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Morphological structure and parsing in the lexicon

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University of California, Los Angeles, 1987

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Morphological Structure and Parsing in the Lexicon

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy in Linguistics

by

Karen Denise Emmorey

1987

The dissertation of Karen Denise Emmorey is approved.

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Victoria A. Fromkin, Committee Chair

University of California, Los Angeles

1987

Language is a virus from outer space.

-- William S. Burroughs

-- Laurie Anderson

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PUBLICATIONS AND PRESENTATIONS

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ABSTRACT OF THE DISSERTATION

Morphological Structure and Parsing in the Lexicon

by

Karen Denise Emmorey
Doctor of Philosophy in Linguistics
University of California, Los Angeles, 1987
Professor Victoria A. Fromkin, Chair

This study explores the relation between formal grammars and psychological parsing models and is concerned with how morphological structure is represented and accessed in the lexicon. A series of auditory lexical decision experiments were conducted with English. The results indicate that morphological structure is analyzed on-line during lexical access. I propose that English prefixed words are stored in the lexicon with their morphological structure marked and that only the roots of suffixed words are contained in the cohort set used for recognition. There was no evidence that parsing is misled by pseudoaffixation. Some evidence suggests that derived suffixed words take longer to recognize than inflected and monomorphemic words. I propose that this delay is due to the category-changing nature of the derivational suffixes.

Morphologically complex words and nonwords were also presented

visually. The results indicate that auditory and visual lexical access procedures are subject to different constraints which affect morphological analysis. For auditory processing recognition of a suffix is tied to the identification of a root. For visual processing, however, recognition of the root and suffix can occur in parallel. Auditory word recognition is constrained by temporal order, whereas visual word recognition can operate more holistically.

Three auditory priming experiments were also conducted. One experiment showed that morphological relationships are represented independently of semantic relatedness. A large priming effect was found for morphologically related words which were not semantically related (e.g. submit, permit). Significant priming was not found for words that were simply phonologically related (e.g. balloon, saloon). The second and third priming experiments indicated that suffixes do not have lexical representations that can be primed during lexical access; morphological priming was not found between words that share a suffix (e.g. blackness, shortness). Formal models which propose separate lexical entries for affixes are not supported. Lastly, phonological priming was observed when the words shared a final syllable but not when they shared final segments. Word-final phonological priming presents problems for the cohort model which predicts that only word-initial priming can occur.

Chapter 1

Language as a Cognitive System

Research concerned with the theory of generative grammar was one of the forces that led to the development of modern cognitive science. This research program, introduced in the mid-1950s, shared with other emerging approaches to the study of mind the view that it was legitimate and in fact necessary to posit mental computational systems of rules and representations to explain human behavior. This belief broke from the earlier stand taken by behaviorist psychologists and American structuralist linguists who rejected "mentalistic" explanations and argued that only observable factors were relevant to language theory. In his review of B.F. Skinner's Verbal Behavior, Chomsky (1959) argued that complex human linguistic behavior cannot be adequately explained by theories based on stimulus-response paradigms; internal mental representations and processes must be posited to explain language comprehension and production as well as how children come to master their language with no instruction and with little effort. The arguments by Chomsky and others were persuasive both within linguistics and psychology, and eventually behaviorist approaches to the study of the mind/brain were replaced with research programs that posited abstract mental representations and processes.

In Syntactic Structures Chomsky (1957) discussed the notion of a generative grammar as a model of the ideal speaker-hearer's internalized knowledge of language. The study of generative grammar has since come to be viewed by many as the study of a particular component of the mind/brain -- the language faculty. The experiments,

discussion, and proposals presented in this thesis are based on this conception of generative grammar.

