphemic adjective *unlockable*. Although this is the same word as the one obtained above, by virtue of a different morphological structure, it licenses a different meaning now: "*able to be unlocked*". This meaning is also referred to as the left-branching meaning.

From a morphological perspective, these two possible structures of structurally ambiguous words are equally valid, and so are the meanings that they license. Nevertheless, it is an empirical question whether both structures are computed on-line and whether both meanings are accessed when structurally ambiguous words are presented in isolation. The present thesis will investigate this question in a series of five psycholinguistic experiments.

1.3 Morphological processing in trimorphemic words

Up to date, the morphological processing research on trimorphemic words has mostly investigated morpheme activation and organization in words with fixed morphological structures (e.g., *unreachable* - right-branching structure, *disconnectable* - left-branching structure). Complex words with "changing morphological structures" (de Almeida & Libben, 2004) such as *unlockable* (that can feature both right-branching and left-branching structures) have only tangentially been discussed in the literature.

However, as will become apparent in this section, despite their very limited number, these previous investigations of structurally ambiguous words (Libben, in press; Libben, 2003; de Almeida & Libben, 2004) provide a comprehensive research context for the present thesis.

The early literature on morphological processing was dominated by two positions that postulated no interaction between whole-word activation and constituent activation. Taft & Forster (1976) suggested that complex word recognition involves a constituent-access process. Butterworth (1983) supported the opposite view: complex word recognition involves a whole-word activation process. More recently (e.g., McQueen & Cutler, 1998), the position that, in fact, both whole-word activation and constituent activation are necessary for complex word recognition to occur has been gaining more and more ground.

As discussed in section 1.2, it has been argued that the morphological constituents of trimorphemic words are organized hierarchically in structures that are determined by the selectional and semantic restrictions of the affixes involved in the derivation process. The questions of whether selectional restrictions play any role in the on-line processing of trimorphemic words and whether the corresponding hierarchical structures have any psychological reality have been addressed in the recent psycholinguistic literature, but no definitive answers have yet been reached.

Over the last three decades, three main approaches to the study of on-line processing in morphologically complex words have been suggested: (1) the automatic prefix-stripping approach (Taft & Forster, 1975), (2) the hierarchical approach (as it follows from Selkirk, 1982), and (3) the network approach (Libben, 2003). The automatic prefix-stripping approach posits that, regardless of hierarchical structure, morphological processing proceeds from left to right and so, by virtue of morpheme order, in complex words that contain both prefixes and suffixes, prefix-stripping takes precedence over suffix-stripping. The hierarchical approach suggests that specific hierarchical structures determine specific morphological processing patterns, thus predicting that right-branching words and left-branching words are processed differently. The network approach proposes yet another view on morphological structure. Rather than hierarchical, the morphological structure of complex words is envisioned as a flat network of lexical relations, where each morpheme is connected with all possible multimorphemic substrings within the complex word and the complex word itself (The specific predictions of these three approaches will be discussed in detail in the preamble of Experiment 5 of this thesis). Below, I will discuss the main findings in morphological processing of trimorphemic words and how they support (or contradict) each of the aforementioned approaches.

Libben (1993) tested the hierarchical approach in a naming task study that employed nonsense stimuli with English-like morphological structures (e.g., *reponkable*). This investigation was focused on two questions: (1) do selectional restrictions play a role in the on-line processing of complex words? and (2) do hierarchical structures have any psychological reality? Libben found that nonsense trimorphemic words with illegal morphological structures (e.g., **reponkity*; compare with **revitality*) were significantly slower than nonsense trimorphemic words with legal morphological structures (e.g., *reponkable*; compare with *returnable*). This result suggests that selectional restrictions do play a role in on-line processing of trimorphemic words, but further investigation is needed to determine it more specifically. As no significant difference was found between right-branching nonsense stimuli (e.g., *reponkize*) and left-branching nonsense stimuli (e.g., *reponkable*) in this experiment, no direct mapping between branching directionality in morphological structures and on-line morphological processing patterns could be advocated. Thus, the hierarchical approach was only partly confirmed.

In Libben (in press), both on-line and off-line tasks were used to re-test the hierarchical approach. Libben employed an off-line segmentation task that required participants to show their parsing preferences in trimorphemic words by drawing a vertical line that divides the stimuli into two parts (e.g., *un/thinkable* or *unthink/able*). It was predicted that, if hierarchical structure counts in on-line processing, different parsing preferences would correspond to different morphological structures. That is, for the right-branching stimuli, the segmentation after the prefix would be preferred (e.g., *un/thinkable*), and, conversely, for the left-branching stimuli, the segmentation after the root would be preferred (e.g., *refill/able*). No specific prediction was made for the structurally ambiguous stimuli.

As predicted, in the case of right-branching stimuli, participants showed great preference (93%) for the segmentation after the prefix (e.g., *un/thinkable*), which indeed corresponds to their internal morphological structure. However, the left-branching stimuli did not followed the pattern predicted. The parsing preferences for these stimuli were balanced: 46% for the segmentation after the prefix and 54% for the segmentation after the root. This result does not support the hierarchical approach, but the network approach, since, both segmentations result in real-word bimorphemic substrings (e.g., *refill, fillable*).

The structurally ambiguous stimuli were also balanced between the left segmentation (e.g., *un/foldable*) (56%) and the right segmentation (e.g., *unfold/able*)(44%). As structurally ambiguous words allow for both right-branching and left-branching structures, this result seems to suggest that these structures are equally morphologically valid. If this is indeed the case, then the corresponding meanings should also be perceived as equally semantically valid. This would predict that structural ambiguity in trimorphemic words triggers semantic ambiguity and, therefore, structurally ambiguous words should be consciously perceived as ambiguous when presented in isolation.

Libben (in press) also explored the role of morphological structure in online processing of trimorphemic words by using a lexical decision paradigm with masked morphological priming. In this experiment, Libben investigated the extent to which final bimorphemic substrings in trimorphemic words can facilitate activation of the whole trimorphemic string. Specifically, it was suggested that, if morphological structure counts in the lexical processing of prefix+root+suffix words, then root+suffix substrings should prime right-branching words better than left-branching words. For example, *sinkable* should prime *unsinkable* better than *fillable* should prime *refillable.* The reason for this differentiated priming effect would be that, although *sinkable* and *fillable* are both real-word substrings of their respective trimorphemic words, *sinkable* is a morphological constituent of *unsinkable* (as the *un-* prefix can modify adjectives), but *fillable* is *not* a morphological constituent of *refillable* (as the *re-* prefix can not modify adjectives). This effect was not found. Instead, it was shown that any real-word substring of a complex word could prime the whole complex word, regardless of their constituent/non-constituent status. This result inspired a new approach to morphological processing: the network approach.

Libben (2003) proposed the network approach as a theoretical framework for testing the relations between trimorphemic words and their morphological constituents. The claim was that, regardless of the selectional restrictions that may command right-branching or left-branching structures, and thereby assign constituent/non-constituent status to independent substrings, all real-word substrings would facilitate whole multimorphemic string recognition. To test both the hierarchical approach and the new network approach, Libben (2003) used a visual lexical decision paradigm in an artificial morpheme boundary experiment. He presented existing and non-existing trimorphemic English words in three conditions: (1) the no break condition, where trimorphemic words were presented as uninterrupted sequences of morphemes (e.g., *refillable*); (2) the first-break condition, where an artificial morpheme boundary was placed after the prefix (e.g., *"re - - fillable"*); and (3) the second-break condition, where the same artificial morpheme boundary was placed after the root (e.g., *"refill - - able"*).

Two main predictions were tested in this experiment. The first one, corresponding to the hierarchical approach, was that non-ambiguous trimorphemic stimuli would be easier to recognize when the artificial morpheme boundary occurs at a major constituent boundary (i.e., when it occurs after the prefix for the right-branching words and after the root for the left-branching words). Thus, it was expected that *"un - - sinkable"* would be recognized faster than *"unsink - - able"* and *"refill - - able"* faster than *"re - - fillable"*. The second prediction, corresponding to the network approach, was that, regardless of the position of the artificial morpheme boundary in this experiment, all stimulus types would be recognized equally easily in the first- and second-break conditions. In other words, when *"re - - fillable"* is presented, both the whole word *refillable* and the substring *fillable* are activated; similarly, when *"refill - - able"* is presented, both the whole word *refillable* and the substring *refill* are activated. As the first- and second-break conditions were (expected to be) slower than the no-break condition, the *break costs* were computed and analyzed comparatively.

A significant difference was found between the first- and second-break conditions for both right-branching and left-branching stimuli: The first-break condition presented a processing advantage over the second-break. This finding contradicts both the hierarchical approach and the network approach. The hierarchical approach predicted that, for the left-branching stimuli, the second-break condition (e.g., *"refill - - able"*) would be faster than the first-break condition (e.g., *"re - - fillable"*). The network approach predicted no difference between these conditions for any stimulus category. However, this result offers support to the automatic prefix-stripping approach which predicts that, regardless of the branching directionality of the hierarchical structures, the first-break condition (i.e., *"un - - reachable"*) would be faster than the second-break condition (i.e., *"unreach - - able"*).

The structurally ambiguous stimuli (e.g., *unfoldable*) showed no difference between the first-break and second-break conditions. This result was interpreted as evidence for the genuine distinctiveness of structurally ambiguous words in comparison with structurally non-ambiguous words. Also, this result was taken to suggest equal morphological validity for the two possible structures in structurally ambiguous words and equal semantic validity for their corresponding interpretations.

de Almeida & Libben (2004) reported the first study of structurally ambiguous words presented in sentence context. They investigated the effects of context on the morphological processing and lexical access in structurally ambiguous English words (e.g., *unlockable*). In a partial replication of Libben's (in press) off-line segmentation experiment, de Almeida & Libben (2004) presented participants with short sentences containing structurally ambiguous and structurally non-ambiguous trimorphemic words in final position. The sentence context was manipulated as follows: (1) neutral context (e.g., *"It was unlockable"*); (2) right-branching biasing context (e.g., *"Unfortunately, it was unlockable"*, which was predicted to activate the right-branching meaning *"not able to be locked"*); and (3) left-branching biasing context (e.g., *"Fortunately, it was unlockable"*, which was predicted to activate the left-branching meaning *"able to be unlocked"*). Participants were asked to perform two tasks: (1) rate the plausibility of each sentence on a five-point scale (1 - least plausible, 5 - most plausible); and (2) segment the last word in the sentence (i.e., the target word) into two parts (e.g., *un/lockable* or *unlock/able*). For each set of five consecutive sentences, participants were instructed to rate plausibility in all five sentences first and then perform the segmentation task for all five target words (The authors acknowledged that this procedure may have nullify the predicted sentence context effect on the segmentation preferences, as it seems likely that participants performed the segmentation task without regard to the sentence context).

It was predicted that, for the structurally ambiguous stimuli, the segmentation after the prefix (e.g., *un/lockable*) would be preferred in the right-branching biasing context (e.g., *"Unfortunately, it was unlockable"*) and the segmentation after the root (e.g., *unlock/able*) would be preferred in the left-branching biasing context (e.g., *"Fortunately, it was unlockable"*). In the neutral contexts, structurally ambiguous words were expected to show a balance between the left and right segmentations. For the non-ambiguous trimorphemic stimuli (right-branching words and left-branching words), it was predicted that the segmentation that corresponds to the internal hierarchical structure of the words would be preferred. The sentence plausibility ratings were expected to be consistent across context types for all stimulus types. The statistical analyses revealed no context effect for either rating or segmentation tasks.

For the word segmentation data, the non-significant effect of context predicts a result pattern similar to the one revealed in Libben (in press) (where structurally ambiguous words were studied in isolation). Indeed, while the non-ambiguous stimuli were divided mostly after the prefix (90%)(e.g., *un/thinkable*), the structurally ambiguous words were divided after the prefix only 38% of the time. Post-hoc analyses showed that the preference for the division after the root in structurally ambiguous words (e.g., *unlock/able*) (62%) was a consequence of the high frequency of the prefix+root substrings (i.e., *unlock*).

For the sentence plausibility rating data, the non-significant effect of context suggests that structurally ambiguous words can indeed license both right-branching and left-branching structures and their corresponding meanings are equally semantically valid. This result would predict that, when presented in isolation, structurally ambiguous words are consciously perceived as ambiguous.

The goal of the present thesis is to test this prediction by investigating structurally ambiguous words in isolation. My investigation approach consisted of three off-line experiments and two on-line experiments.

1.4 Overview of experiments

Experiment 1 explored meaning availability in structurally ambiguous words (e.g., *unlockable*). I wanted to find out whether structurally ambiguous words are perceived as ambiguous when presented in isolation. I employed an ambiguity detection task where participants were asked to decide whether the words with which they were presented had a single meaning (i.e., non-ambiguous words) or two or more meanings (i.e., ambiguous words). I contrasted lexical ambiguity (e.g., *bat*) and structural ambiguity (e.g., *unlockable*), and I predicted that lexical ambiguity would be easily detectable, while structural ambiguity would pass mostly unnoticed. The data confirmed my prediction, showing that lexically ambiguous words (e.g., *bat*) were perceived as ambiguous, while structurally ambiguous words (e.g., *unlockable*) were *not* perceived as ambiguous. This finding raised two questions: (1) why do native speakers associate structurally ambiguous words (presented in isolation) with only one meaning? and (2) which meaning is that (i.e., the right-branching meaning or the left-branching meaning)? These questions were addressed in Experiments 2 and 3.

Experiment 2 consisted of a meaning definition verification task. I reasoned that, although derivation morphology makes two meanings available for structurally ambiguous words, only one meaning is semantically acceptable, and therefore, that is the meaning with which these words are most consistently associated. To test this hypothesis, participants were presented with structurally ambiguous words accompanied by meaning definitions that correspond to either their right-branching or left-branching structures (e.g., *unlockable* means "*not able to be locked*"). They were required to decide whether the definitions matched the meaning of the words. The data suggested that both meanings are semantically acceptable, but not equally so. The semantic acceptability rates for the right-branching meanings were significantly higher than those for the left-branching meanings. This finding pointed to the conclusion that structurally ambiguous words *can* license two meanings, but they are strongly biased toward their right-branching meanings. Why would *unlockable* rather mean "*not able to be locked*" than "*able to be unlocked*"?

Experiment 3 investigated a possible explanation for the bias toward the right-branching meanings in structurally ambiguous words. I proposed that this bias is a frequency effect. I entertained two hypotheses: (1) structurally ambiguous words are being used with their right-branching meanings more often than with their left-branching meanings, and (2) the right-branching meanings of structurally ambiguous words are semantically more plausible than their left-branching counterparts. In order to test these hypotheses, I designed a meaning frequency & plausibility subjective rating task. I found that the right-branching meanings were rated significantly higher than the left-branching meanings for both frequency and plausibility. This result confirmed the semantic bias revealed in Experiment 2 and identified the biasing factors under the form of semantic plausibility and frequency of use. The next step in my investigation was to find an explanation for the direction of the bias: Why are the right-branching meanings preferred over the left-branching meanings and not the other way around?

Experiments 4 and 5 investigated possible explanations for the semantic dominance of the right-branching meanings in structurally ambiguous words.

Experiment 4 tested the hypothesis that a semantic bias at the prefix level can trigger a semantic bias at the whole-word level in structurally ambiguous words. As discussed in section 1.2, the *un-* prefix is ambiguous between the "*not*" meaning, that it contributes to adjectives (e.g., *unhappy* means *"not happy"*) and the "*reverse the action of the verb root*" meaning, that it contributes to verbs (e.g., *unlock* means *"undo the locking"*). However, as the *un-* prefix combines more productively with adjectives than with verbs in English, it seems plausible that this derivational imbalance creates a prefix-internal bias toward the *"not"* meaning. As this is the meaning that the *un-* prefix contributes to the dominant right-branching meanings of structurally ambiguous words (e.g., *"not able to be locked"* for *unlockable*), I hypothesized that the bias toward these interpretations in structurally ambiguous words is triggered by a prefix-internal bias toward the *"not"* meaning.

To test this hypothesis, I designed a visual lexical decision experiment that contrasted the on-line processing of two categories of *un-* prefixed words: (1) *un-* adjectives (e.g., *unhappy*) and (2) *un-* verbs (e.g., *unlock*). I predicted that, due to the prefix-internal bias toward the *"not"* meaning, the prefixation costs associated with adjectives (where the *"not"* meaning of the prefix is activated) are lower than the ones associated with verbs. I found null results.

Experiment 5 investigated yet another possible explanation for the bias toward the right-branching meaning in structurally ambiguous words. This explanation was based on the automatic prefix-stripping view (Taft & Forster, 1975). According to this view, multimorphemic words are parsed in a left-to-right manner, prefix-stripping is automatic and it takes precedence over suffix-stripping. In structurally ambiguous trimorphemic words, this may create a strong advantage for the right-branching structures and their corresponding meanings. To test this possibility, I designed another visual lexical decision experiment that involved three categories of stimuli: (1) structurally ambiguous trimorphemic words (e.g., *unlockable*), (2) right-branching trimorphemic words (e.g., *unreachable*), and (3) left-branching trimorphemic words (e.g., *disconnectable*). The stimuli were presented under three conditions: (1) neutral condition (e.g., *unlockable*), (2) right-branching-biased condition (e.g., *unLOCKABLE*), and (3) left-branching-biased condition (e.g., *UNLOCKable*). My main hypothesis was that, due to the semantic bias toward the right-branching meanings, structurally ambiguous words would be recognized faster in the right-branching-biased condition (e.g., *unLOCKABLE*) than in left-branching-biased condition (e.g., *UNLOCKable*). This hypothesis was not confirmed . In fact, because of strong substring frequency interference, a significant difference in the opposite direction was found. I also hypothesized that, in the neutral condition, due to automatic prefix-stripping, right-branching trimorphemic words (e.g., *unreachable*) would be faster than left-branching trimorphemic words (e.g., *disconnectable*). This hypothesis was confirmed by the data. Two more findings are noteworthy: (1) structurally ambiguous words take significantly longer to process than right-branching words; and (2) there is no significant difference between left-branching words and structurally ambiguous words.

As will become apparent throughout my thesis, the approach outlined above is both descriptive and explanatory. Its descriptive and explanatory components intertwine nicely: the data collected from Experiments 1, 2, and 3 describe *what* is going on at the level of meaning in structurally ambiguous words, while Experiments 4 and 5 investigate processing patterns that can explain *why* that is the case. Despite its seeming simplicity, this approach has the advantage of conceptual resonance with the literature that inspired the present thesis and to which it aims to contribute.

Chapter 2

Experiment 1: Ambiguity Detection

As discussed in the introduction, recent investigations of morphological processing and lexical access in trimorphemic words have revealed two interesting findings. First, unlike the right-branching and left-branching trimorphemic words, structurally ambiguous words do not show any parsing preference (Libben, 2003), which suggests that both possible parses (i.e., [[*un-*] [*lockable*] and [[*unlock*][*-able*]]) are perceived as equally valid. Second, when presented in sentential contexts (biased or neutral), structurally ambiguous words license two meanings (de Almeida & Libben, 2004). This evidence fuels the prediction that, when presented in isolation, structurally ambiguous words license two meanings and, hence, are perceived as ambiguous.

In order to test this prediction, I designed a *word ambiguity detection task* that asked participants to decide whether the stimuli presented have one or more meanings. The purpose of the task was to investigate meaning access in structurally ambiguous words, by contrasting two types of word ambiguity: (a) lexical ambiguity (e.g., *bat*) and (b) structural ambiguity (e.g., *unlockable*). My main hypothesis was that, unlike the words that feature lexical ambiguity, structurally ambiguous trimorphemic words are *not* perceived as ambiguous when presented in isolation.