Some have argued that models of linguistic knowledge (i.e. grammars) proposed by linguists are simply descriptions of linguistic data and should not be construed as being "real" or represented in the mind (Searle 1980; Kintsch, 1974; Rachlin, 1980; Shank and Birnbaum, 1984). However, this is a difficult position to support. Consider the analogy given by Chomsky (1980) between an astronomer studying the hidden internal processes of the sun and a linguist studying the hidden mental properties of language. Both scientists are studying the properties of systems that cannot be directly observed. Suppose the astronomer puts forth a theory which postulates thermonuclear reactions within the sun, and this theory explains aspects of the sun's behavior (e.g. properties of light emission and heat). Now consider the following allegation put to the astronomer: "'True, you have presented a theory that explains the available evidence, but how do you know that the constructions of your theory have physical reality -- in short how do you know your theory is true (Chomsky, 1980: 189)?'" The astronomer can only answer this question by showing how well his/her theory can account for the available data. The same holds for linguistic theories -- they are true (i.e., "psychologically real") to the extent that they account for the observed phenomena they purport to explain, namely, the speaker-hearer's linguistic knowledge and how children acquire this knowledge.

The notion of "psychological reality" is often mistakenly inter-

preted as meaning that "psychological" evidence (e.g., from reaction time experiments) can establish the reality of hypothesized mental representations and computations, but "linguistic" evidence (e.g. speaker judgments of grammaticality) cannot. Why should one type of evidence be given a privileged status to confirm or disconfirm the reality of mental constructs? Fromkin (1985) observes that "when [psycholinguistic data] coincides with the constructs and concepts required by linguistics, they provide additional evidence to support the theory . . . If such coincidence is not found, however, this does not 'prove' that such concepts are not 'real' . . .[p. 21]" Fromkin does not deny that data from psychological experiments may be relevant to the development of grammatical theory. However, it is necessary to determine what effects observed in an experiment reflect the structure of knowledge systems (the topic of linguistic theory) as opposed to the effects which are due to performance mechanisms.

The crux of these arguments is not the "psychological reality" of grammars, but the relation between linguistic knowledge and processing.[1] Some experiments which claim to test the "psychological reality" of a particular linguistic structure or rule reflect, instead, whether that structure or rule is relevant to a particular processing task. For example, the "psychological reality" of the phoneme might be questioned because some experimental evidence indicates that phonemes are not perceptual units required for speech recognition (e.g., Savin and Bever, 1970). However, what should be questioned is not the reality of phonemes -- there exists abundant evidence to support the concept of the phoneme; rather, what these

results suggest is that phonemes may not be perceptual units required for speech segmentation and recognition. Evidence supporting the "psychological reality" of phonemes derives in part from the clear demonstration that an abstract notion of phoneme is necessary to account for what speakers know about the sound patterns of their language, why they produce certain sounds in one environment and other sounds in different contexts, as well as several other behavioral facts about sound perception and production. There is, howeverstill considerable controversy about the role of the phoneme in speech segmentation, but this controversy is not about the "psychological reality" of phonemes. Rather, it is about whether words are segmented into their component phonemes during speech perception.

Furthermore, if phonemes turn out to play no role in the perception of speech, an important question arises: what is the relationship between a grammar in which a phonemic level of analysis is fundamental and a perceptual system in which the phoneme is not a necessary level of analysis? To ultimately understand language as a cognitive system, questions concerning how formal grammars and processing models interact must be resolved. In the remainder of this Chapter I will discuss some theoretical problems involved in determining how grammars are related to models of linguistic performance.

Historical Perspective

When the theory of Transformational Grammar was first proposed, many psychologists were attracted to the theory as a model of language behavior (Bever, in press). Psychologists hypothesized that the same model proposed to explain speakers' knowledge of language

could also function as a model of language use. Although Transformational Grammar was not proposed as a processing model -- this was in fact explicitly denied (Chomsky, 1957; 1965) -- the grammar was appealing as a model of linguistic performance. Part of the appeal may have been due to the process-like terms and notations that were used in the model. For example, the grammar was "generative," and transformations "operated" on sentential structures "deriving" one phrase marker from another. Even if transformational grammar was not proposed as a processing model, the hypothesis that a model of linguistic knowledge might also explain sentence processing is a plausible one. Our knowledge of linguistic rules and representations is most likely exploited during language comprehension and production, and a direct mapping between grammatical rules and perceptual computations is the simplest proposal to explain how linguistic knowledge is exploited by a processing system.

The experiments conducted in the early 1960s were based on the assumption that every syntactic rule in the grammar corresponded to a psychological operation. Therefore, linguistic complexity, defined by the number of transformations needed to derive the deep structure of a sentence, was linked directly to processing complexity defined by various time and accuracy measures -- this hypothesis constituted the Derivational Theory of Complexity (DTC) (Fodor, Bever, and Garrett, 1974). Essentially, the DTC predicted that the more transformations relating surface structure to deep structure, the longer it should take to understand or produce a sentence. Initially, experimental results confirmed this prediction. The number of transforma-

tions applied to a sentence predicted its recall probability -- the more transformations, the less likely the recall (Mehler, 1963), transformationally complex sentences took longer to comprehend (MacMahon, 1963; Gough, 1965), and the transformational distance between sentences predicted their confusability (Clifton, Kurcz, and Jenkins, 1965). At this stage in the theory, transformations also generated morphologically complex lexical items. For example, derived nominals (e.g., description, refusal) were the result of a transformation applied to their more basic verb forms (describe, refuse) (see Lees, 1960). Therefore, according to the DTC, derived nominals should be more difficult to understand than the corresponding verbal forms, and, in fact, Coleman (1964) found that sentences which contained derived nominals were harder to comprehend than sentences which contained the corresponding base verbs, and Coleman and Blumenfeld (1963) found that cloze tasks were harder to complete for derived nominals than for their base verbs.

The initial success of the DTC did not last, however, because further experiments showed that processing difficulty could not be reliably predicted from linguistic complexity defined by number of transformations. For example, some sentences required the same number of transformations but appeared to differ in their processing difficulty, and some sentences which differed in number of transformations nonetheless required the same amount of processing time (e.g. Slobin, 1966; Fodor and Garrett, 1967). Furthermore, results that had shown an increase in processing time with an increase in transformations were argued to be artifacts of off-line strategies adopted

by subjects and not due to the employment of transformation-like operations. The direct interpretation of the grammar as a model of language behavior was abandoned.

Fodor, Bever, and Garrett (1974) concluded that the experimental evidence did not support the "psychological reality" of transformations but that there was considerable evidence supporting the recovery of deep and surface structures during speech perception. Fodor et al. (1974) argued that these structures were computed during sentence recognition but not by operations represented in the grammar; other "heuristic" strategies were used. For example, "lexical strategies" could extract parts of the deep structure configuration based on syntactic information provided by the verb (Levelt, 1974). Experimental evidence for lexical strategies was provided by Fodor, Garrett, and Bever (1968). They assumed that lexical items were stored with information about the types of deep structure configurations in which they could occur, and they proposed that the listener employed the lexicon in sentence recognition by postulating only those deep structure configurations for a given sentence that were compatible with the lexical items of that sentence[2].

Note that the heuristic provided by this lexical analysis did not resemble a transformation in any way, and yet the strategy accounted for differences in processing time. It was concluded that the psychological operations that construct syntactic representations were completely distinct from grammatical operations, and the grammar was "probably not concretely realized in the perceptual model (Fodor, Bever, and Garrett, 1974; p. 369)."