This experiment tested three predictions: (1) structural ambiguity (e.g., *unlockable*) is much more difficult to detect than lexical ambiguity (e.g., *bat*); (2) native speakers' ability to detect structural ambiguity *can* be manipulated experimentally, by providing explicit information about word ambiguity in general, and structural ambiguity in particular; and (3) despite this type of manipulation, the discrepancy between the levels of detectability of these two ambiguity types would remain sizable. In other words, considering the 0% - 100% ambiguity scale as divided into three equal intervals: (a) *low detectability* (0% - 33%), (b) *medium detectability* (33% - 66%), and (c) *high detectability* (66% - 100%), it is predicted that the lexical ambiguity rates would belong to the high detectability interval (in both experimental conditions), while the structural ambiguity rates would belong to the low detectability interval (in both experimental conditions).

2.1 Method

2.1.1 Participants

Twenty-five undergraduate students from the University of Alberta participated in this experiment. They did not participate in any other experiments reported in this thesis. All of them were native speakers of English and were paid $10 for a 45-minute session that also included other unrelated psycholinguistic experiments.

2.1.2 Stimuli

I selected 96 English words (see Appendix A for the complete list) that were divided in four 24-item categories:

(a) lexically ambiguous monomorphemic words (e.g., *bat*);

(b) lexically non-ambiguous monomorphemic words (e.g., *integer*);

(c) structurally ambiguous trimorphemic words (e.g., *unlockable*); and

(d) structurally non-ambiguous (right-branching) trimorphemic words (e.g., *unreachable*).

Most of the trimorphemic stimuli that I employed in this experiment were drawn from Libben (2003). For the monomorphemic stimuli, I used the WordNet 2.0 linguistic reference system (online) that provides definitions and sentential contexts for all the meanings of 152,059 English words. Selected results of the WordNet searches were checked by two English native-speaker academics separately. They were presented with 100 words and were asked to create two lists: (1) ambiguous words (e.g., words that have two or more unrelated meanings) and (2) non-ambiguous words (e.g., words that have a single meaning). The monomorphemic stimuli that I employed in this experiment are the words that both academics had assigned to the same selection list.

2.1.3 Procedure

Participants were presented with all 96 stimuli in random order and were instructed to press the key labeled "1" for the words that have *one* meaning (i.e., non-ambiguous words) and the key labeled "2" for the words that have *two* or more meanings (i.e., ambiguous words). Participants were randomly assigned to one of two experimental conditions: (a) *Hints* and (b) *NoHints.* In the *Hints* condition (n = 8), the practice session was followed by a debriefing session that gave participants information about the general purpose of the experiment, about what structural ambiguity at word level is and how it can play out in sentential contexts. As I had hypothesized that structural ambiguity was more subtle than lexical ambiguity (and, therefore, more difficult to detect), the goal of this condition manipulation was to increase participants' sensitivity to the structural ambiguity phenomenon and, therefore, enhance their ability to detect it during the experiment. In the *NoHints* condition (n = 17), the debriefing session occurred at the end the experiment and was optional (The unequal number of participants in the two experimental conditions was due to an accident that did not affect randomization).

The experiment was conducted in a single block of trials. Each trial consisted of a single event: the stimulus word appeared in New Times Roman 40 font and remained on the screen until the participants responded by pressing either the key labeled "1" or the key labeled "2". The "1" responses were provided with the left hand and the "2" responses were provided with the right hand. The experiment was designed in PsyScope (Cohen et al., 1993) and was conducted on PowerMac 4,5 computers running MacOS 9.2.

2.2 Results and discussion

The data set consisted of two types of responses: (a) "1" (i.e., *one* meaning) responses, that were treated as *non-ambiguity* judgements, and (b) "2" (i.e., *two* or more meanings) responses, that were treated as *ambiguity* judgements.

For data analysis purposes, the "2" responses were assigned a value of 100 and the "1" responses were assigned a value of 0. Ambiguity detectability rates were computed by averaging the corresponding values for both individual stimuli (in the by-items analyses) and individual stimulus types (in the by-participants analyses).

The data from two participants were excluded from the analyses for the following reasons: (a) one participant provided 100% incorrect responses on the non-ambiguous simple stimuli (e.g., *integer*), responding "2" (i.e., ambiguous) to all of them; and (b) another participant showed no variation in responses to the complex stimuli - ambiguous (e.g., *unlockable*) and non-ambiguous (e.g., *unreachable*), responding "2" (i.e., ambiguous) to all of them. The overall means of ambiguity detection rates for these participants were 83% and 93%, in comparison to the grand mean of 37%. The corresponding z-scores were 2.2 and 2.6, respectively, which justified their exclusion from the data analyses (both these participants were run in the NoHints condition).

The ambiguity detection experiment involved three factors with two levels each: Ambiguity (Ambiguous and Non-ambiguous), Complexity (Complex and Simple), and Hints (Hints and No Hints). The four types of stimuli that I employed represent the crossing between the Ambiguity and Complexity factors.

The data were originally analysed in three-way ANOVAs. For the by-participants analysis, the Ambiguity and Complexity factors were treated as within-participants factors and the Hints factor was treated as a between-participants factor. For the by-items analysis, the Ambiguity and Complexity factors were treated as between-items factors and the Hints as a within-items factor. The subsequent two-way ANOVAs involved only the Ambiguity and Complexity factors, which were treated as within participants factor in the by-participants analysis and as between-items factors in the by-items analysis. All analyses involved 23 participants ($n_{Hints} = 8$, $n_{NoHints} = 15$) and 96 items (four categories of 24 items each).

Both by-participants (F_1) and by-items (F_2) three-way ANOVAs revealed a significant Ambiguity x Complexity x Hints interaction ($F_1(1, 21) = 7.61$, p = .01; $F_2(1, 92) = 16.78$, p < .0001). As the first order interaction between Ambiguity and Complexity was also found significant in both analyses (F_1 (1, 21) = 253.16, p < .0001; $F_2(1, 92) = 228.81$, p < .0001), I will discuss the implications of the three-way interaction in terms of the differences in the Ambiguity x Complexity simple interaction at each level of Hints (i.e., 2 two-way ANOVAs).

	Complexity	
Ambiguity	Simple	Complex
Ambiguous	85 (e.g., *bat*)	20 (e.g., *unlockable*)
Non-Ambiguous	14 (e.g., *integer*)	14 (e.g., *unreachable*)

Table 2.1: Ambiguity detectability rates (%) for the Ambiguity x Complexity interaction (by-items).

The Ambiguity x Complexity interaction suggests that participants' ability to detect ambiguity varied as a function of the morphological complexity of the stimuli. That is, lexical ambiguity (or ambiguity in *mono*morphemic words) is significantly different from structural ambiguity (or ambiguity in *tri*morphemic words). The simple effects of the Complexity factor were calculated and, as expected, significance was found only for the ambiguous stimuli ($F_1(1, 22) =$ 135.49, p < .0001; $F_2(1, 46) = 389.77$, p < .0001). As can be seen in Table 2.1, the detectability rates of ambiguity in structurally ambiguous stimuli (e.g., *unlockable*) are much smaller than those in lexically ambiguous stimuli (e.g., *bat*). This result confirmed my first prediction that structural ambiguity is more difficult to detect than lexical ambiguity. More specifically, it shows that, unlike their lexically ambiguous words, structurally ambiguous words presented in isolation are *not* perceived as ambiguous, being commonly associated with unique meanings (very much like their non-ambiguous counterparts).

The significance of the Ambiguity x Complexity x Hints interaction confirmed my second prediction: speakers' ability to detect ambiguity *can* increase by exposure to explicit information about word ambiguity phenomena. However, as can be seen in Figure 2.1, the locus of the three-way interaction regards only the structurally ambiguous stimuli. This suggests that participants' ability to detect lexical ambiguity (e.g., *bat*) did not vary significantly as a function of the explicit information about ambiguity that was provided in the Hints condition, but their ability to detect structural ambiguity did increase significantly (from 9% to 29%).

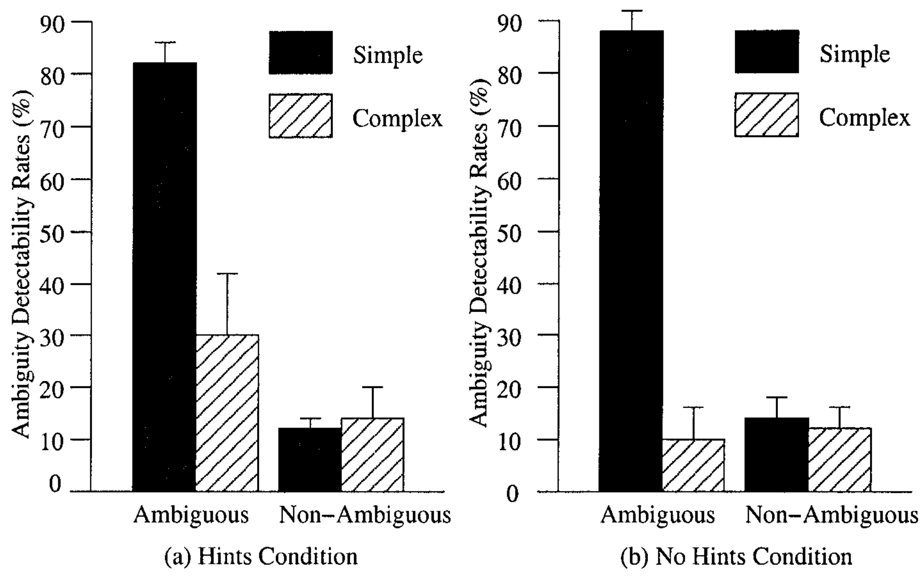

Figure 2.1: Ambiguity detectability rates (%) for the Ambiguity x Complexity interaction in the Hints and NoHints conditions (by-participants)[1].

To test the significance of the simple effects of Hints on the structurally ambiguous stimuli, the data were restructured in the sense of viewing the experimental design as involving only two factors: Hints and Stimulus Type (instead of the original three factors). The Hints factor had the same two

[1]The error bars indicate one standard error in all the graphs presented in the thesis.

levels (Hints and NoHints), but the *new* Stimulus Type factor had four levels (representing the four possible combinations between the levels of the original factors: Ambiguity and Complexity): (1) Ambiguous Simple (or lexically ambiguous) (e.g., *bat*), (2) Ambiguous Complex (or structurally ambiguous) (e.g., *unlockable*), (3) Non-Ambiguous Simple (e.g., *integer*), and (4) Non-Ambiguous Complex (e.g., *unreachable*).

By doing so, I could test directly the prediction that awareness of structural ambiguity is sensitive to metalinguistic knowledge (unlike awareness of lexical ambiguity, which is high and stable in both experimental conditions). Both by-participants and by-items two-way ANOVAs were performed. The Hints x Stimulus Type interaction was significant in both analyses ($F_1(3, 63) = 20.27$, $p = .0001$; $F_2(3, 92) = 3.34$, $p = .02$), but the simple effect of Hints on the structurally ambiguous stimuli (i.e., Ambiguous Complex level of the new factor Stimulus Type) was significant only in the by-items analysis ($F_2(1, 23) = 83.95$, $p = .0001$). As can be seen in Figure 2.2, the detectability rates of structural ambiguity in the Hints condition were indeed higher than in the NoHints condition. However, the structural ambiguity rates in both experimental conditions belong to the low detectability interval (9% in the NoHints condition and 29% in the Hints condition), while the lexical ambiguity rates belong to the high detectability interval (81% in the NoHints condition and 88% in the Hints condition). This result suggests that structurally ambiguous words are *not* perceived as ambiguous, because of the low detectability type of ambiguity that they feature.

To summarize, the statistical analyses confirmed all the three predictions tested, showing that (1) structural ambiguity is more difficult to detect than lexical ambiguity; (2) sensitivity to structural ambiguity *can* be increased by exposure to explicit metalinguistic information; and (3) most importantly, by contrast with their lexically ambiguous counterparts (e.g., *bat*), structurally ambiguous words (e.g., *unlockable*) are *not* consciously perceived as ambiguous when presented in isolation. Two possible reasons why this may be the case were investigated in Experiment 2.

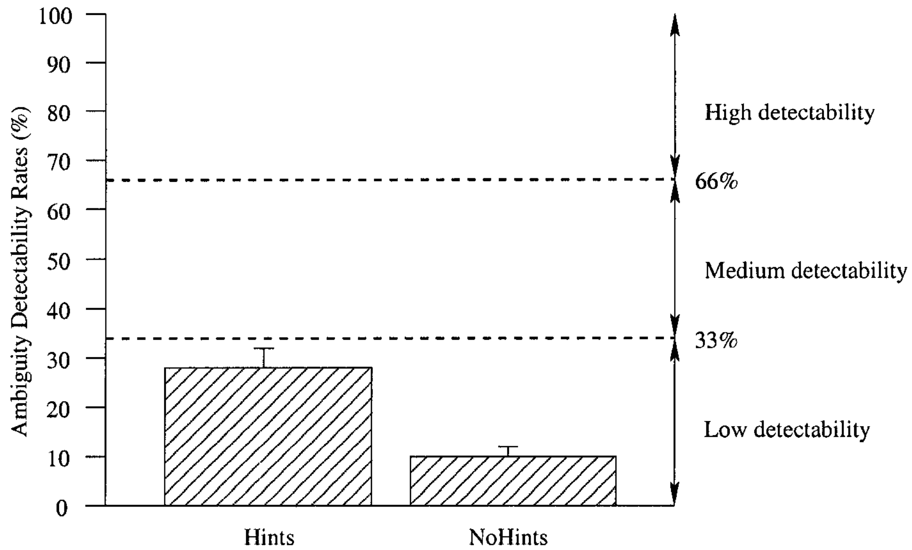

Figure 2.2: Simple effect of factor Hints on the structurally ambiguous stimuli (by-items).

Chapter 3

Experiment 2: Meaning Definition Verification

Experiment 2 consisted of a definition verification task and investigated two possible explanations for the results in Experiment 1. The ambiguity detection task in Experiment 1 revealed that structurally ambiguous trimorphemic words such as *unlockable* are *not* perceived as ambiguous when presented in isolation.

One possible explanation for this fact is that, although English derivation morphology makes *two* meanings available for the structurally ambiguous words, only one meaning is semantically acceptable/plausible and therefore, that meaning is *the* one that these words are consistently associated with.

Another possible explanation is that, although both structures that can represent the morphological constituency of the structurally ambiguous words (i.e., [[un-][*lockable*]] and [[*unlock*][-able]]) are equally valid from a theoretical perspective, the meanings they license are not equally plausible. This semantic unbalance may be the source of a strong bias toward one meaning and, therefore, the reason why structurally ambiguous words are *not* perceived as ambiguous when presented in isolation (i.e., the dominant meaning is perceived as unique). In order to explore these two possibilities, I designed the definition verification experiment described below. It tested two predictions: (1) both meanings of structurally ambiguous words are plausible, but not equally plausible; and (2) the right-branching meanings are significantly more plausible than the left-branching meanings.

3.1 Method

3.1.1 Participants

Sixty-two undergraduate students from the University of Alberta participated in this experiment. None of them participated in any other experiments reported in this thesis. They were all native speakers of English and were paid $10 for a 45-minute session that also included other unrelated psycholinguistic experiments.

3.1.2 Stimuli

The set of stimuli contained 60 English complex words (see Appendix B for the complete list): 24 structurally ambiguous words served as core stimuli and 36 structurally non-ambiguous words served as fillers. The filler word set consisted of complex words ending in the suffixes *-able* or *-ible* (e.g., *incurable*, *immersible*), containing real or pseudo-prefixes (e.g., *unreachable*, *understandable*), and featuring right- or left-branching structures (e.g., *unwearable*, *disconnectable*).

All stimuli in this experiment were presented accompanied by one paraphrasal meaning definition. The structurally ambiguous stimuli were presented under two meaning type conditions:

(a) *right-branching condition*, where the stimuli were presented accompanied by their right-branching meaning definition (e.g., *unlockable* means *"can not be locked"*), and

(b) *left-branching condition*, where the stimuli were presented accompanied by their left-branching meaning definition (e.g., *unlockable* means *"can be unlocked"*).

Unlike the target stimuli, the filler words were arbitrarily assigned either correct definitions (e.g., *undrinkable* means *"one cannot drink it"*) or incorrect definitions (e.g., *unreachable* means *"one can reach it"*). Thus, 12 fillers were presented with correct definitions and 24 with incorrect definitions. Each filler was presented with the same (correct or incorrect) definition to all participants.

I employed four types of meaning definitions (X = *root verb*):

(a) "possible to un-X (to be un-X-ed)" or "impossible to X (to be X-ed)" (e.g., *"possible to unlock"* or *"impossible to lock")*;

(b) "capable of being un-X-ed" or "incapable of being X-ed" (e.g., *"capable of being unlocked"* or *"incapable of being locked")*;

(c) "one can un-X it" or "one cannot X it" (e.g., *"one can unlock it"* or *"one cannot lock it")*; and

(d) "can be un-X-ed" or "cannot be X-ed" (e.g., *"can be unlocked"* or *"cannot be locked")*.

3.1.3 Procedure

Participants were asked to decide whether the paraphrases they were presented with were possible definitions of the words with which they appeared. They were instructed to press the key labeled *"yes"* if the definition matched the meaning of stimulus word, and the key labeled *"no"* if the definition did not match the meaning of the word. Each participant saw 60 words and 60 definitions. As meaning type was a within-items factor for the structurally ambiguous stimuli (i.e., each structurally ambiguous stimulus was presented with both its right-branching and left-branching meanings), to avoid repetition effects, participants were randomly assigned to one of two groups such that each structurally ambiguous stimulus was presented in both meaning type conditions across groups and each participant saw half of the targets under each condition.

The experiment was run in a single block of trials. Each trial consisted of three text events, each of which presented their stimuli centered in one of three equally sized regions of the screen: (a) the upper region, (b) the mid region, and (c) the lower region. The three text events were:

(1) *Event 1: stimulus word*; the trimorphemic stimuli appeared in the upper region of the screen and remained there until the end of the trial; 800 milliseconds later, Event 2 occurred;

(2) *Event 2: linking word*; the word *"means"* (vb., 3^{rd} pers., sg.) appeared

in the mid region of the screen and remained there until the end of the trial; 500 milliseconds later, Event 3 occurred;

(3) *Event 3: meaning definition*; the meaning definition appeared in the lower region of the screen and remained there until the end of the trial.

All three events ended simultaneously when participants pressed one of the response keys, which also completed the trial. The structure of a trial is presented graphically in Figure 3.1.

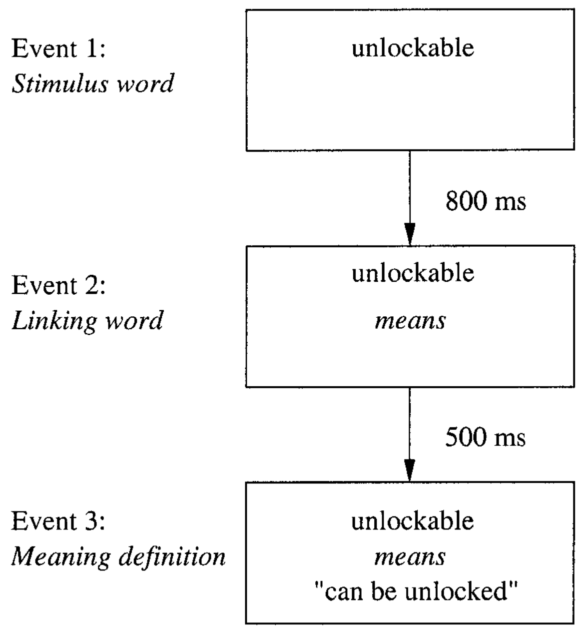

Figure 3.1: A single trial structure in the definition verification experiment.