Although Fodor et al. (1974) emphasized that more research should be directed to the theoretical problem of the relation between linguistic and psychological models, very little research was concerned with this question. In fact, after the demise of the Derivational Theory of Complexity, linguistic theory was often considered to be irrelevant to psychological processing models. For example, Kintsch (1974) wrote "As long as a linguistic theory is strictly a competence theory, it is of no interest to the psychologist (p. 3)." Levelt (1974) observed that psychologists "started studying psychological processes of understanding without much recourse to grammar (p. 72)." The division between linguistics and psychology was perhaps exacerbated by the "linguistic wars" in the 1970s between generative semanticists and interpretavists (see Newmeyer, 1980). Linguistic theory was perceived as being in a state of great fluctuation, and this was a problem for psychologists who wanted to base their theory of language processing on a particular grammar. In his review of the field, Fillenbaum (1971) observed that "to the extent that psycholinguistic work is based on some linguistic formulation, it may be embarrassing, or likely much worse, to find that linguists have now rejected that formulation, making very difficult indeed the interpretation of any results (p. 254)."

Psycholinguistic research shifted away from studying the nature of representations constructed during language comprehension or production and toward investigations of psychological processes. For example, psychological models dealing with the lexicon emphasized word recognition mechanisms, but much of the internal structure of

the lexicon was left unspecified and unclear. Most experiments dealt with lexical semantics, and very few investigated the morphological or syntactic phenomena associated with lexical representations. The problem of exactly what information was accessed during word recognition was ignored and has still not been adequately addressed (Gerrig, 1986).

In addition, some researchers interested in sentence interpretation developed computational systems that did not contain a level of syntactic representation at all. No link was assumed between systems of grammatical knowledge and process models, a view particularly represented by researchers in artificial intelligence (e.g., Shank, 1972; Winograd 1972). The psychologists Marslen-Wilson, Tyler, and Seidenberg (1978) also argued that purely syntactic representations do not exist. They claimed that the internal representation constructed during sentence comprehension "would not be describable in strictly linguistic terms, since it would have to contain the products of inferences drawn from the listener's non-linguistic knowledge. So it would not, in itself, be either a syntactic or a semantic representation. . . (p. 243)."[3] The period roughly covering the 1970s was a time in which many investigators assumed no connection between the grammar and processing systems. It was not clear that grammars developed within linguistic theory were relevant to processing models, or conversely, that processing models provided evidence concerning the form of grammars.

However, within the last half-dozen years or so, some linguists and psychologists have joined forces again, and the theoretical

issues concerning how a grammar might be related to a processing model are being discussed. In response to Kintsch's (1974) claim that processing models need not be concerned with linguistic theory, Chomsky (1980) observes that the assumption that process models can ignore what speakers know about language is a dogmatic and odd a priori assumption. The most likely state of affairs is that speakers' knowledge of language is relevant to processing mechanisms. Furthermore, Berwick and Weinberg (1984) argue that a strange redundancy would exist if the linguistic knowledge (specified within the grammar) that the child brings to the task of language learning were not also exploited for the purposes of language processing.

Type Transparency

Berwick and Weinberg (1984) provide an enlightening discussion of the possible mappings between grammars and syntactic parsers. They observe that a direct grammar-parser relationship in which every rule in the grammar corresponds to a computation within the parser is probably not correct given the failure of the DTC experiments described above. They label this direct mapping a "token-token" transparency between the grammar and parser. Berwick and Weinberg argue instead for a weaker "type-type" transparency in which "the logical organization of rules and structures incorporated in a grammar [is] mirrored rather exactly in the organization of the parsing mechanism (p. 39)." Under type transparency, the distinctions between structures and rules made within the grammar must also be preserved within the parsing model. Although the parsing model is allowed to make more distinctions than the grammar, it cannot make fewer. Berwick

and Weinberg further argue that current theories of transformational grammar (Government Binding theory; Chomsky, 1981) as well as Lexical Functional Grammar (Bresnan and Kaplan, 1982; Bresnan, 1978) can meet the demands of type transparency and are also compatible with the results from the DTC studies.

Lexical Functional Grammar (LFG) was designed in part to comply with the DTC results (Bresnan, 1978). For example, in LFG the same grammatical operations interpret both active and passive sentences, and therefore actives and passives should take the same amount of time to understand as found by Slobin (1966). Berwick and Weinberg argue against Bresnan's (1978) claim that LFG should be preferred over a transformational model because it can account for these results. They show that Government Binding theory embedded in a Marcus-like parser is also compatible with Slobin's (1966) results (and others) if limited parallel processing is allowed. Berwick and Weinberg suggest that Surface and Deep Structure are built in parallel and stress that one must be careful in using reaction time data to argue against a grammar or parsing model given that non-serial processing is possible.