The experiment was designed in PsyScope (Cohen et al., 1993) and was conducted on PowerMac 4,5 computers running MacOS 9.2.

3.2 Results and discussion

The single factor involved in this design was Meaning Type, and it had two levels: (1) Right branching meaning and (2) Left branching meaning. The experiment measured the semantic acceptability of the two meanings that structurally ambiguous words can license (e.g., *"can not be locked"* and *"can be unlocked"* for *unlockable*). The data set consisted of "yes" (i.e., "acceptable") and "no" (i.e., "unacceptable") responses. For the data analyses, only the responses to the structurally ambiguous stimuli were selected. The "yes" responses were assigned a value of 100, and the "no" responses were assigned a value of 0. Then, semantic acceptability rates were computed by averaging the corresponding values for both meanings of each target word (in the by-items analysis) and for each meaning type across targets (in the by-participants analysis). The meanings with acceptability rates ranging between 50% - 100% were to be considered "semantically acceptable", while the ones with acceptability rates ranging between 0% - 50% were to be considered "semantically unacceptable".

The following two predictions were tested: (1) structurally ambiguous words *can* license two meanings (a right-branching meaning and a left-branching meaning), both of which are semantically acceptable; and (2) in structurally ambiguous words, the right-branching meanings are significantly more semantically acceptable than the left-branching meanings. In other words, I expected that acceptability rates for each meaning type (right- and left-branching) would be 50% or higher, and that the difference between these rates would be statistically significant in the direction hypothesized.

As predicted, the semantic acceptability rates for both the right-branching and left-branching meanings of structurally ambiguous words were higher than 50%: $M_{RightBranching}$ = 84% (SD = 18) and $M_{LeftBranching}$ = 67% (SD = 30). This finding suggests that structurally ambiguous words *can* indeed license two meanings, both of which are semantically acceptable. Most importantly, the by-participants (F_1) and by-items (F_2) one-way ANOVAs revealed a highly significant effect for Meaning Type: $F_1(1, 61) = 13.86$, p = .0004; $F_2(1, 23) = 73.89$, p <.0001. Figure 3.2 presents the bar plot for this effect. This result indicates that, also as predicted, the right-branching meanings of structurally ambiguous words *are* more acceptable than the left-branching meanings.

The highly significant differences between the acceptability rates of the two meanings were interpreted as strong evidence of a semantic bias toward the right-branching meanings in structurally ambiguous words. While this finding can explain the results obtained in Experiment 1 (where the structurally am-

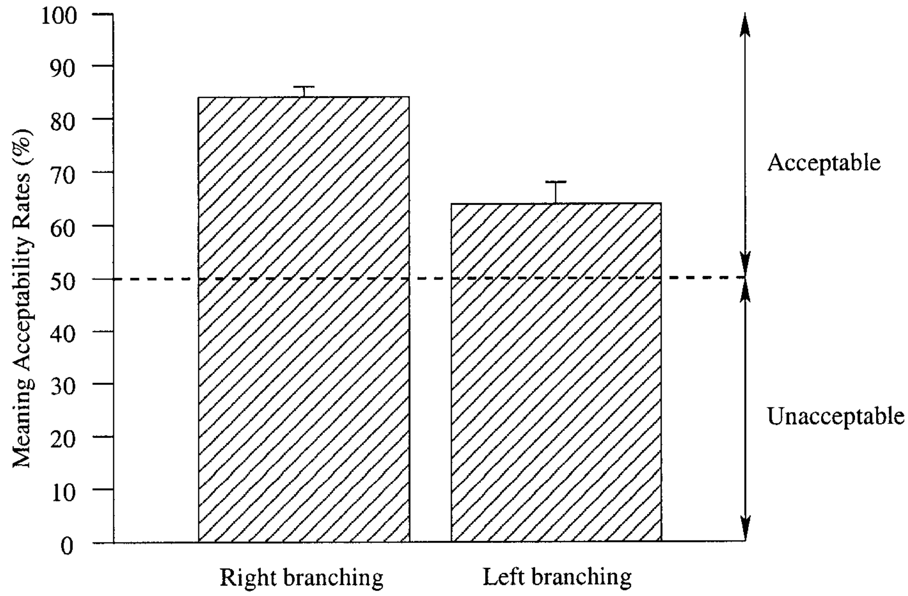

Figure 3.2: Meaning acceptability rates for the main effect of Meaning Type (by-participants).

biguous words were *not* perceived as ambiguous when presented in isolation), it also raises a new question: what causes this semantic bias?

In Experiment 3, I investigated one possible explanation for the bias toward the right-branching meanings in structurally ambiguous words.

Chapter 4

Experiment 3: Meaning Frequency & Plausibility Rating

Experiment 3 investigated a possible explanation for the semantic bias revealed in Experiment 2. I tested two main hypotheses. The first one predicted that the preference for the right-branching meaning in structurally ambiguous words (e.g., *"not able to be locked"* for *unlockable*) is a frequency effect. That is, native speakers of English tend to use these words far more often with their right-branching meaning than with their left-branching meaning. The second hypothesis predicted that this frequency bias toward the right-branching meanings is a direct consequence of a plausibility bias toward these meanings. In other words, native speakers use structurally ambiguous words mostly with their right-branching meanings because these meanings are more plausible than their left-branching counterparts. Consequently, due to "overuse" of the right-branching meanings, the structurally ambiguous words tend to be associated with these meanings as *unique* meanings, rather than dominant meanings, which explains native speakers' inability to perceive structurally ambiguous words as ambiguous.

To test the two hypotheses described above, I designed a pencil-and-paper subjective rating task. The task was mainly targeted at *meaning frequency*, but, as structurally ambiguous words have very low (or zero) token frequency (which makes subtle differences between alternative meanings even harder to detect), I chose to employ an extra measure of semantic bias: *meaning plausibility*. I expected the rating data to reveal that the more plausible a meaning is, the more frequently used it is, and so, the better a candidate it becomes for the dominant meaning position in structurally ambiguous words.

4.1 Method

4.1.1 Participants

Seventy-two undergraduate students from the University of Alberta participated in this experiment as volunteers. They were native speakers of English and did not participate in any other experiments reported in this thesis.

4.1.2 Stimuli

The stimuli list contained 24 structurally ambiguous words (see Appendix C for the complete list) and no fillers. The stimuli were presented accompanied by paraphrasal definitions corresponding to either one or both of their possible meanings. Unlike in Experiment 2, where four paraphrasal definition types were employed, in this experiment only one type was used: *impossible/possible to X/un-X* (e.g., *unlockable* – *"impossible to lock", "possible to unlock"*).

Three types of rating questionnaire sheets were used to present the stimuli:

(1) *paired frequency* rating sheets (where both possible meanings of structurally ambiguous words were subjected to frequency rating),

(2) *paired plausibility* rating sheets (where both possible meanings of structurally ambiguous words were subjected to plausibility rating), and

(3) *unpaired plausibility* rating sheets (where only one possible meaning of structurally ambiguous words was subjected to plausibility rating).

The paired rating sheets raised concerns of rating order effects and rating complementarity effects. That is, given the strong bias toward the right-branching meaning in structurally ambiguous words, rating the right-branching meanings before the left-branching meanings may bias negatively the rating of the latter. Similarly, using a five-point rating scale, if one meaning was given a rating of 4, the other will probably be given a rating of 1, so the two ratings would balance each other out ($4 + 1 = 5$). Therefore, to control for the rating order effect, two subtypes of *paired* rating sheets were designed: the order of meanings presentation was varied so that, for each stimulus, some participants rated the right-branching meaning before the left-branching meaning, while others did the rating in the reversed order. The *unpaired* plausibility rating sheet type was designed to control for the rating complementarity effect. I reasoned that rating the plausibility of the two meanings of structurally ambiguous words independently (i.e., unaccompanied by their counterpart) could also give insight about the source of the semantic bias toward the right-branching meanings in structurally ambiguous words.

4.1.3 Procedure

Participants were presented with all 24 structurally ambiguous stimuli accompanied by paraphrasal definitions of meaning. Depending on the questionnaire sheet type they were assigned to, participants were required to rate either frequency or plausibility of either one or both meanings of the stimuli. A five-point rating scale was used, on which 5 stood for *"most frequent/plausible"* and 1 for *"least frequent/plausible"*. Participants were tested in a single session in a large university amphitheater. They received the questionnaire sheets at the same time and completed the task in 20 minutes or less.

The questionnaires used in this experiment were optically readable rating sheets that I designed specifically for the purpose of this investigation (see Appendix C for questionnaire sheet samples). The completed questionnaire forms were processed at the University of Alberta Center for Questionnaire Services. All the statistical analyses that I developed for the data collected in this experiment are entirely reliant on the optical reader output files.

4.2 Results and discussion

The data consisted of subjective rating scores (ranging between 1 - 5) for the plausibility and frequency of the two possible meanings of 24 structurally ambiguous words. The participants were randomly assigned to one of three groups: (a) Paired Frequency (n = 21), (b) Paired Plausibility (n = 23), and

(c) Unpaired Plausibility (n = 28).

Two types of data analyses were performed. The data collected from the *paired* (frequency and plausibility) rating sheets were analysed in three-way ANOVAs, while the data collected from the *plausibility* (paired and unpaired) rating sheets were analysed in two-way ANOVAs. The factors involved in the three-way ANOVAs were: (a) Meaning Type (two levels: Right-branching meaning and Left-branching meaning), (b) Rating Task (two levels: Frequency and Plausibility), and (c) Rating Order (two levels: Right-branching meaning - Left-branching meaning and Left-branching meaning - Right-branching meaning). The factors involved in the two-way ANOVAs for plausibility rating were: Meaning Type (same levels as above) and Rating Condition (two levels: Paired and Unpaired). In the by-participants analyses, the Meaning Type factor was treated as a within-participants factor, and all the other factors as between-participants factors. In the by-items analyses, all factors were treated as within-items factors.

The three-way ANOVAs were performed to test the prediction that the right-branching meanings are more frequent than the left-branching meanings and that they are also more plausible than the left-branching meanings. A significant effect for Meaning Type was found in both by-participants and by-items analyses: $F_1(1, 40) = 28.7$, $p < .0001$, and $F_2(1, 23) = 129.82$, $p < .0001$. As can be seen in Figure 4.1, the ratings for the right-branching meanings are higher than for the left-branching ones ($M_{Right-Branching} = 3.7$, SD = .92; $M_{Left-Branching} = 2.4$, SD = .90). As the Meaning Type factor was not involved in any significant interactions, it seems in order to conclude that the prediction that structurally ambiguous words are semantically biased toward their right-branching meanings was confirmed.

The by-items analysis also revealed significant main effects of Task ($F_2(1, 23) = 8.83$, $p < .006$) and Order ($F_2(1, 23) = 10.42$, $p < .003$), and a significant Task x Order interaction ($F_2(1, 23) = 7.91$, $p < .009$). These results suggest three important facts. First, both meanings of structurally ambiguous words were rated higher in the meaning plausibility task than in the meaning frequency task. This finding was predicted, as the very low (or zero) frequen-

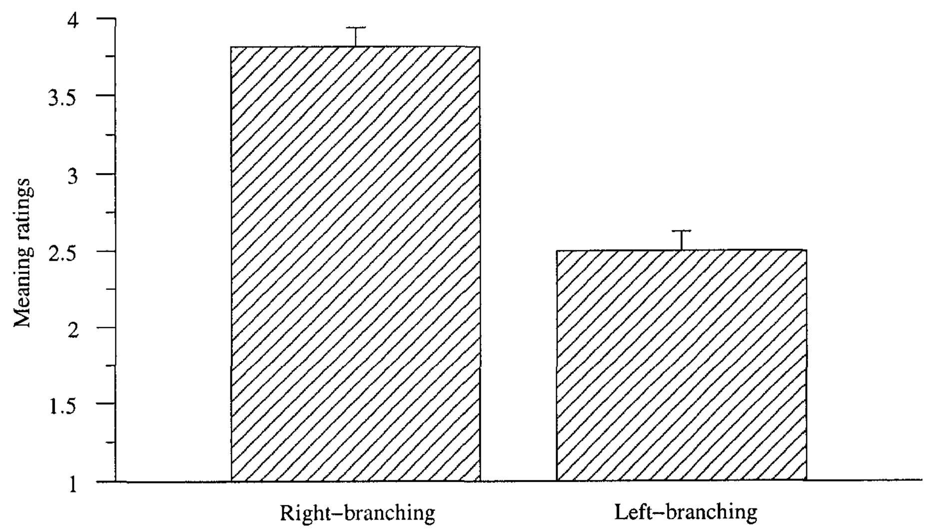

Figure 4.1: Meaning ratings for the main effect of Meaning Type (by-participants).

cies of the structurally ambiguous words were expected to bias negatively the frequency ratings, but not the plausibility ratings.

Second, the order in which the meanings were presented affected equally the frequency and plausibility ratings in the sense that, whenever the left-branching meanings were presented first, both meanings were rated higher than when the right-branching meanings were presented first. That is, being presented first, and thus escaping interference from the dominant meaning (i.e., right-branching meaning), the subdominant meaning was rated higher than it would have been if presented *after* the dominant meaning. However, when the dominant meaning was presented second, it was rated even higher than it would have been if presented first, so the difference between the two meanings (i.e., the bias toward the right-branching meaning) stayed the same.

Third, as can be seen in Figure 4.2, the Task x Order interaction concerned only the frequency rating task. Indeed, the simple effect of Order was found significant for the Frequency task ($F_2(1, 23) = 15.46$, $p = .0007$), but not for the Plausibility task ($F_2(1, 23) = .013$, $p = .91$).

As the three-way ANOVAs showed that the order of meaning presentation did not affected significantly the plausibility ratings of individual meanings,

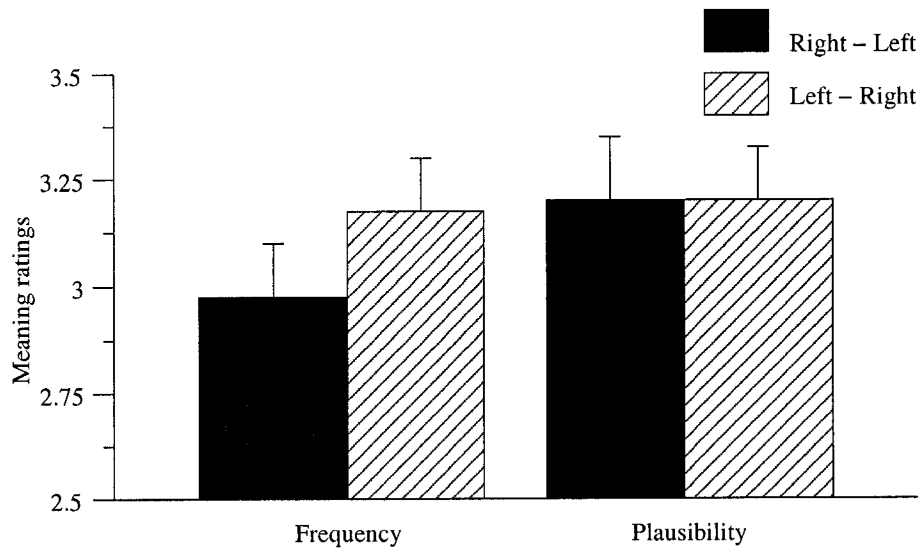

Figure 4.2: Meaning ratings for the Task x Order interaction (by-participants).

the two-way ANOVAs discussed below investigated the question of whether the plausibility ratings of individual meanings were significantly affected by the presence (and rating) of their counterparts. In other words, do the right-branching meanings get the same ratings in the Paired and Unpaired conditions? As the analyses in Experiment 2 and the ones performed so far in Experiment 3 had found strong evidence for a semantic bias toward the right-branching meanings in structurally ambiguous, my prediction was that, by contrast with the "obscure" left-branching meanings, the right-branching meanings tend to be rated higher in the Paired condition than in the Unpaired condition.

To test this prediction, the data from the two plausibility rating sheet types were analysed in two-way ANOVAs. The Rating Condition factor had two levels: Paired and Unpaired, and the Meaning Type factor also had two levels: Right-branching meaning and Left-branching meaning. As predicted, both by-participants and by-items analyses revealed a significant main effect for Meaning Type ($F_1(1, 49) = 22.02$, $p < .0001$; $F_2(1, 23) = 74.45$, $p < .0001$), reconfirming the strong bias toward the right-branching meanings in structurally ambiguous words. Most importantly, the interaction between Rating Condition and Meaning Type was found significant: $F_1(1, 49) = 6.93$, p = .01, $F_2(1, 23) = 25.95$, p < .0001. Figure 4.3 presents the bar plot for this interaction effect. The simple effects of Rating Condition were computed in both by-participants and by-items analyses. As predicted, only the ratings for the right-branching meanings varied significantly as a function of whether the two meanings of structurally ambiguous words were presented together or separately ($F_1(1, 49) = 7.42$, p = .008, $F_2(1, 23) = 18.26$, p = .0003). No significant simple effect of Rating Condition was found for the left-branching meanings ($F_1(1, 49) = 1.27$, p = .26, $F_2(1, 23) = 3.84$, p = .06).

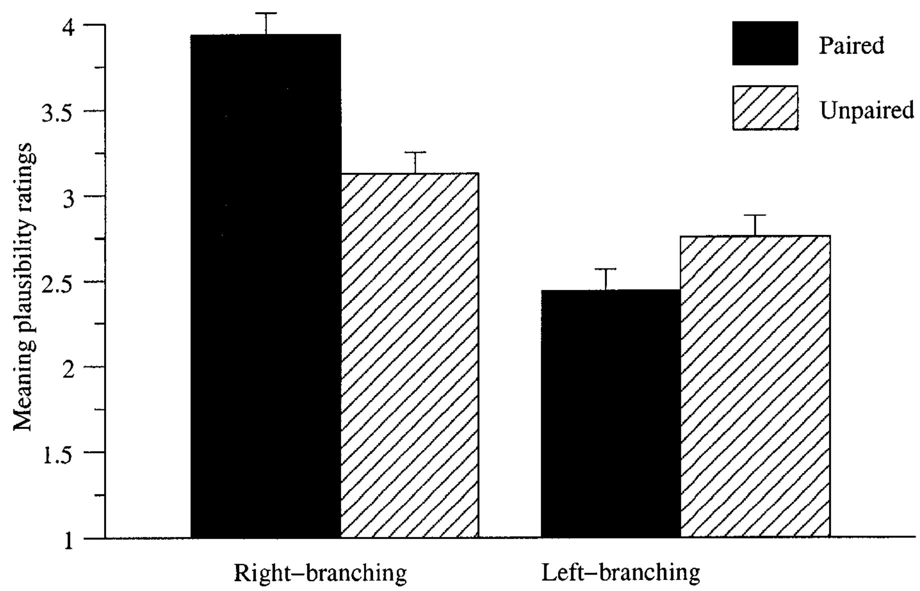

Figure 4.3: Meaning plausibility ratings for the Meaning Type x Rating Condition interaction (by-participants).

In conclusion, the subjective rating tasks used in this experiment showed that the right-branching meanings of structurally ambiguous words (e.g., *"not able to be locked"* for *unlockable*) are significantly more plausible and more frequent than their left-branching counterparts (e.g., *"able to be unlocked"* for *unlockable*). While this finding provided a sound explanation for the strong semantic bias revealed in Experiment 2, it also raised a new question: Why are the right-branching meanings "preferred" over the left-branching meanings?

Experiments 4 and 5 investigated two possible explanations for the directionality of the semantic bias in structurally ambiguous words.

Chapter 5

Experiment 4: *un*-Adjectives vs. *un*-Verbs

Experiment 4 explored a possible explanation for the direction of the semantic bias in structurally ambiguous words. By using specific psycholinguistic experimental procedures, I investigated comparatively the on-line processing of *un*- prefixed bimorphemic English adjectives and verbs (e.g., *unhappy, unlock*). The rationale for this shift of scope of investigation is detailed below.

As discussed in the introduction, word syntax theory presumes *equal* validity for the two morphological structures that allow structurally ambiguous words to license two meanings: (1) [[*un-*][*lockable*]], which licenses the meaning *"not able to be locked"*; and (2) [[*unlock*][*-able*]], which licenses the meaning *"able to be unlocked"*. This presumption predicted that structurally ambiguous words would be perceived as *balanced* ambiguous words, but empirical evidence to the contrary was found: they are strongly *biased* towards their right-branching meanings. It seems clear, then, that this semantic bias can not be explained from the perspective of word syntax theory. However, insight about the source of the bias may be gained by investigating the manner in which complex words (bimorphemic words in this case) are processed in the mind and how lexical access is achieved.

Specifically, Experiment 4 investigated the possibility that the semantic bias at the whole-word level in structurally ambiguous words may be a consequence of a semantic bias localized at a deeper morphological level: the *un*-prefix level.

Morphologically speaking, the *un-* prefix can combine with both adjectives and verbs, resulting in complex adjectives and complex verbs (e.g., *un-happy, un-lock*) (For the reasons mentioned in section 1.2, the ability of the *un-* prefix to combine with nouns will not be discussed here). Semantically speaking, depending on the lexical category of the word to which it attaches, the *un-* prefix can contribute two completely unrelated meanings to the composite interpretation of the derived lexical items. On the one hand, when the prefix combines with adjectival roots, its semantic contribution is plain negation (e.g., *unhappy* means *"not happy"*). On the other hand, however, when it combines with verbal roots, the *un-* prefix contributes a more complex meaning - reversal of the action expressed by the root verb (e.g., *unlock* means *"undo the locking"*). Therefore, it can be argued that the *un-* prefix is intrinsically ambiguous between the two meanings that it can contribute during the derivation process.

Assuming that decomposition does occur and prefix-stripping is automatic, this semantic ambiguity can play out in two ways. First, if the *un-* prefix is balanced between the adjectival and verbal meanings, the on-line semantic decoding of the prefix is withheld until the lexical category of its base has been identified. This would delay processing, but would predict no differences between the *un-* prefixed adjectives and the *un-* prefixed verbs. Second, if the *un-* prefix is biased toward one of its meanings, then that meaning will be assumed by default. Therefore, when the meaning assumed by default (i.e., the dominant meaning) matches the lexical category of the root, the processing proceeds smoothly. However, when the dominant meaning does not match the lexical category of the root, the processing is slowed down, as the original assumption about the meaning of the prefix needs to be revisited and adjusted accordingly (i.e., the dominant meaning is replaced with the subordinate meaning). This would predict that the bimorphemic words belonging to the lexical category that matches the dominant meaning of the *un-* prefix would be faster to recognize than their counterparts.

Before making specific predictions about the role that the *un-* prefix plays in the on-line processing of bimorphemic adjectives and verbs, and in what way that could be relevant for the on-line processing of structurally ambiguous words, two questions need to be addressed: (1) Is the *un-* prefix semantically balanced, or is it biased? and (2) If it is biased, which is its dominant meaning?

To research these questions, I searched the Celex database (Baayen et al., 1995) (the lemma written English corpus) and I found that (1) there are four times more *un-* prefixed adjectives than *un-* prefixed verbs in English (166 *un-* adjectives vs. 43 *un-* verbs listed); and (2) the summed frequency of the *un-* prefixed adjectives is about ten times the summed frequency of the *un-* prefixed verbs (1,752 vs. 12,044 per 1 million words; token frequency). These results suggest two important facts: (1) the *un-* prefix combines more productively with adjectives than with verbs in English; and (2) native speakers of English access (in the visual modality) the adjectival meaning of the *un-* prefix ten times more often than the verbal meaning (decomposition being assumed). Therefore, it is conceivable that the *un-* prefix's high derivational productivity with adjectival roots and the high frequency of the derived adjectives themselves can trigger a prefix-internal bias toward the adjectival meaning (i.e., *"not"*). In other words, it may be the case that during on-line processing, the *un-* prefix is assumed to mean *"not"* and therefore, an adjectival root is anticipated. If the root is an adjective, the morphological processing is sped up. If, however, the root is a verb, the processing is slowed down, as the initial assumption about the meaning of the prefix needs to be adjusted. This adjustment would result in extra processing costs for the *un-* prefixed verbs and it would translate into a processing advantage for the *un-* prefixed adjectives as compared with *un-* prefixed verbs. The base-line prediction is that the *un-* prefixation costs associated with adjectives are lower than those associated with verbs.

How does this line of reasoning apply to structurally ambiguous words? Structurally ambiguous words are biased toward their right-branching meanings, which incorporate the *"not"* meaning of the *un-* prefix (e.g., *"not able to be locked"* for *unlockable*). If it is found that a processing advantage is associated with the *"not"* meaning of the prefix, then it could be argued that the semantic bias in structurally ambiguous words is triggered by the semantic bias within the *un-* prefix.

To investigate this possibility, I used a standard visual lexical decision experiment. I contrasted *un-* prefixed bimorphemic adjectives and *un-* prefixed bimorphemic verbs (e.g., *unhappy*, *unlock*).

5.1 Method

5.1.1 Participants

Thirty undergraduate students from the University of Alberta participated in this experiment. They did not participate in any other experiments reported in this thesis. They were all native speakers of English and were paid $10 for a 45-minute session that also included other unrelated psycholinguistic experiments.

5.1.2 Stimuli

Fifty bimorphemic English words were selected from the Celex database (Baayen et al., 1995) and were used as target stimuli in this experiment (see Appendix D for the complete list). All the targets contained the *un-* prefix and a free monomorphemic root. As a function of the lexical category of the root, the stimuli were divided into two types: (1) adjectives (e.g., *unhappy*) and (2) verbs (e.g., *unlock*).

The target stimuli were presented under two conditions:

(1) *prefix & root condition*, where the bimorphemic words were presented in full (e.g., *unhappy*, *unlock*); and

(2) *root condition*, where the free monomorphemic roots of the target words were presented as stand-alone stimuli (e.g., *happy*, *lock*).

Beside the 50 target stimuli (25 items of each type), 100 real words and 100 non-sense words were employed as fillers.

5.1.3 Procedure

Participants were asked to decide as quickly and accurately as possible whether the words presented on the screen were *real* English words (e.g., words they had seen before). Each participant in the experiment was presented with all 250 stimuli. As both Lexical Category and Presentation Condition were within-participants factors, to eliminate repetition effects, participants were randomly assigned to one of two groups such that each target stimulus was presented in both conditions across groups and each participant saw one-half of the targets in each category under each condition.

The experiment was conducted in a single block of trials. Each trial consisted of a single event: the stimulus word appeared in New Times Roman 40 font and remained on the screen until participants responded by pressing either the key labeled *"yes"* or the key labeled *"no"*. The *"yes"* responses were provided with the right hand and the *"no"* responses were provided with the left hand. The experiment was designed in PsyScope (Cohen et al., 1993) and was conducted on PowerMac 4,5 computers running MacOS 9.2.

5.2 Results and discussion

The basic assumption in this experiment was that the monomorphemic adjectives and verbs that can combine with the *un-* prefix (e.g., *happy, lock*) are faster to recognize than their *un-* prefixed counterparts (e.g., *unhappy, unlock*). Therefore, "prefixation costs" were expected for both *un-* adjectives and *un-* verbs. However, my prediction was that, due to a semantic bias toward the *"not"* meaning of the *un-* prefix, the prefixation costs for adjectives (which would access the dominant meaning of the prefix, i.e., *"not"*) would be lower than for verbs (which would access the subdominant meaning, i.e., *"reverse the action of the root"*). Confirmation of this prediction would suggest that the semantic bias towards the right-branching meanings in structurally ambiguous words (e.g., *"not able to be locked"* for *unlockable*) could be interpreted as a consequence of a semantic bias toward the *"not"* meaning of the ambiguous *un-* prefix itself.

The data set consisted of lexicality judgements (i.e., *"yes"* for real words, *"no"* for non-sense words) for which response times (in milliseconds) were recorded. Response times were used as the dependent variable. The responses to the target words were selected for statistical analyses. From these, the correct responses below 300 ms and above 1500 ms (5%), and all the wrong responses (5%)were excluded.

The two factors involved in this experimental design were: Lexical Category (two levels: Adjectives and Verbs) and Presentation Condition (two levels: Root and Prefix & Root). For the initial two-way ANOVAs, both factors were treated as within-participants factors in the by-participants analysis, while in the by-items analysis, Lexical Category was treated as a between-items factor and Presentation Condition as a within-items factor. For the final one-way ANOVAs (where prefixation costs were used as dependent variable), Lexical Category was treated as a within-participants factor in the by-participants analysis, and as a between-items factor in the by-items analysis.

As predicted, both by-participants (F_1) and by-items (F_2) two-way ANOVAs revealed a main effect of Presentation Condition: $F_1(1, 29) = 94.74$, $p < .0001$; $F_2(1, 48) = 66.68$, $p < .0001$. This finding suggests that indeed, in a visual lexical decision experiment, *un-* prefixed bimorphemic words are slower than their free monomorphemic roots (However, there is no evidence that this effect is a true prefixation effect rather than a mere word length effect). Figure 5.1 presents the bar graph for the Presentation Condition main effect.

The by-participants analysis revealed a significant main effect of Lexical Category ($F_1(1, 29) = 9.37$, $p = .0047$), suggesting that, overall, adjectives are faster to recognize than verbs. However, it could be argued that this effect is not a *pure* measure of lexical-category-specific processing differences, because, when presented in the Root condition, 70% of the target stimuli feature categorial ambiguity (e.g., *sound* can be an adjective, a noun, and a verb; *lock* can be a verb and a noun). Figure 5.2 presents the bar graph for the Lexical Category main effect. The two-way interaction was not significant in either analysis ($p > .31$).

The next step in the analysis was to compute the prefixation costs associated with each lexical category. These prefixation costs were used to minimize the possible effects of uncontrolled inter-stimulus variables. Their calculations were done by subtracting the *root* responses from the *prefix & root* responses

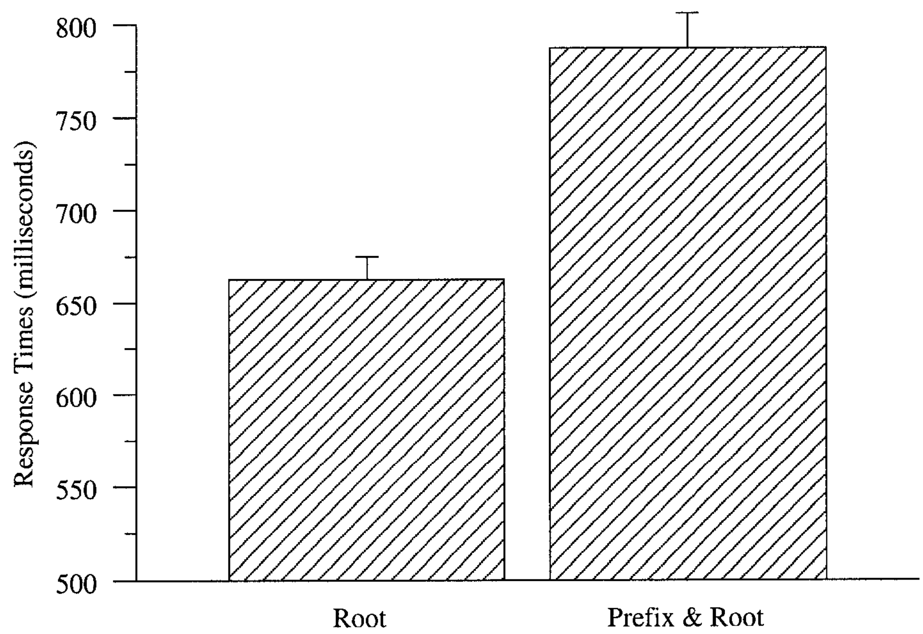

Figure 5.1: Response times (in milliseconds) for the main effect of Presentation Condition (by-participants).

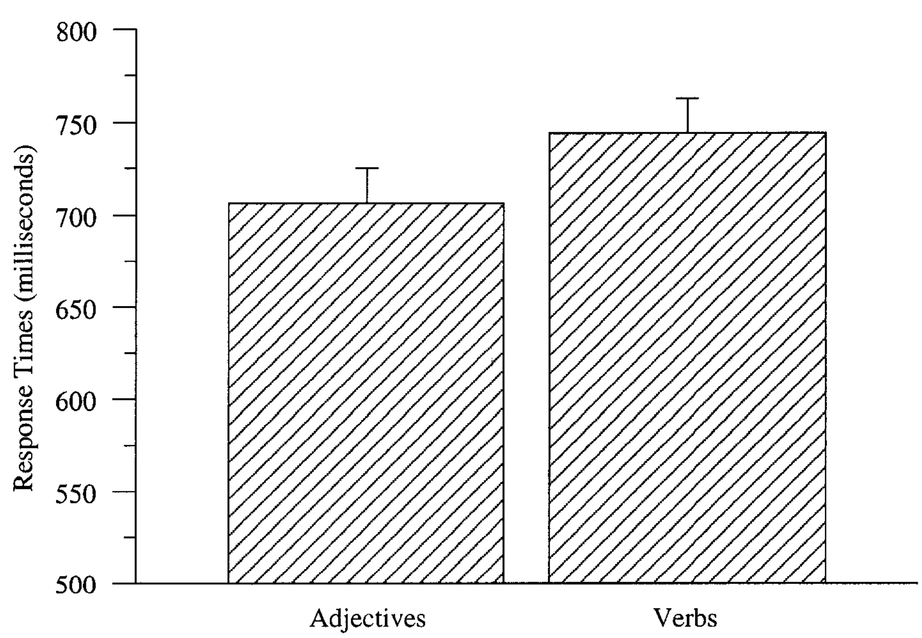

Figure 5.2: Response times (in milliseconds) for the main effect of Lexical Category (by-participants).

for both adjectives and verbs. By-participants and by-items one-way ANOVAs were performed to test the hypothesis that the prefixation costs associated with adjectives are lower than those associated with verbs. The effect of Lexical Category was not significant in either analysis ($F_1(1, 29) = .02$, $p = .88$; $F_2(1, 48) = .82$, $p = .36$). Table 5.1 presents the mean response times for each stimulus type in each presentation condition and the prefixation costs associated with each lexical category. As can be seen in column four, the prefixation costs are almost same for adjectives and verbs.

	Presentation condition		
Lexical category	Root (SD)	Prefix & Root (SD)	Prefixation costs
Adjectives	650 (84)	770 (106)	**120**
Verbs	683 (91)	806 (127)	**123**

Table 5.1: Response times (in milliseconds) and standard deviations (SD) for the Lexical Category x Presentation Condition interaction; prefixation costs for adjectives and verbs (by-items).

Therefore, I concluded that there is no evidence of a semantic bias toward the *"not"* meaning of the *un-* prefix and therefore, the bias toward the right-branching meanings in structurally ambiguous words (e.g., *"not able to be locked"* for *unlockable*) remains to be explained. In Experiment 5, I investigated a possible explanation regarding computational ease as a potential biasing factor.

Chapter 6

Experiment 5: Left-branching vs. Right-branching Processing

As was suggested in the previous chapters, the right-branching and left-branching morphological structures in structurally ambiguous words are assumed to be equally valid. This assumption predicts that structurally ambiguous words are perceived as balanced ambiguous words when presented in isolation. In Experiment 1, evidence to the contrary was provided: structural ambiguity passed mostly unnoticed in the ambiguity detection task. However, Experiments 2 and 3 found evidence that structurally ambiguous words *can* have two meanings, but they are strongly biased toward their right-branching ones (e.g., *"not able to be locked"* for *unlockable*). Experiment 4 investigated a plausible explanation for this bias, by exploring the on-line processing of *un*-prefixed bimorphemic words (adjectives and verbs). The assumption was that the difference between the high derivation productivity of the *un-* prefix with adjectives and its comparatively low derivation productivity with verbs would translate into a processing advantage for the *un-* prefixed adjectives, and by extension, for the right-branching meanings in structurally ambiguous words. This effect was not found.

Experiment 5 investigated another plausible explanation for the semantic bias toward the right-branching meanings in structurally ambiguous words. Namely, it was assumed that, due to automatic prefix-stripping (Taft & Forster, 1975), the right-branching parse (which results in the dominant meanings of structurally ambiguous words) is the "default" decomposition procedure in the on-line processing of trimorphemic words, regardless of their morphological structure. If and only if the "default" parse (i.e., right-branching parse) results in an unacceptable interpretation, then the left-branching parse is performed as a "back-up" decomposition procedure. Two major predictions follow from this assumption: (1) lexical access in right-branching words is faster than in left-branching words; and (2) when presented in isolation, structurally ambiguous words are processed like (non-ambiguous) right-branching words, the right-branching meanings are accessed automatically and, therefore, they are perceived as *unique* (rather than dominant). These predictions were tested in a visual lexical decision experiment.

The goal of Experiment 5 was to investigate the parsing patterns involved in the on-line processing of prefixed and suffixed trimorphemic English words. Three types of target stimuli were used: left-branching words (e.g., *disconnectable*), right-branching words (e.g., *unreachable*), and structurally ambiguous words (e.g., *unlockable*). The main experimental manipulation concerned the presentation condition of the trimorphemic stimuli. The assumption behind this manipulation was that, in the context of a visual lexical decision task, making pairs of morphemes particularly salient (e.g., use of capital letters: *unLOCKABLE* vs. *UNLOCKable*) would interfere with on-line processing in predictable and revealing ways.

In this experiment, the stimuli were presented under three conditions:

(a) *plain condition*, where all constituent morphemes of the stimuli were presented in lowercase letters (e.g., *unlockable*);

(b) *prefix+BASE condition*, where the prefix was presented in lowercase letters and its base (i.e., the root and the suffix) in uppercase letters (e.g., *unLOCKABLE*); and

(c) *BASE+suffix condition*, where the suffix was presented in lowercase letters and its base (i.e., the prefix and the root) in uppercase letters (e.g., *UNLOCKable*).

The latter two conditions will also be referred to as *mixed* conditions.

The empirical evidence reported in the literature so far could account for three possible outcomes of this experiment. First, if it is found that trimorphemic words are faster to recognize when presented in a condition that matches their hierarchical structure (e.g., *unREACHABLE*) rather than contradicts it (e.g., *UNREACHable*), then I will conclude that the internal morphological structure does play a role in lexical processing. This finding would lend support to the hierarchical approach, which posits that complex words *are* decomposed in the mind and their meanings are computed according to their hierarchical structures. Thus, the two main decomposition patterns - prefix-stripping and suffix-stripping - are believed to correspond to the right- and left-branching structures, respectively.

Second, if it is found that the left-branching words are equally fast in both mixed conditions (i.e., there is no significant difference in response times between *DISCONNECTable* and *disCONNECTABLE*), then I will conclude that, rather than being a function of hierarchical structure, lexical processing is a function of whether the substrings of trimorphemic words have their own representations in the mental lexicon, regardless of their constituent/non-constituent status in complex words (e.g., in *disconnectable*, "disconnect" is a legal constituent, while "connectable" is not). This finding would lend support to Libben's (2003) network approach.

Third, if it is found that, regardless of internal hierarchical structure, the prefix+BASE condition is faster than the BASE+suffix condition (e.g., *unREACHABLE*, *disCONNECTABLE*, and *unLOCKABLE* are faster to process than *UNREACHable*, *DISCONNECTable*, and *UNLOCKable*, respectively), then I will conclude that the data support neither the hierarchical approach nor the network approach. In fact, this last possibility would lend support to the automatic prefix-stripping view that was originally proposed by Taft & Forster (1975). According to this view, in on-line processing, the hierarchical structure of trimorphemic words is overrun by the left-to-right parsing directionality. This implies that prefix-stripping takes precedence over suffix-stripping by reasons of left-to-right morpheme ordering. This assumption would predict that the prefix+BASE condition (e.g., *unREACHABLE*) in this experiment should be faster than the BASE+suffix condition (e.g., *UNREACHable*) in all the three trimorphemic word types under investigation.

The main prediction tested in this experiment was that, under normal presentation conditions (i.e., the plain condition), right-branching words would be faster than left-branching words. This prediction follows from a two-fold rationale: If processing of trimorphemic words is a function of the hierarchical structure of the words, and if indeed, as suggested by Taft & Forster (1975), prefix-stripping is automatic in complex words, then processing of left-branching words (that require suffix-stripping) would take longer than processing of right-branching words. The delay would be caused by the word processor having to "recover" from the automatic (but misleading) prefix-stripping (e.g., **dis-connectable*; compare with *dis-functional*) before performing the suffix-stripping (e.g., *disconnect-able*), which appropriately constructs the meaning of left-branching words (e.g., *"able to be disconnected"* for *disconnectable*).

The main prediction ties in with the processing of structurally ambiguous words in the following manner: if it is found that right-branching words are indeed faster than left-branching words, then the automatic prefix-stripping can be claimed responsible for the bias toward the right-branching meanings in structurally ambiguous words. In other words, as suggested above, the automatic prefix-stripping in left-branching words results in a morphologically inappropriate parse (e.g., **dis-connectable*; compare with *dis-functional*) and therefore, in order to arrive at the correct parse (e.g., *disconnect-able*), suffix-stripping is necessary. However, in structurally ambiguous words, the automatic prefix-stripping results in an appropriate parse (e.g., *un-lockable*) and so, unless contextual evidence invalidates the corresponding (right-branching) meaning (i.e., *"not able to be locked"*), the suffix-stripping becomes unnecessary. Hence, it is very likely that it is not even perceived as an equally appropriate parsing alternative. I propose that this fact may be the source of the native speakers' inability to detect ambiguity in structurally ambiguous words presented out of context.

Along with the prediction that right-branching words are faster than left-branching words, I tested two more specific predictions regarding structurally ambiguous words: (1) structurally ambiguous words are perceived and processed like (non-ambiguous) right-branching words; and (2) for the structurally ambiguous stimuli, the prefix+BASE condition (which corresponds to their dominant meanings; e.g., *unLOCKABLE*) would be less disruptive than the BASE+suffix condition (which corresponds to their subordinate meanings; e.g., *UNLOCKable*). Also, for the right-branching and left-branch-ing words, the prediction was that the mixed condition that matches their internal hierarchical structure would be less disruptive than the one that contradicts it.

To summarize, this experiment tested four predictions: (1) the right-branching trimorphemic stimuli (e.g., *un-reachable*) are faster than the left-branching trimorphemic stimuli (e.g., *disconnect-able*); (2) the structurally ambiguous stimuli are perceived as non-ambiguous right-branching words and so, there should be no significant difference in response times between the structurally ambiguous stimuli (e.g., *unlockable*) and the right-branching stimuli (e.g., *unreachable*); (3) due to their being perceived as non-ambiguous right-branching words, the structurally ambiguous stimuli are faster in the prefix+BASE condition (e.g., *unLOCKABLE*) than in the BASE+suffix condition (e.g., *UNLOCKable*); and (4) the right-branching stimuli are faster in the prefix+BASE condition (e.g., *unREACHABLE*) than in the BASE+suffix condition (e.g., *UNREACHable*), and conversely, the left-branching stimuli would be faster in the BASE+suffix condition (e.g., *DISCONNECTable*) than in the prefix+BASE condition (e.g., *disCONNECTABLE*).

6.1 Method

6.1.1 Participants

Thirty-four undergraduate students from the University of Alberta participated in this experiment. They did not participate in any other experiments reported in this thesis. They were all native speakers of English and were paid $10 for a 45-minute session that also included other unrelated psycholinguistic experiments.

6.1.2 Stimuli

The full stimulus set in this experiment comprised 252 items. Twenty-five percent of them were target stimuli (i.e., 63 complex words; see Appendix E for the complete lists) and 75% were filler words (i.e., 189 items).

All target stimuli were trimorphemic words and shared the following morphological composition: (1) one prefix (*un-*, *de-*, or *dis-*), (2) verbal root, and (3) the suffix *-able*. The target stimuli were divided into three groups:

(a) *structurally ambiguous words* (e.g., *un-lock-able*);

(b) *right-branching words* (e.g., *un-reachable*); and

(c) *left-branching words* (e.g., *disconnect-able*).

The first group of stimuli was composed of 24 structurally ambiguous trimorphemic words that contained the prefix *un-*, a verb root, and the suffix *-able*. According to word syntax theory, the morphological constituency of these words can be represented by two hierarchical structures (e.g., [[*un-*] [*lockable*]] and [[*unlock*][*-able*]]), each of which licenses a distinct meaning (e.g., *"not able to be locked"* and *"able to be unlocked"*). Hence, it is assumed that these words allow for two morphological parses.

The second group of target stimuli consisted of 24 trimorphemic words that shared the same morphological constituency as the ones in the first group, but allow for only one parse, namely the right-branching one (e.g., *un*-reachable).

The third group was composed of 15 trimorphemic words that contained the prefixes *de-* or *dis-*, a verb root, and the suffix *-able*, and also allow for only one parse, namely the left-branching one (e.g., disconnect-*able*).

The dependent variable in this experiment were response times. As it is known that they are highly sensitive to factors such as letter count, lexical category, and morphological complexity, a number of precautions needed to be taken. Thus, in order to minimize variability in the data and maximize the generalizibility of the results, all roots in the target stimuli (structurally ambiguous or non-ambiguous) needed to meet the following criteria:

(a) were verbs (so, words like *unalienable* were not selected);

(b) were monomorphemic (so, words like *unforgettable* were not selected);

(c) did not end in a silent *"-e"* (so, for example, because the silent "-e" in *believe* gets dropped before the suffix *-able*, the word *unbelievable* was not selected); and

(d) if ending in a consonant, they did not double it in front of the suffix *-able* (so, words like *unstoppable* were not selected).

The last criterion was particularly important, given the critical role that the mixed presentation conditions were expected to play in this investigation of morphological processing patterns. For instance, if the word *unstoppable* were presented in the BASE+suffix condition, it would result in either *UNSTOPpable* or *UNSTOPPable*, neither of which would be consistent with the rationale of this experiment.

Also, the roots of structurally ambiguous words needed to meet another criterion: They all expressed a reversible action (or, in morphological terms, they could combine freely with the *un-* prefix to form *un*-verbs; e.g., *lock* – *unlock* vs. *reach* – **unreach*).

The set of filler words in this experiment contained 189 stimuli. Thirty-three percent of those were real word fillers (i.e., 63 items) and 66% were non-sense fillers (i.e., 126 items). The real word fillers included multimorphemic words with real English affixes (e.g., *discourage*, *extinguishable*), monomorphemic words with English pseudo-affixes (e.g., *reprimand* and *discipline* vs. *restart* and *discharge*), and long monomorphemic words (e.g., *kaleidoscope*). The non-sense fillers included letter strings containing real English prefixes (e.g., *preblajure*, *infroom*), letter strings containing real English suffixes (e.g., *devauchable*, *fedinity*), and "monomorphemic" non-words (i.e., letter strings with no obvious English-like morphological constituency) (e.g., *mangdore*, *strungle*). All non-sense words fully complied with the phonotactic rules of English.

Unlike the target stimuli, that were presented under three conditions across participants, the filler words were initially assigned to a specific presentation condition that did not vary. The non-sense stimuli featuring real English prefixes were presented in the prefix condition, and the ones featuring real English suffixes were presented in the suffix condition. However, to prevent the participants from developing a morphological decomposition strategy in this lexical decision experiment, 50% of the fillers presented in either mixed condition did not contain any real English affixes. In these cases, the assignment of the letters to lowercase or uppercase presentation had to satisfy a formal constraint: all same-case letters had to be consecutive within the string (e.g., *MANGdore* or *mangDORE* rather than *MaNgDORe*).

6.1.3 Procedure

This experiment consisted of a visual lexical decision task. Participants were asked to decide as quickly and accurately as possible whether the words presented on the screen were *real* English words (i.e., words they had seen before). Participants were warned that some words might be shown in a combination of uppercase and lowercase letters, but they were also instructed to ignore that and respond to the meaning of the words.

Each participant in the experiment was presented with all 252 stimuli. As both Stimulus Type and Presentation Condition were within-participants factors, to eliminate repetition effects, participants were randomly assigned to one of three groups such that each target word was presented in all three conditions across groups, and each participant saw one-third of the targets in each category under each of the presentation conditions.

The experiment was conducted in a single block of trials. Each trial consisted of a single event: the stimulus word appeared in New Times Roman 40 font and remained on the screen until the participant responded by pressing either the key labeled *"yes"* or the key labeled *"no"*. The *"yes"* responses were provided with the right hand and the *"no"* responses were provided with the left hand. The experiment was designed in PsyScope (Cohen et al., 1993) and was conducted on PowerMac 4,5 computers running MacOS 9.2.

6.2 Results and discussion

The data in this experiment consisted of response times measured in milliseconds. Participants were presented with English real words (target words and fillers) and non-words (fillers). Only the responses to the target words were selected for statistical analyses. From these, the correct responses below 500 ms and above 2000 ms (8%), and all the wrong responses (2%) were excluded. Also, the stimulus *disagreeable* was excluded from the analyses, because, despite its apparent left-branching structure (i.e., *disagree-able*), it does not license a left-branching meaning along the lines discussed in this thesis (i.e., *"able to be disagreed"*; compare with *"able to be disconnected"* for *disconnectable*, for example). The exclusion of this item brought the number of left-branching stimuli used in this experiment to 14.

To test the four predictions listed in the preamble, by-participants (F_1) and by-items (F_2) two-way ANOVAs were performed. The Stimulus Type factor had three levels: (1) Structurally Ambiguous, (2) Left-branching and (3) Right-branching and the Presentation Condition factor also had three levels: (1) Plain condition, (2) prefix+BASE condition, and (3) BASE+suffix condition. In the by-participants analysis, both Stimulus Type and Presentation Condition were treated as within-participants factors, while in the by-items analysis, Stimulus Type was treated as a between-items factor and Presentation Condition as a within-items factor.

The analysis of the response times began with the basic assumption that combinations of lowercase and uppercase letters in a visual lexical decision experiment disrupts the stimulus presentation and, therefore, should elevate response times in the two mixed conditions. Thus, it was expected that, across stimulus types, there should be *"mixing costs"* associated with both the prefix+BASE condition and the BASE+suffix condition. This assumption predicted a significant main effect for Presentation Condition.

Both by-participants and by-items analyses revealed significant main effects for both Presentation Condition ($F_1(2, 66) = 13.07$, $p < .0001$; $F_2(2, 118) = 7.96$, $p = .0006$) and Stimulus Type ($F_1(2, 132) = 15.20$, $p < .0001$;

$F_2(2, 59) = 6.50$, p = .0028). Figure 6.1 presents the bar graph for the Stimulus Type main effect and Figure 6.2 presents the bar graph for the Presentation Condition main effect. As no significant Stimulus Type x Presentation Condition interaction was found ($F_1(4, 132) = 2.29$, p = .06; $F_2(4, 118) = 1.83$, p = .12), planned comparisons were performed for the two main effects.

For the Stimulus Type factor, the planned comparisons confirmed the prediction (1) that right-branching stimuli (e.g., *un-reachable*) are faster than left-branching stimuli (e.g., *disconnect-able*). Both by-participants (t_1) and by-items (t_2) analyses revealed significant results: $t_1(33) = 6.0$, $p < .0001$; $t_2(36) = 3.2$, p = .0013. However, the prediction (2) that the structurally ambiguous stimuli (e.g., *un-lock-able*) are perceived and processed in the same manner as the right-branching stimuli (e.g., *un-reachable*) was contradicted by the data. Both by-participants and by-items planned comparisons revealed highly significant differences between the these two types of items, suggesting that structurally ambiguous stimuli are, in fact, slower than the right-branching stimuli ($t_1(33) = 3.6$, p = .0008; $t_2(46) = 2.9$, p = .0046).

Although Experiment 1 showed strong evidence that structurally ambiguous words were not *consciously* perceived as ambiguous when presented in isolation, the results in Experiments 2 and 3 (where, along with the dominant right-branching meanings, the left-branching meanings of structurally ambiguous words were accepted as valid above the chance rate) did, in fact, signal the intrinsic ability of structurally ambiguous words to license two meanings, unlike their right-branching counterparts. Along the same lines, it seems relevant to mention that de Almeida & Libben (2004) found that both meanings of structurally ambiguous words were available when sentential context was provided. Against this background evidence, the significant difference found in this experiment between the right-branching words and the structurally ambiguous ones seems unsurprising. The non-significant difference between the structurally ambiguous stimuli and the left-branching stimuli also seems unsurprising now, as it indicates that the left-branching structure that these stimuli share slows them down equally.

For the Presentation Condition factor, the planned comparisons revealed

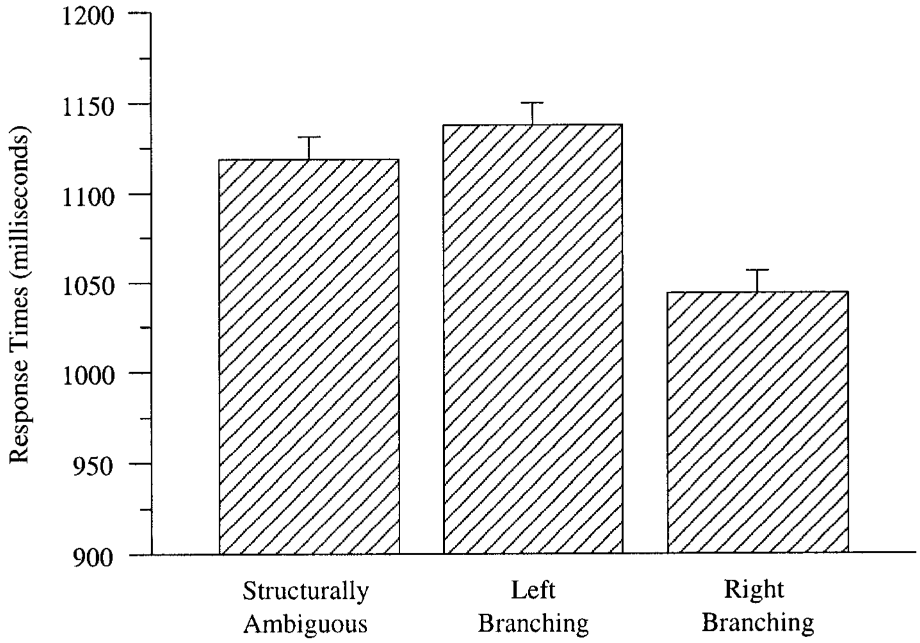

Figure 6.1: Response times for the main effect of Stimulus Type (by-participants).

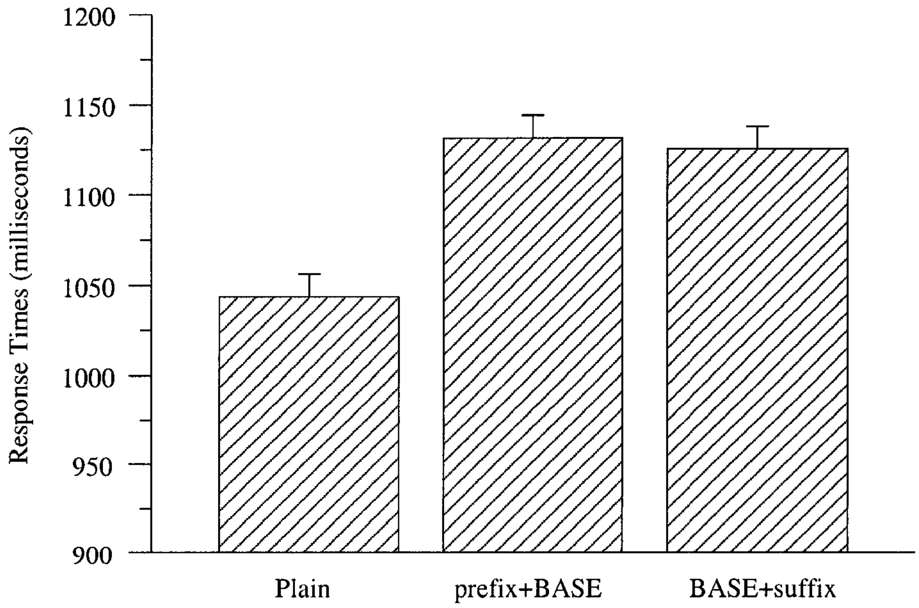

Figure 6.2: Response times for the main effect of Presentation Condition (by-participants).

significant results for the predicted difference between the plain and mixed conditions, suggesting that indeed the combination of lowercase and uppercase letters disrupted stimulus presentation. Both by-participants and by-items analyses showed significant results: the prefix+BASE condition was slower than the plain condition ($t_1(33) = 3.9$, p = .0002; $t_2(61) = 3.3$, p = .0007) and so was the BASE+suffix condition ($t_1(33) = 4.8$, p < .0001; $t_2(61) = 3.9$, p = .0001). The difference between the mixed conditions themselves was not found significant (p > .75).

Predictions (3) and (4) regarded the difference between the prefix+BASE condition and the BASE+suffix condition for each stimulus type, and were also tested in by-participants and by-items planned comparisons. To that end, the costs associated with each mixed condition were calculated for each stimulus type. This was done by subtracting the plain response times from the response times for the prefix+BASE condition and the BASE+suffix condition, respectively. Of the six planned comparisons performed (one for each stimulus type in both by-participants and by-items analyses), only the one for the structurally ambiguous stimuli reached significance in the by-participants analysis: $t_1(33) = 2.09$, p = .04. This result clearly contradicts prediction (3), which stated that, given the semantic bias toward the right-branching meanings in structurally ambiguous words, the cost associated with the prefix+BASE condition (which corresponds to the right-branching meanings, the dominant ones; e.g., *unLOCKABLE*) would be lower than the cost associated with the BASE+suffix condition (which corresponds to the left-branching meanings, the subdominant ones; e.g., *UNLOCKable*). In was shown that, in fact, for the structurally ambiguous stimuli, the BASE+suffix condition is less disruptive than the prefix+BASE condition.

Although they did not reach statistical significance levels, the results of the other planned comparisons described interesting unpredicted patterns. Table 6.1 presents the response times by-items (in milliseconds) for each stimulus type in each presentation condition, along with the costs (in milliseconds) associated with each mixed condition. As can be seen, despite their opposing hierarchical structures, the left- and right-branching stimuli pattern the same way: The prefix+BASE condition is less disturbing than the BASE+suffix condition for both stimulus types.

Comparable results from a similar lexical decision experiment were reported by Libben (2003). In Libben's paradigm, the same three types of trimorphemic stimuli (i.e., left-branching, right-branching, and structurally ambiguous) were presented under three conditions that were very similar to the ones employed in this experiment: (1) the *no-break condition* (e.g., *unlockable*), (2) the *first-break condition* (e.g., *un - - lockable*), and (3) the *second-break condition* (e.g., *unlock - - able*). As can be seen in Table 6.1, Libben (2003)[1] found significant differences between the first- and second-break conditions (in by-participants analyses) for both right-branching and left-branching stimuli. Specifically, he found that the first-break condition (corresponding to the prefix+BASE condition in my experiment) was less disruptive than the second-break condition (corresponding to the BASE+suffix condition in my experiment) for *both* right-branching and left-branching stimuli. No significant difference was found between the first- and second-break conditions for the structurally ambiguous stimuli, though.

Overall, it is clear that the result patterns in the two experiments are the same. The numbers in the last column of Table 6.1 are most revealing in this respect. As can be seen, the differences between the costs associated with the presentation conditions corresponding to the right-branching structures (i.e., the prefix+BASE condition in my experiment and the first-break condition in Libben (2003)), denoted by "Cost1", and the ones corresponding to the left-branching structures (i.e., the BASE+suffix condition in my experiment and the second-break condition in Libben (2003)), denoted by "Cost2" are *negative* for both the left-branching and right-branching stimuli in both experiments (-50 and -45; -43 and -59). Therefore, it can be suggested that morphological parsing proceeds from left to right, prefix-stripping is automatic and is blind to the internal morphological structure of complex items. In other words, it seems plausible that the hierarchical structure of non-ambiguous trimorphemic

[1]G. Libben (personal communication, April 15, 2004) acknowledged a miscalculation reported in Libben (2003) and confirmed the values presented in Table 6.1.

Popescu (MSc Thesis, 2004)				
	Presentation Condition			
Stimulus Type	Plain	prefix+BASE (Cost1)	BASE+suffix (Cost2)	Cost1 minus Cost2
Left-branching	1067	1146 (79)	1189 (122)	**-43**
Right-branching	996	1035 (39)	1094 (98)	**-59**
Structurally Ambiguous	1069	1164 (95)	1101 (32)	**63** *P
Libben (2003)				
	Presentation Condition			
Stimulus Type	No-break	First-break (Cost1)	Second-break (Cost2)	Cost1 minus Cost2
Left-branching	927	960 (33)	1010 (83)	**-50** *P
Right-branching	985	1014 (29)	1059 (74)	**-45** *P
Structurally Ambiguous	951	1014 (63)	1000 (49)	**14**

Table 6.1: Response times (in milliseconds) for the Stimulus Type x Presentation Condition interaction in Popescu (MSc Thesis, 2004) and Libben (2003) (by-items). Significance at the .05 level in the by-participants planned comparisons between Cost1 and Cost2 is denoted by "*P".

words is overrun by the left-to-right parsing directionality, and so, in words containing both prefixes and suffixes, prefix-stripping takes precedence over suffix-stripping by reasons of left-to-right morpheme order.

The structurally ambiguous stimuli showed a distinct pattern form the non-ambiguous (right-branching and left-branching) ones in both experiments. The differences between the costs associated with the presentation conditions corresponding to the right-branching structures and those corresponding to the left-branching structures were *positive* for the structurally ambiguous stimuli (14 and 63). That is, *UNLOCKable* was found less disruptive than *unLOCKABLE*. This pattern was not predictable by any of the approaches discussed in the preamble of this chapter. While Libben (2003) did not find a significant difference between the costs associated with the first- and second-break conditions for the structurally ambiguous stimuli, my by-participants analysis revealed a significant cost difference between the prefix+BASE condition and the BASE+suffix condition for these stimuli ($t_1(33) = 2.09$, $p = .04$). Given the strong evidence found in Experiments 1, 2, and 3 that structurally ambiguous words are biased towards their right-branching meanings, this result seems really surprizing.

However, a similar result was reported by de Almeida & Libben (2004). In an off-line morphological parsing task, participants were asked to "divide" structurally ambiguous words into "two main parts", by drawing a vertical line between two constituents (e.g., either *un/lockable* or *unlock/able*). Participants chose suffix-stripping (e.g., *unlock/able*) 63% of the time. The authors figured that this preference was not a suffix-stripping effect proper, but rather a "substring" frequency side effect. They suggested that the prefix+root substrings in the structurally ambiguous words (e.g., *unlock* in *unlockable*) may have frequencies that could strongly bias *against* the presence of a word boundary within them. As the bimorphemic substrings in the structurally ambiguous words used in their experiment had very low frequencies in Celex (Baayen et al., 1995), or were not listed at all, the authors resorted to the internet. Using words frequencies from English Google searches, they found that the more frequent a prefix+root substring was (e.g., *unlock*), the stronger the suffix-stripping tendency became (e.g., *unlock/able*).

For the purpose of explaining the "advantage" of the BASE+suffix condition (e.g., *UNLOCKable*) over the prefix+BASE condition (e.g., *unLOCKABLE*) for the structurally ambiguous stimuli used in my experiment, I employed the same procedure. It was expected that the prefix+root substrings in the structurally ambiguous stimuli were significantly more frequent than the corresponding root+suffix substrings. Using the Google search engine, I collected frequencies (i.e., number of hits per search word) for all the prefix+root and root+suffix substrings in the structurally ambiguous stimuli used in my experiment (e.g., *unlock* and *lockable* for *unlockable*). The values for the prefix+root substring words range between 2,600 (*unglue*) and 7,120,000 (*unwrap*), with a mean of 580,000, and the values for the root+suffix substring words range between 23 (*leashable*) and 186,000 (*loadable*), with a mean of 34,000. The difference between the frequencies of these two substring types was significant in the direction predicted ($t(23) = 1.8$, $p = .03$): The prefix+root substring words (e.g., *unlock*) were more frequent than the root+suffix substring words (e.g., *lockable*). This result explains the advantage of the BASE+suffix condition (e.g., UNLOCKable) over the prefix+BASE condition (e.g., *unLOCKABLE*) in the lexical decision experiment reported above.

To summarize, Experiment 5 set out to test four prediction: (1) the right-branching trimorphemic stimuli (e.g., *un-reachable*) are faster than left-branching trimorphemic stimuli (e.g., *disconnect-able*); (2) the structurally ambiguous stimuli (e.g., *un-lock-able*) are perceived as non-ambiguous right-branching and so, there would be no significant difference in response times between the structurally ambiguous stimuli and the right-branching stimuli; (3) following from (2) above, the structurally ambiguous stimuli are faster in the prefix+BASE condition (e.g., *unLOCKABLE*) than in the BASE+suffix condition (e.g., *UNLOCKable*); and (4) the right-branching stimuli are faster in the prefix+BASE condition (e.g., *unREACHABLE*) than in the BASE+suffix condition (e.g., *UNREACHable*), and conversely, the left-branching stimuli would be faster in the BASE+suffix condition (e.g., *DISCONNECTable*) than in the prefix+BASE condition (e.g., *disCONNECTABLE*).

The data analyses confirmed only the first prediction. It was found that the right-branching words are faster to process than left-branching words. The other three predictions were contradicted (partially or entirely).

Prediction (2) was contradicted, as it was shown that, despite native speakers' inability to detect ambiguity in structurally ambiguous words presented in isolation (Experiment 1) and the strong bias toward the right-branching meanings (Experiments 2 and 3) (results which have predicted that structurally ambiguous words are perceived and processed like the right-branching stimuli), structurally ambiguous words were, in fact, processed differently from the right-branching stimuli, being responded to slower. The non-significant difference between the structurally ambiguous words and the left-branching words was also revealing: native speakers may not be *consciously* aware of the structural ambiguity, but they seem to just "know" that whatever kind of on-line processing left-branching words require, structurally ambiguous words do too, as they share the ability to license left-branching meanings.

Prediction (3) was also contradicted. It turned out that the specific type of stimulus presentation conditions employed in this experiment did manipulate the role that certain substrings played in the decomposition process of trimorphemic words, *but* it inadvertently allowed them to bring in their own lexical "baggage" (e.g., frequency effects), which eventually interfered with the result patterns. Specifically, it was found that, because the prefix+root substrings (e.g., *unlock*) in the structurally ambiguous stimuli have higher frequencies than the root+suffix substrings (e.g., *lockable*), the BASE+suffix condition (illustrating the suffix-stripping; e.g., *UNLOCKable*) was less disruptive than the prefix+BASE condition (illustrating the prefix-stripping; e.g., *unLOCKABLE*). In other words, it was shown that the automatic prefix-stripping can be overrun by suffix-stripping in the on-line processing of structurally ambiguous words presented in a visual lexical decision task, *if* high-frequency root+suffix substrings are made particularly salient.

Prediction (4) was contradicted partly, as, unlike the right-branching stimuli, the left-branching stimuli showed an unexpected pattern. The hierarchical approach predicted that the presentation condition that matches the internal structure of the stimuli (e.g., *unREACHABLE*) would be faster than the one that contradicts it (e.g., *UNREACHable*). It was found that, regardless of the hierarchical structure, the prefix+BASE condition was faster than the BASE+suffix condition for both stimulus types. The same was found in Libben (2003).

6.3 Stimulus frequency control: concerns and remedies

Given the strong impact that frequency effects had on the results involving the structurally ambiguous words presented in the mixed conditions in Experiment 5, serious concerns can be raised regarding the reliability and generalizability of the rest of the results in this experiment. These concerns are legitimate, as it is well-known that psycholinguistic phenomena are very sensitive to real-word effects such as frequency, lexical category, or abstractness. To deal with like effects, two experimental remedies have been suggested: (1) controlling them, by balancing the real-word stimuli along the corresponding dimensions; and (2) eliminating them, by employing *nonsense* stimuli that carry no real-word "baggage". Below, I will discuss the reasons why no frequency control measures were taken in Experiment 5, and also how nonsense stimuli can be used to verify the results reported in section 6.2.

Trimorphemic words of the type *un-/de-/dis*-verbroot-*able* are extremely difficult to balance for frequency, because two or three types of frequency are involved. On the one hand, the right-branching words need balancing for two types of frequency: (1) whole-word frequency (e.g., *unreachable*) and (2) root+suffix substring frequency (e.g., *reachable*). On the other hand, the left-branching and the structurally ambiguous words need balancing for three types of frequecy: (1) whole-word frequency (e.g., *unlockable, disconnectable*), (2) prefix+root substring frequency (e.g., *unlock, disconnect*), and (3) root+suffix substring frequency (e.g., *lockable, connectable*). Given the restricted sampling pool for all these three categories of trimorphemic real words, proper balancing would result in very low numbers of stimuli, which, in turn, would render inferential statistics approaches inappropriate. Under such circumstances, experimentation with nonsense words is advisable (see Libben, 1993, 2003). The nonsense stimuli have the advantage of extreme controllability of structure, length, and presentation without any frequency interference.

I suggest that the source of the bias towards the right-branching meanings in structurally ambiguous words (e.g., *unlockable*) can be investigated by using structurally ambiguous nonsense words in an experiment similar in design and procedure with Experiment 5. Appropriate nonsense stimuli would contain: (1) the *un-* prefix, (2) a nonsense root (that fully complies with English phonotactics), and (3) the suffix *-able*. As the root is a nonsense word, no semantic restrictions apply, and therefore, due to the *un-* prefix's intrinsic ambiguity and ability to combine with both adjectives and verbs, any *un*-nonsenseroot-*able* word can be argued to feature structural ambiguity. For example, a nonsense word such as *unponkable* can be represented by either of two structures: (1) [[un-][*ponkable*]] (i.e., the right-branching structure) and (2) [[*unponk*][-able]] (i.e., the left-branching structure). Along the lines suggested in Experiment 5, the prediction would be that structurally ambiguous nonsense words would be rejected faster in the presentation condition that corresponds to their right-branching hierarchical structure than in the one that corresponds to their left-branching hierarchical structure.

Such an experiment was conducted and reported by Libben (2003). In fact, the nonsense trimorphemic word that I used as an example in the previous paragraph is one of his stimuli. However, what is most interesting about Libben's investigation is that he identifies items such as *unponkable* as right-branching (Libben, 2003, p. 234) rather than structurally ambiguous, which, as discussed above, they truly are. As Libben's subsequent interpretation of the results seems to exclude the possibility of an oversight, this misidentification of ambiguous morphological structures as (non-ambiguous) right-branching structures can be taken to suggest that indeed structural ambiguity escapes awareness, because, due to the automaticity of prefix-stripping in on-line processing, the right-branching structure is perceived as unique. That is, (as shown in Experiment 1) despite their potential for ambiguity, structurally ambiguous words are *not* perceived as ambiguous, and more importantly, (as shown in Experiments 2 and 3) structurally ambiguous words are perceived as (non-ambiguous) right-branching (even by those native speakers whose *conscious* awareness of the structural ambiguity phenomenon is beyond doubt).

As discussed in the introduction, as well as earlier in this chapter, Libben (2003) used a visual lexical decision task with three stimulus presentation conditions: (1) no-break condition (e.g., *unponkable*), (2) first-break condition (e.g., *un - - ponkable*) (corresponding to the right-branching structure), and (3) second-break condition (e.g., *unponk - - able*) (corresponding to the left-branching structure). The results that Libben (2003) reported concerning the structurally ambiguous nonsense stimuli (e.g., *unponkable*) (to which he referred as right-branching) are particularly relevant in the context of the present thesis. He found that, in the absence of any frequency effect interference, the structurally ambiguous nonsense stimuli were rejected faster in the first-break condition than in the the second-break condition, which means that the first-break condition (corresponding to the right-branching structure) was less disruptive than the second-break condition (corresponding to the left-branching structure). The response time difference was 42 ms and was significant at the .05 level in the by-participants planned comparisons. This finding implies that right-branching structures are faster to compute than left-branching structures. It is important to recall that the same was found in Experiment 5, where, in the plain presentation condition, the real-word right-branching stimuli (e.g., *unreachable*) were recognized faster than the real-word left-branching stimuli (e.g., *disconnectable*). These results suggest two important facts. First, the hierarchical structure does play a role in the on-line lexical processing, which offers support for the hierarchical view. Second, the semantic bias toward the right-branching meanings in structurally ambiguous words can be explained by an interaction between the effects of automatic prefix-stripping and of hierarchical structure on the on-line lexical processing, which offers support to both the hierarchical view and the prefix-stripping view.

Chapter 7

General discussion and Conclusions

7.1 Summary of the experimental procedures and results

The goal of this thesis was a psycholinguistic investigation of meaning access and morphological processing in structurally ambiguous trimorphemic English words (e.g., *unlockable*). I conducted five experiments, each of which addressed one of the following questions: (1) Are structurally ambiguous words perceived as ambiguous when presented in isolation?; (2) Do structurally ambiguous words license two meanings?; (3) Are both meanings equally frequent/plausible?; (4) If not, can the unbalance be due to a semantic bias within the *un-* prefix?, and (5) Can it be due to a computational bias?

Experiment 1 consisted of an ambiguity detection task where participants were asked to decide whether the words with which they were presented have one meaning (e.g., *integer*, *unreachable*) or two meanings (e.g., *bat*, *unlockable*). The main purpose of the experiment was to compare the detectability rates of two ambiguity types: (1) lexical ambiguity (e.g., *bat*) and (2) structural ambiguity (e.g., *unlockable*). My prediction was that lexical ambiguity would be easily detected, while structural ambiguity would pass mostly unnoticed. Indeed, it was found that the detectability rates for structural ambiguity were significantly lower than those for lexical ambiguity, suggesting that, unlike lexically ambiguous words, structurally ambiguous words are *not* consciously perceived as ambiguous, being associated with only one meaning.

Experiment 2 investigated a possible explanation for the fact that structurally ambiguous words are associated with only one meaning when presented in isolation. It seemed plausible that, although derivation morphology makes two meanings available for structurally ambiguous words, only one meaning is semantically acceptable, and that is *the* one with which these words are consistently associated. To explore this possibility, I employed a definition verification task. The goal was to test the semantic acceptability of the two possible meanings of structurally ambiguous words. Participants were presented with pairs of structurally ambiguous words and paraphrasal definitions (e.g., *"unlockable"* means *"able to be unlocked"*) and were asked to decide whether the definition matched the meaning of the word. I found that both the right-branching meanings and the left-branching meanings of structurally ambiguous words were judged semantically acceptable above chance level, but the difference between the acceptability rates for the two meaning types was statistically significant. Specifically, the acceptability rates for the right-branching meanings (e.g., *"not able to be locked"* for *unlockable*) were higher than the ones for the left-branching meanings (e.g., *"able to be unlocked"*). This finding suggests that structurally ambiguous words *can* indeed license two meanings, but they are strongly biased toward their right-branching meanings.

Experiment 3 explored two possible explanations for the semantic bias toward the right-branching meanings in structurally ambiguous words. I tested two main predictions: (a) the bias is a frequency effect (i.e., native speakers of English tend to use these words more often with their right-branching meaning than with their left-branching meaning); and (b) the bias is a direct consequence of a plausibility bias toward the right-branching meanings (i.e., the right-branching meanings are more plausible than their left-branching counterparts). The experiment consisted of subjective frequency and plausibility ratings of the two possible meanings of structurally ambiguous words. The meanings were presented as paraphrases (e.g., *"possible to unlock"* for *unlockable*) and were rated on a five-point scale (1 - least frequent/plausible; 5 - most frequent/plausible). The results confirmed the predictions tested, suggesting that indeed the right-branching meanings of structurally ambiguous words are both more plausible and more frequent than the left-branching meanings.

Experiment 4 investigated a possible cause for the directionality of the semantic bias in structurally ambiguous words. Specifically, I addressed the question of why the right-branching meanings are preferred (in terms of both plausibility and frequency) over the left-branching meanings. I hypothesized that the semantic bias at the whole-word level may be triggered by a semantic bias at the *un-* prefix level. Namely, due to its high productivity in combination with adjectives, the *un-* prefix may be biased towards the *"not"* meaning which it contributes to the right-branching meanings of structurally ambiguous words (e.g., "`not` *able to be locked*"). To test this hypothesis, I compared the role that the *un-* prefix plays in the on-line processing of bimorphemic adjectives (e.g., *unhappy*) and verbs (e.g., *unlock*). I predicted that, due to the hypothesized prefix-internal semantic bias toward the *"not"* meaning, the *un-* prefixation costs for adjectival roots would be lower than for verbal roots. No significant effect was found.

Experiment 5 set out to explore the role that hierarchical morphological structures play in the lexical processing of structurally ambiguous words (e.g., *unlockable*). For comparison purposes, two other types of trimorphemic words were investigated: (1) right-branching words (e.g., *unreachable*), and (2) left-branching words (e.g., *disconnectable*). I employed a visual lexical decision paradigm where the stimuli were presented in three conditions: (1) the plain condition (e.g., *unlockable*), (2) the prefix+BASE condition (e.g., *unLOCKABLE*), and (3) the BASE+suffix condition (e.g., *UNLOCKable*). My hypothesis was that the strong bias toward the right-branching meanings in structurally ambiguous words can be explained by a processing advantage that the automatic prefix-stripping (Taft & Forster, 1975) creates for the right-branching structures in general. I found that, in the plain condition, the right-branching stimuli were processed faster than the left-branching stimuli. This finding supports the automatic prefix-stripping view and could explain the semantic bias toward the right-branching meanings in structurally ambiguous words. Also, I reasoned that, if indeed the right-branching structures are easier to process than the left-branching structures, structurally ambiguous words should be recognized faster in the prefix+BASE condition (which corresponds to their right-branching meaning; e.g., *unLOCKABLE*) than in the BASE+suffix condition (which corresponds to their left-branching meanings; e.g., *UNLOCKable*). Due to a strong substring frequency interference (e.g., the Google frequency of *unlock* is about ten times the Google frequency of *lockable*), the opposite of the predicted effect was found: the structurally ambiguous stimuli were faster in the BASE+suffix condition than in the prefix+BASE condition. However, Libben (2003) reported a similar experiment where he used *nonsense* structurally ambiguous stimuli (e.g., *unponkable*) (The nonsense words have the advantage of no frequency effect interference). Libben found that the presentation condition corresponding to the right-branching structure was faster than the condition corresponding to the left-branching structure. This result constitutes further evidence for the prefix-stripping view and confirms the hypothesis that the semantic bias toward the right-branching meanings in structurally ambiguous words is a consequence of the prefix-stripping automaticity.

To summarize, the present thesis reveals two important findings. The first finding is that, despite their potential for ambiguity, structurally ambiguous words (e.g., *unlockable*) are *not* perceived as ambiguous when presented in isolation. Due to prefix-stripping, the right-branching structures are computed automatically and thus the right-branching meanings are obtained (e.g., *"not able to be locked"*). These meanings are perceived as unique, because there is no contextual evidence to the contrary. The second finding is that structurally ambiguous words *can* license two meanings, but they are strongly biased toward their right-branching meanings.

More generally, the thesis offers evidence for on-line decomposition in the trimorphemic English words obtained by derivation. However, despite the proven validity of selectional restrictions in on-line processing of complex words, it is not clear whether decomposition patterns map directly onto derivational patterns. Specifically, trimorphemic words are obtained in two derivational steps (i.e., prefixation and suffixation) (e.g., (1) [*un-*] + [*lock*] =

[*unlock*], (2) [*unlock*] + [*-able*] = [*unlockable*]), but the parsing patterns discussed in this thesis seem to construe decomposition as a single-step process: either prefix- stripping (e.g., [[*un-*][*lockable*]) or suffix-stripping (e.g., [[*unlock*][-*able*]). Indeed, to tap into parsing patterns, stimulus presentation has been experimentally manipulated in ways that may have inadvertently biased our understanding of decomposition in that way. The artificial morpheme boundary that divided trimorphemic words into two morphological entities (Libben, 2003) (e.g., *un - - lockable*) or the capitalization of bimorphemic substrings of trimorphemic words (used in Experiment 5) (e.g., *unLOCKABLE*) could have induced extraneous effects that the respective tasks were able to measure accurately, but that may not pertain to normal on-line processing. The role that the frequency of the prefix+root substrings in structurally ambiguous words (e.g., *unlock* in *unlockable*) played in the pattern of results for the BASE+suffix condition in Experiment 5 is an example of such an experimental confound.

This study also offered a new perspective on the role of morphology in the on-line processing of complex words. It was shown that, although derivational morphology makes two hierarchical structures available for structurally ambiguous words, parsing preferences apply (e.g., prefix-stripping) such that only one structure is computed and only the corresponding meaning is produced when the stimuli are presented in isolation. For the non-ambiguous trimorphemic stimuli, for which morphology makes available one structure, the same parsing preferences apply, but when they are found inconsistent with the hierarchical structure of the words, alternative parses are considered. In Experiment 5, the left-branching trimorphemic stimuli took longer to process than right-branching trimorphemic ones, presumably because the preferred prefix-stripping parsing approach was found inconsistent with their internal structure and the suffix-stripping alternative was ultimately considered. This finding can also be taken as evidence for the psychological reality of hierarchical structure of trimorphemic English words.

To conclude, the present thesis provided evidence that, despite the close interaction between morphology and on-line processing, structural ambiguity does not trigger semantic ambiguity. As a consequence, structurally ambiguous trimorphemic English words are *not* perceived as ambiguous and their hierarchical structure is perceived as right-branching.

7.2 Interdisciplinary relevance of the results: Is Hay's (2003) parsing account of affix-ordering borne out by the present results?

The parsing account of affix ordering (Hay, 2003) is a recent psycholinguistically informed approach to affix-ordering restrictions in English derivational morphology. As I will discuss below, this approch brings together evidence from speech perception, corpus linguistics, morphology, phonology and psycholingustics to provide a unified explanation of the range of affix-ordering behaviors commonly associated with level-ordering.

The Level Ordering Hypothesis is a theoretical approach to English derivational morphology whose purpose is to identify and explain the mechanisms that regulate multiple affixation (specifically affix-stacking; i.e., two or more prefixes or suffixes applying one after the other at the same end of a root; e.g., *helpfulness*). Originally proposed by Siegel (1974) and later on taken up by Allen (1979), Selkirk (1982), Kiparsky (1982), Mohanan (1986) and Giegerich (1999), level-ordering posits the existence of two types of affixes in English: (1) level 1 affixes (e.g., *pre-, ir-, -(i)al, -ity*) and (2) level 2 affixes (e.g., *re-, de-, non-, -ism, -ful, -ness*). The distinctions between these two types of affixes was made in terms of phonological and morphological properties. For example, level 1 affixes trigger and undergo phonological processes (e.g., *productívity* vs. *prodúctiveness*), while level 2 affixes are phonologically inert; level 1 affixes may attach to stems (i.e., bound morphemes; e.g., *inept*), while level 2 affixes only attach to words (e.g., *unfair, motionless*). The affix-ordering maxim goes as follows: During derivation, a level 2 affix should not attach before a level 1 affix. On these grounds, a complex word such as *provinc-ial-ism* is perfectly acceptable, while a word such as **provinc-ism-ial* is not. As pointed out by Fabb (1988) and (Plag, 1996, 1999), the affix-ordering approach has two main drawbacks: (1) the dual level membership of some affixes damage the stratification-by-affix hypothesis itself (e.g., *-able* can be argued to belong to both levels; level 1 *-able*, as in *cómparable*, meaning *"roughly the same"*, and level 2 *-able*, as in *compárable*, meaning *"able to be compared"*)(Aronoff, 1976); and (2) the limited ability to account for a number of possible occurring affixal combinations (e.g., *governmental*, where level 2 *-ment* attaches before the level 1 *-al*), as well as to rule out possible, but non-occurring affixal combinations in English (e.g., *kafkaesquism*)(Plag, 1996).

As shown above, the differences between the two affix levels and the restrictions that regulate their ordering have been discussed within the theoretical delimitations of morphology and phonology. As an attempt at a unified understanding of the way derivation morphology works in English, Hay (2003) proposes a psycholinguistical approach that accounts for affix-ordering in terms of *parsing*. She argues that, in fact, morphological complexity is a function of morphological parsing, which in turn is largely influenced by at least two factors: *phonotactics* and *frequency*. She assumes *degrees of parsability* for individual affixes, such that, depending on lexical frequency and phonotactic probabilities, they may be parsable in some derived words and non-parsable in others. Her main claim is that affix-ordering constraints are directly related to the perception and storage of morphologically complex words. Specifically, Hay (2002, 2003) hypothesises that the likelihood of parsability for specific affixes can predict their membership to level 1 and level 2, and consequently, can account for affix ordering restrictions in English. Thus, in the light of Hay's parsing account of affix-ordering, the affix-ordering maxim now becomes: An affix that is likely to be parsed out should not occur inside the base of an affix that is not likely to be parsed out (Hay, 2003). Hay argues that this perceptually grounded restriction accounts for the range of facts commonly associated with affix-ordering, in addition to predicting differential behavior of *some* individual forms (e.g., *governmental* vs. **containmental*). Indeed, Plag (1988) shows that there is a considerable range of potential combinations where parsing considerations do not make any prediction.

While Hay (2002, 2003) acknowledges that phonotactics and frequency are not the only factors nor the most important ones that influence parsing patterns in the processing of complex words, she argues that they are definitely valuable sources of insight about morphological processing. Below I will briefly discuss Hay's perspective on these two factors.

Hay et al. (2004) and Hay (2003) demonstrated experimentally that English speakers do use phonotactic information to parse words into constituent morphemes. Specifically, complex words with low probability inter-morphemic phonotactic transition (e.g., /pf/ as in *pipeful*) were rated as more complex than complex words with high probability inter-morphemic phonotactic transition (e.g., /lf/ as in *bowlful*). This was shown both for non-sense words and for real words. Phonotactic patterns, therefore, appear to provide evidence as to whether a word is perceived as complex and, therefore, whether it is likely to be decomposed during processing.

Lexical frequency is also known to influence morphological processing of complex words. The negative correlations found between lexical decision times and lexical frequency (Balota & Chumbley, 1984) suggest that more frequent words are accessed faster. However, Hay argues that, depending on the ratio between the derived form frequency and the base frequency (ratio also referred to as *relative frequency*; see Hay & Baayen, 2002), complex words can be processed via the decomposed access route or the whole-word access route. If the derived form is more frequent than the base it contains, (e.g., *government* is more frequent than *govern*), then the whole-word route will have an advantage. If the derived form is less frequent than the base it contains (e.g., *containment* is less frequent than *contain*), then the decomposed route will be advantaged.

As a first step toward the experimental investigation of her proposed parsing account of affix-ordering, Hay (2002) explored non-experimentally the frequency and phonotactic profiles of 30 suffixes whose membership to either level 1 or level 2 has received relative consensus in the literature (e.g., Siegel, 1974; Aronoff, 1976; Selkirk, 1982; Fabb, 1988):

(1) Level 1 suffixes: *-al, -an, -ary, -ate, -ese, -ette, -ian, -ic, -ify, -ity, -or, -ory, -ous, -th*;

(2) Level 2 suffixes: *-age, -en, -er, -dom, - ish, -ful, -hood, -less, -let, -like, -ling, -ly, -most, -ness, -ship, -some.*

It is apparent that level 1 suffixes tend to begin with vowels and level 2 suffixes tend to begin with consonants. The difference was found statistically significant (Fisher exact test, $p < .001$). This finding confirms Hay's prediction about the high parsability of level 2 affixes. Indeed, since in English most low probability or illegal junctures involve clusters of consonants, it is more likely for a complex word with a consonant-initial suffix to contain a phonological violation across the morpheme boundary, than it is for a complex word with a vowel-initial suffix. Therefore, Hay suggests that the consonant-initial suffixes tend to be more parsable than the vowel-initial ones. (However, Plag (1988) argues that, in fact, there is no robust evidence for a generalizable parsing difference between consonant-initial and vowel-initial suffixes).

Hay & Baayen (2002) used the Celex database (Baayen et al., 1995) to compute statistics that reflect the frequency and the likelihood of 80 English affixes to be parsed, based on the frequency characteristics of the words which contain them. Based on relative frequency ratios, they calculated, for any given affix, the number of different words in which the affix is likely to be parsed out. For example, *-ment* is probably parsed in *containment* (because *contain* is much more frequent than *containment*), whereas it is probably not parsed out in *government* (because *government* is more frequent than *govern*). Therefore, the word *containment* would contribute to this figure, but the word *government* would not. They also calculated the total number of tokens containing the affix which are likely to be parsed (i.e., the sum of the words prone to parsing, each weighted by their lexical frequency). For each affix, parsing ratios were also calculated. A parsing ratio indicates the proportion of types (the type parsing ratio) or tokens (token parsing ration) containing an affix which is likely to be parsed. For example, if an affix was represented only by words which are unlikely to be parsed, the type parsing ratio would be 0. If it was represented only by words which are likely to be parsed, the type parsing ratio would be 1. The higher the type parsing ratio, the greater the proportion of types which are prone to parsing. For affixes which are highly parsable, all four of these calculations are expected to be high. For affixes which are not prone to parsing, these calculations are expected to be low.

	Affix level	
Type of statistic	Level 1	Level 2
Average number of types parsed	34.64	143.81
Average type-parsing ratio	0.3	0.61
Average number of tokens parsed	1,139.21	3,711.44
Average token-parsing ratio	0.12	0.34

Table 7.1: Averaged frequency-based statistics calculated by Hay & Baayen (2002) for affixes typically classified as "level 1" and "level 2" (from Hay, 2002).

Table 7.1 presents the four types of statistics for affixes typically classified as level 1 and level 2. As can be seen, by all four of these frequency-based measures, level 2 affixes are predicted to be markedly more parsable than level 1 affixes (for more frequency-based statistics, see Hay & Baayen, 2002). Therefore, it can be concluded that both the phonotactic and the frequency profiles of level 1 and level 2 affixes predict that level 2 affixes tend to be parsed out, whereas level 1 affixes do not. This result suggests that the affix-ordering generalization can be largely reduced to a perceptually grounded maxim: An affix which can be easily parsed out should not occur inside the base of an affix which can not. Based on this result, Hay (2002, 2003) made five specific predictions:

(1) The same suffix will be differently separable in individual words depending on the phonotactics (e.g., *pipeful* vs. *bowlful*);

(2) The same suffix will be differently separable in individual words depending on the frequency (e.g., *government* vs. *containment*);

(3) Suffixes beginning with consonants will tend to be more separable than suffixes beginning with vowels (e.g., *-ness* in *tenderness* tends to be more parsable than *-ess* in *hostess*);

(4) Suffixes represented by many words which are less frequent than their bases will tend to be more parsable than suffixes represented by few words which are less frequent than their bases (e.g., *-ish* tends to be more separable than *-ic*); and

(5) More parsable affixes will occur outside the base of less parsable affixes.

For the purpose of connecting Hay's (2003) parsing account of affix-ordering to the results obtained in the present thesis, I will briefly discuss only the first two predictions. These predictions were tested in independent experiments which tapped into participants' intuitions about the likelihood of *-al* affixation to a range of *-ment* final forms (e.g., *requiremental*). It was expected that participants' preferences about "possible" trimorphemic English words would reflect the parsing patterns of the base (e.g., *requirement*). One experiment investigated the role of phonotactics across the morpheme boundary in morphological processing. The prediction was that low probability phonotactics provide a cue to decomposition. The sufix *-al* (which is a level 1 affix) was expected to attach preferentially to *-ment* forms which display legal phonology (e.g., *requiremental*) over *-ment* forms which contain a low probability phonotactic transition which may trigger decomposition (e.g., *recruitmental*). Participants were presented with pairs of stimuli visually and were required to "decide which stimulus sounds more like it could be a word of English". As predicted, subjects displayed a strong preference for *-al* affixation to forms which contained legal phonotactics across the morpheme boundary (e.g., *requiremental*), suggesting that, indeed, the phonotactics across the morpheme boundary in complex words plays a key-role in morphological processing. This result was extremely robust (wilcoxon_{items} $p < .005$ and $\text{wilcoxon}_{participants}$ $p < .0001$; the wilcoxon is a non-parametric paired test which takes into account both the direction and the magnitude of the observed difference).

Another experiment investigated the role of frequency in the morphological processing of complex words. The prediction was that the suffix *-al* would be most likely to attach to bimorphemic bases where the root (e.g., *detach*) is less frequent than the bimorphemic base-word (e.g., *detachment*), than to bimorphemic bases where the root (e.g., *involve*) is more frequent than the bimorphemic base-word (e.g., *involvement*). Participants were presented with pairs of stimuli visually and were required to "decide which stimulus sounds more like it could be a word of English". Overall, 56% of all responses favored affixation to derived forms which were more frequent than their respective bases (e.g., *detachmental*), whereas 44% favored their matched counterparts. Indeed, a wilcoxon test revealed that subjects had a significant preference for *-al* affixation to *-ment* forms which were more frequent than their bases ($\text{wilcoxon}_{participants}$ $p < .05$). The by-items results fell slightly short of reaching significance on a wilcoxon test ($p < .08$). Two items went strongly in the opposite direction and their exclusion from the by-item analyses brought the significance level to .05. This result suggests that, as predicted by the parsing account of affix-ordering, the ratio between the base frequency and the whole derived word frequency plays an important role in morphological processing, influencing crucially the decomposability of complex words.

Taken together, the results obtained in these two experiments constitute evidence for the validity of Hay's (2003) parsing account of affix-ordering. However, as these experiments investigated only suffixed words (e.g., *government*), it is an empirical question whether Hay's findings are generalizable to other types of English complex words. Below, I will test this parsing account by using structurally ambiguous words (i.e., prefixed and suffixed trimorphemic words such as *unlockable*). If Hay's findings are to be generalized to prefixed and suffixed trimorphemic words, the parsing account should explain the results in the present thesis. In other words, based on phonotactic and frequency reasons alone, the processing bias toward the right-branching structure in structurally ambiguous words should be predicted by Hay's parsing account.

The structurally ambiguous words are complex words containing a root flanked by two affixes: the *un-* prefix and the suffix *able* (e.g., *unlockable*). The *un-* prefix is a level 2 affix (Spencer, 1991), while the suffix *-able* has dual membership (Aronoff (1976) suggests that there are two *-able* suffixes). However, as the *same* suffix *-able* (i.e., the phonologically inert level 2 *-able*) occurs in all structurally ambiguous words (and their right-branching and left-branching counterparts studied in this thesis; e.g., *unreachable, disconnectable*), I will refer to it as a level 2 suffix. As discussed in the previous chapters, the results of the five experiments conducted in this thesis show that, despite the ambiguity for which English derivational morphology provides in structurally ambiguous words, these words are *not* perceived as ambiguous. Moreover, although they *can* license both a right-branching meaning and a left-branching meaning, structurally ambiguous words are consistently associated with their right-branching meanings when presented in isolation (e.g., *"not able to be locked"* for *unlockable*). How does Hay's (2003) parsing account of affix-ordering explain this bias?

First, the *un-* prefix is a level 2 affix, which makes it highly prone to parsing. The suffix *-able* is also a level 2 affix, but the left-to-right nature of language processing will make it much less parsing-salient. Second, phonotactically speaking, most structurally ambiguous words contain a consonant cluster across the prefix-root morpheme boundary. Although the cluster itself may be legal or even frequent in English (/nl/ as in *unlockable*), the phonotactic pattern that obtains, namely /un+consonant/, is extremely low frequent morpheme-initially in English (e.g., *uncle, undulate, ungula*). The extreme low probability of this phonotactic pattern causes the parser to automatically posit a morpheme boundary to break the consonant cluster. The obtained parsing pattern corresponds to the right-branching structure (e.g., [[un-][*lockable*]]) which licenses the meaning which is commonly perceived as unique for structurally ambiguous words. Third, the frequency ratio between the prefix+root substring (e.g., *unlock*) and the root (e.g., *lock*) also predicts this parsing pattern. As discussed in Chapter 6, the *un-* prefixed verbs are less frequent than their roots, which means that they are highly likely to be parsed during processing. As Hay (2003) demonstrated experimentally, bimorphemic words contribute their parsing patterns to the trimorphemic words that contain them, and therefore it is not surprising that the preferred parsing for structurally ambiguous words is the one that correspond to their prefix+root substrings.

In conclusion, it seems that Hay's parsing account could explain the bias toward the right-branching meanings of structurally ambiguous words. However, there is no experimental evidence that the degree of parsability of level 2 prefixes in trimorphemic words (e.g., *un-* in *unlockable*) is indeed different from the degree of parsability of level 1 prefixes in words with similar morphological structure (e.g., *im-* in *impenetrable*), as Hay's account would predict. This prediction is still out for future psycholinguistic research to investigate. Although the experiments reported in this thesis were not designed to test Hay's parsing account of affix-ordering, the fact that they produce results that align with some of its predictions add validity to the present study and reinforce the idea that our understanding of language as a system relies on linguistic research that is done in an integrated manner.

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Appendix A

Stimuli used in Experiment 1

	Structurally non-ambiguous stimuli	Structurally ambiguous stimuli	Lexically non-ambiguous stimuli	Lexically ambiguous stimuli
1	unattainable	unbendable	aspirin	band
2	unbearable	unbucklable	desk	bank
3	unbeatable	unbuttonable	dictionary	bark
4	unbelievable	uncoilable	fungus	bat
5	undesirable	uncorkable	geography	bug
6	unfathomable	uncoverable	integer	cricket
7	undecipherable	undoable	karat	draft
8	undefeatable	undressable	kitchen	fan
9	undetachable	unfastenable	leather	light
10	undoubtable	unfoldable	linoleum	organ
11	unenjoyable	unglueable	mitten	page
12	unexplainable	unhookable	oven	pen
13	unalterable	unloadable	patio	pole
14	unanswerable	unlockable	physician	punch
15	unbreakable	unpackable	pollen	race
16	unstoppable	unpluggable	radar	racket
17	unnoticeable	unrollable	ravine	ring
18	unidentifiable	unscrambleable	river	rock
19	unimaginable	unscrewable	saliva	school
20	unmeasurable	unsealable	shirt	spell
21	unreliable	untwistable	surgeon	spit
22	unpredictable	unwindable	tomb	spring
23	unshakable	unwrappable	tulip	tap
24	unthinkable	unzippable	vaccine	watch

Appendix B

Stimuli used in Experiment 2

	Structurally ambiguous stimuli	Right-branching meanings	Left-branching meanings
1	unbendable	"one cannot bend it"	"one can unbend it"
2	unbuttonable	"impossible to button up"	"possible to unbutton"
3	uncoilable	"incapable of being coiled"	"capable of being uncoiled"
4	uncorkable	"one cannot cork it"	"one can uncork it"
5	undoable	"cannot be done"	"can be undone"
6	undockable	"incapable of being docked"	"capable of being undocked"
7	unfastenable	"impossible to fasten"	"possible to unfasten"
8	unfoldable	"impossible to be folded"	"possible to be unfolded"
9	unglueable	"incapable of being glued"	"capable of being unglued"
10	unhookable	"one cannot hook it"	"one can unhook it"
11	unlearnable	"cannot be learned"	"can be unlearned"
12	unleashable	"cannot be leashed"	"can be unleashed"
13	unloadable	"incapable of being loaded"	"capable of being unloaded"
14	unlockable	"impossible to be locked"	"possible to be unlocked"
15	unpackable	"incapable of being packed"	"capable of being unpacked"
16	unpluggable	"one cannot plug it in"	"one can unplug it"
17	unrollable	"cannot be rolled"	"can be unrolled"
18	unscrewable	"one cannot screw it"	"one can unscrew it "
19	unsealable	"impossible to seal"	"possible to unseal"
20	untieable	"impossible to tie up"	"possible to untie"
21	untwistable	"incapable of being twisted"	"capable of being untwisted"
22	unwindable	"cannot be wound"	"can be unwound"
23	unwrappable	"one cannot wrap it"	"one can unwrap it"
24	unzippable	"cannot be zipped up"	"can be unzipped"

Appendix C

Rating sheets used in Experiment 3

C.1 Frequency rating sheet - sample 1a

C.2 Frequency rating sheet - sample 1b

C.3 Plausibility rating sheet - sample 2a

C.4 Plausibility rating sheet - sample 2b

C.5 Plausibility rating sheet - sample 3

C.1 Frequency rating sheet - sample 1a

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FREQUENCY RATING – PAIRED (Left–Right)

Using an HB pencil, fill in only one circle for each question. Completely erase any response you wish to change.

My first language is: **1**=English; **2**=Other .... ①②③④⑤

Please read the words in **bold**. Each one can have 2 distinct meanings, M1 and M2 (following the word). Please fill in the circle on each scale to indicate how frequently you think a native speaker of English is likely to encounter these words being used with each of the two given meanings. By doing so, you help us get the frequency ratings for the distinct meanings of each word.

Least frequently 1 ... 2 ... 3 ... 4 ... 5 **Most frequently**

unbendable --	possible to unbend	①②③④⑤
unbendable --	impossible to bend	①②③④⑤
unbucklable --	possible to unbuckle	①②③④⑤
unbucklable --	impossible to buckle	①②③④⑤
unbuttonable --	possible to unbutton	①②③④⑤
unbuttonable --	impossible to button	①②③④⑤
uncoilable --	possible to uncoil	①②③④⑤
uncoilable --	impossible to coil	①②③④⑤
uncorkable --	possible to uncork	①②③④⑤
uncorkable --	impossible to cork	①②③④⑤
undoable --	possible to undo	①②③④⑤
undoable --	impossible to do	①②③④⑤
undressable --	possible to undress	①②③④⑤
undressable --	impossible to dress	①②③④⑤
unfastenable --	possible to unfasten	①②③④⑤
unfastenable --	impossible to fasten	①②③④⑤
unfoldable --	possible to unfold	①②③④⑤
unfoldable --	impossible to fold	①②③④⑤
unglueable --	possible to unglue	①②③④⑤
unglueable --	impossible to glue	①②③④⑤
unhookable --	possible to unhook	①②③④⑤
unhookable --	impossible to hook	①②③④⑤
unloadable --	possible to unload	①②③④⑤
unloadable --	impossible to load	①②③④⑤

1 of 2

Figure C.1: Frequency rating sheet: Rating condition: Paired; Meaning presentation order: Left branching - Right branching (Page 1 of 2).

C.2 Frequency rating sheet - sample 1b

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FREQUENCY RATING - PAIRED (Left-Right)

Using an HB pencil, fill in only one circle for each question. Completely erase any response you wish to change.

My first language is: 1=English; 2=Other .... ①②③④⑤

Please read the words in **bold**. Each one can have 2 distinct meanings, M1 and M2 (following the word). Please fill in the circle on each scale to indicate how frequently you think a native speaker of English is likely to encounter these words being used with each of the two given meanings. By doing so, you help us get the frequency ratings for the distinct meanings of each word.

Least frequently 1 ... 2 ... 3 ... 4 ... 5 **Most frequently**

unlockable -- possible to unlock .... ①②③④⑤
unlockable -- impossible to lock .... ①②③④⑤
unpackable -- possible to unpack .... ①②③④⑤
unpackable -- impossible to pack .... ①②③④⑤
unpluggable -- possible to unplug .... ①②③④⑤

unpluggable -- impossible to plug .... ①②③④⑤
unrollable -- possible to unroll .... ①②③④⑤
unrollable -- impossible to roll .... ①②③④⑤
unscrambleable --possible to unscramble .... ①②③④⑤
unscrambleable --impossible to scramble .... ①②③④⑤

unscrewable -- possible to unscrew .... ①②③④⑤
unscrewable -- impossible to screw .... ①②③④⑤
unsealable -- possible to unseal .... ①②③④⑤
unsealable -- impossible to seal .... ①②③④⑤
untieable -- possible to untie .... ①②③④⑤

untieable -- impossible to tie .... ①②③④⑤
untwistable -- possible to untwist .... ①②③④⑤
untwistable -- impossible to twist .... ①②③④⑤
unwindable -- possible to unwind .... ①②③④⑤
unwindable -- impossible to wind .... ①②③④⑤

unwrappable -- possible to unwrap .... ①②③④⑤
unwrappable -- impossible to wrap .... ①②③④⑤
unzippable -- possible to unzip .... ①②③④⑤
unzippable -- impossible to zip .... ①②③④⑤

2 of 2

Figure C.2: Frequency rating sheet: Rating condition : Paired; Meaning presentation order: Left branching - Right branching (Page 2 of 2).

C.3 Plausibility rating sheet - sample 2a

PLEASE DO NOT DISTURB THIS AREA

PLAUSIBILITY RATING - PAIRED (Right-Left)

Using an HB pencil, fill in only one circle for each question. Completely erase any response you wish to change.

My first language is: 1=English; 2=Other .... ①②③④⑤

Please read the words in **bold**. Each one can have 2 distinct meanings, M1 and M2 (following the word). Please fill in the circle on each scale to indicate how plausible you think each of these meanings is. By doing so, you help us get the semantic plausibility ratings for the distinct meanings of each word.

Least plausible 1 ... 2 ... 3 ... 4 ... 5 **Most plausible**

unbendable --	impossible to bend	①②③④⑤
unbendable --	possible to unbend	①②③④⑤
unbucklable --	impossible to buckle	①②③④⑤
unbucklable --	possible to unbuckle	①②③④⑤
unbuttonable --	impossible to button	①②③④⑤
unbuttonable --	possible to unbutton	①②③④⑤
uncoilable --	impossible to coil	①②③④⑤
uncoilable --	possible to uncoil	①②③④⑤
uncorkable --	impossible to cork	①②③④⑤
uncorkable --	possible to uncork	①②③④⑤
undoable --	impossible to do	①②③④⑤
undoable --	possible to undo	①②③④⑤
undressable --	impossible to dress	①②③④⑤
undressable --	possible to undress	①②③④⑤
unfastenable --	impossible to fasten	①②③④⑤
unfastenable --	possible to unfasten	①②③④⑤
unfoldable --	impossible to fold	①②③④⑤
unfoldable --	possible to unfold	①②③④⑤
unglueable --	impossible to glue	①②③④⑤
unglueable --	possible to unglue	①②③④⑤
unhookable --	impossible to hook	①②③④⑤
unhookable --	possible to unhook	①②③④⑤
unloadable --	impossible to load	①②③④⑤
unloadable --	possible to unload	①②③④⑤

1 Of 2

Figure C.3: Plausibility rating sheet: Rating condition: Paired; Meaning presentation order: Right branching - Left branching (Page 1 of 2).

C.4 Plausibility rating sheet - sample 2b

PLEASE DO NOT DISTURB THIS AREA

PLAUSIBILITY RATING - PAIRED (Right-Left)

Using an HB pencil, fill in only one circle for each question. Completely erase any response you wish to change.

My first language is: 1=English; 2=Other .... ①②③④⑤

Please read the words in **bold**. Each one can have 2 distinct meanings, M1 and M2 (following the word). Please fill in the circle on each scale to indicate how plausible you think each of these meanings is. By doing so, you help us get the semantic plausibility ratings for the distinct meanings of each word.

Least plausible 1 ... 2 ... 3 ... 4 ... 5 **Most plausible**

unlockable -- impossible to lock .... ①②③④⑤
unlockable -- possible to unlock .... ①②③④⑤
unpackable -- impossible to pack .... ①②③④⑤
unpackable -- possible to unpack .... ①②③④⑤
unpluggable -- impossible to plug .... ①②③④⑤

unpluggable -- possible to unplug .... ①②③④⑤
unrollable -- impossible to roll .... ①②③④⑤
unrollable -- possible to unroll .... ①②③④⑤
unscrambleable --impossible to scramble .... ①②③④⑤
unscrambleable --possible to unscramble .... ①②③④⑤

unscrewable -- impossible to screw .... ①②③④⑤
unscrewable -- possible to unscrew .... ①②③④⑤
unsealable -- impossible to seal .... ①②③④⑤
unsealable -- possible to unseal .... ①②③④⑤
untieable -- impossible to tie .... ①②③④⑤

untieable -- possible to untie .... ①②③④⑤
untwistable -- impossible to twist .... ①②③④⑤
untwistable -- possible to untwist .... ①②③④⑤
unwindable -- impossible to wind .... ①②③④⑤
unwindable -- possible to unwind .... ①②③④⑤

unwrappable -- impossible to wrap .... ①②③④⑤
unwrappable -- possible to unwrap .... ①②③④⑤
unzippable -- impossible to zip .... ①②③④⑤
unzippable -- possible to unzip .... ①②③④⑤

2 of 2

Figure C.4: Plausibility rating sheet: Rating condition: Paired; Meaning presentation order: Right branching - Left branching (Page 2 of 2).

C.5 Plausibility rating sheet - sample 3

PLEASE DO NOT DISTURB THIS AREA

PLAUSIBILITY RATING – UNPAIRED

Using an HB pencil, fill in only one circle for each question. Completely erase any response you wish to change.

My first language is: **1**=English; **2**=Other .... ①②③④⑤

Please read the words in **bold**. Each one can have 2 distinct meanings, but we are only interested in one of them. Please fill in the circle on each scale to indicate how plausible you think the given meaning is. By doing so, you help us get the semantic plausibility ratings for the distinct meanings of each word.

Least plausible 1 ... 2 ... 3 ... 4 ... 5 **Most plausible**

Part I: "Impossible to _________" meanings:

unbendable --	impossible to bend	①②③④⑤
unbucklable --	impossible to buckle	①②③④⑤
unbuttonable --	impossible to button	①②③④⑤
uncoilable --	impossible to coil	①②③④⑤
uncorkable --	impossible to cork	①②③④⑤
undoable --	impossible to do	①②③④⑤
undressable --	impossible to dress	①②③④⑤
unfastenable --	impossible to fasten	①②③④⑤
unfoldable --	impossible to fold	①②③④⑤
unglueable --	impossible to glue	①②③④⑤
unhookable --	impossible to hook	①②③④⑤
unloadable --	impossible to load	①②③④⑤

Part II: "Possible to _________" meanings:

unlockable --	possible to unlock	①②③④⑤
unpackable --	possible to unpack	①②③④⑤
unpluggable --	possible to unplug	①②③④⑤
unrollable --	possible to unroll	①②③④⑤
unscrambleable --	possible to unscramble	①②③④⑤
unscrewable --	possible to unscrew	①②③④⑤
unsealable --	possible to unseal	①②③④⑤
untieable --	possible to untie	①②③④⑤
untwistable --	possible to untwist	①②③④⑤
unwindable --	possible to unwind	①②③④⑤
unwrappable --	possible to unwrap	①②③④⑤
unzippable --	possible to unzip	①②③④⑤

Figure C.5: Plausibility rating sheet: Rating condition: Unpaired.

Appendix D

Stimuli used in Experiment 4

	Root adjective	Prefix-root adjective	Root verb	Prefix-root verb
1	able	unable	arm	unarm
2	aware	unaware	balance	unbalance
3	born	unborn	bend	unbend
4	certain	uncertain	buckle	unbuckle
5	civil	uncivil	burden	unburden
6	clean	unclean	coil	uncoil
7	common	uncommon	cork	uncork
8	due	undue	couple	uncouple
9	easy	uneasy	cover	uncover
10	equal	unequal	do	undo
11	even	uneven	dress	undress
12	fit	unfit	fold	unfold
13	happy	unhappy	hook	unhook
14	holy	unholy	load	unload
15	just	unjust	lock	unlock
16	kind	unkind	mask	unmask
17	like	unlike	pack	unpack
18	necessary	unnecessary	roll	unroll
19	quiet	unquiet	saddle	unsaddle
20	real	unreal	scramble	unscramble
21	social	unsocial	screw	unscrew
22	sound	unsound	seat	unseat
23	tidy	untidy	settle	unsettle
24	usual	unusual	tangle	untangle
25	well	unwell	veil	unveil

Appendix E

Stimuli used in Experiment 5

E.1 Structurally ambiguous stimuli

	Plain condition	prefix+BASE condition	BASE+suffix condition
1	unbendable	unBENDABLE	UNBENDable
2	unbuttonable	unBUTTONABLE	UNBUTTONable
3	uncoilable	unCOILABLE	UNCOILable
4	uncorkable	unCORKABLE	UNCORKable
5	undoable	unDOABLE	UNDOable
6	undockable	unDOCKABLE	UNDOCKable
7	unfastenable	unFASTENABLE	UNFASTENable
8	unfoldable	unFOLDABLE	UNFOLDable
9	unglueable	unGLUEABLE	UNGLUEable
10	unhookable	unHOOKABLE	UNHOOKable
11	unlearnable	unLEARNABLE	UNLEARNable
12	unleashable	unLEASHABLE	UNLEASHable
13	unloadable	unLOADABLE	UNLOADable
14	unlockable	unLOCKABLE	UNLOCKable
15	unpackable	unPACKABLE	UNPACKable
16	unplugable	unPLUGABLE	UNPLUGable
17	unrollable	unROLLABLE	UNROLLable
18	unscrewable	unSCREWABLE	UNSCREWable
19	unsealable	unSEALABLE	UNSEALable
20	untieable	unTIEABLE	UNTIEable
21	untwistable	unTWISTABLE	UNTWISTable
22	unwindable	unWINDABLE	UNWINDable
23	unwrapable	unWRAPABLE	UNWRAPable
24	unzipable	unZIPABLE	UNZIPable

E.2 Right-branching stimuli

	Plain condition	prefix+BASE condition	BASE+suffix condition
1	unaccountable	unACCOUNTABLE	UNACCOUNTable
2	unanswerable	unANSWERABLE	UNANSWERable
3	unapproachable	unAPPROACHABLE	UNAPPROACHable
4	unattainable	unATTAINABLE	UNATTAINable
5	unconquerable	unCONQUERABLE	UNCONQUERable
6	undetectable	unDETECTABLE	UNDETECTable
7	undrinkable	unDRINKABLE	UNDRINKable
8	unemployable	unEMPLOYABLE	UNEMPLOYable
9	unexplainable	unEXPLAINABLE	UNEXPLAINable
10	unfathomable	unFATHOMABLE	UNFATHOMable
11	unimpeachable	unIMPEACHABLE	UNIMPEACHable
12	unmanageable	unMANAGEABLE	UNMANAGEable
13	unmatchable	unMATCHABLE	UNMATCHable
14	unmentionable	unMENTIONABLE	UNMENTIONable
15	unnoticeable	unNOTICEABLE	UNNOTICEable
16	unpardonable	unPARDONABLE	UNPARDONable
17	unpayable	unPAYABLE	UNPAYable
18	unprintable	unPRINTABLE	UNPRINTable
19	unpronounceable	unPRONOUNCEABLE	UNPRONOUNCEable
20	unquestionable	unQUESTIONABLE	UNQUESTIONable
21	unreachable	unREACHABLE	UNREACHable
22	unreadable	unREADABLE	UNREADable
23	unserviceable	unSERVICEABLE	UNSERVICEable
24	unsinkable	unSINKABLE	UNSINKable

E.3 Left-branching stimuli

	Plain condition	prefix+BASE condition	BASE+suffix condition
1	decompressable	deCOMPRESSABLE	DECOMPRESSable
2	deconstructable	deCONSTRUCTABLE	DECONSTRUCTable
3	deformable	deFORMABLE	DEFORMable
4	disagreeable	disAGREEABLE	DISAGREEable
5	disallowable	disALLOWABLE	DISALLOWable
6	disarmable	disARMABLE	DISARMable
7	dischargeable	disCHARGEABLE	DISCHARGEable
8	disclaimable	disCLAIMABLE	DISCLAIMable
9	disconnectable	disCONNECTABLE	DISCONNECTable
10	discreditable	disCREDITABLE	DISCREDITable
11	disengageable	disENGAGEABLE	DISENGAGEable
12	disinfectable	disINFECTABLE	DISINFECTable
13	dislodgeable	disLODGEABLE	DISLODGEable
14	dismountable	disMOUNTABLE	DISMOUNTable
15	displaceable	disPLACEABLE	DISPLACEable