Recently, much debate about syntactic parsing has assumed that a type transparency exists between the grammar and parser. For example, Frazier, Clifton, and Randall (1983) present evidence that phrase structure rules and constraints on filler-gap dependencies reside in different components of the parser. The grammar proposed within the Government Binding (GB) theory mirrors this organization of PS rules and binding (i.e. filler-gap) constraints. Within the GB

framework PS rules (in the form of X-bar theory) are part of the base component and binding constraints operate at S-structure. PS rules and binding constraints are part of separate modules within the GB model. Frazier et al. propose that the compatibility of GB theory and their parsing model argues for the correctness of both. Crain and Fodor (1985), on the other hand, present experimental evidence which suggests that binding constraints and phrase structure rules are not separated within the human parser, and they argue that their data support a Generalized Phrase Structure Grammar (GPSG) in which constraints on filler-gap dependencies and phrase structure rules do not form separate components within the grammar. Future research must determine which model is correct, but the important point is to note the type of argumentation that has been used. Neither group argues that their evidence forces a choice of grammar, but they do assume that the grammar and parser should be optimally related and that their evidence supports a particular combination of parser and grammar.

Within neurolinguistics, a type transparency constraint has also been assumed and has been used to argue for one model of grammar over another. For example, Grodzinsky (1985) proposes that a grammar should be "break-down compatible" -- that is, it must be compatible with the language breakdown patterns observed in aphasia. Grodzinsky (1985) shows that some agrammatic patients are able to comprehend lexical passives (e.g., The boy is interested in the girl.) but not sentential passives (e.g., The boy was pushed by the girl.) Within a GB framework these two structures are generated by different compo-

nents of the grammar (the lexicon and the syntax). However, in LFG both structures are generated in the lexicon. Grodzinsky (1985) argues that the dissociation he observes in the aphasia data between lexical and sentential passives supports a GB model over an LFG model. Furthermore, Caplan and Hildebrandt (in press) have been able to explain a large body of aphasia data assuming a type transparency between the grammar (a GB model) and parser (a Berwick and Weinberg-modified Marcus parser). Caplan and Hildebrandt (in press) also present evidence that a GB grammar can account for dissociations of syntactic comprehension that cannot be adequately characterized by an LFG model.

Much progress has been made in our understanding of both the human parser and the nature of aphasia by assuming that grammars developed within linguistic theory are relevant to process models. But should we assume that a type transparency constraint <u>must</u> hold between the grammar and processing system? A type transparent relationship is desirable because we can then use facts about the grammar to constrain the parser, and the nature of the parser can be used to constrain the form of grammars. But is type transparency a logical necessity or an empirical question? Berwick and Weinberg (1984) observe that although type transparency may be the most preferred relationship between the grammar and parser, this correspondence is not <u>logically</u> necessary. Furthermore, the notion of type transparency has not been made particularly rigorous such that a wide range of degrees of correspondence is possible. A very weak correspondence might exist in which only the global distinctions made by

the grammar (say between syntax and semantics) are reflected by the processing system. In contrast, a much tighter relationship might exist in which the same distinctions between structural categories (e.g. types of anaphora) are made by both the grammar and parser.

In addition, the nature of the correspondence may differ for speech perception and production. For example, the research cited earlier suggested that the phoneme might not be a unit used in speech perception; in contrast, other evidence from speech errors strongly indicate that the phoneme is a representational unit used in speech production (Fromkin, 1971; Stemberger, 1985). In the case of production a type transparent relationship would hold between the the grammar and the mechanisms involved in the production of speech; whereas for perception this type transparent relationship would not exist because the grammar would make distinctions that the speech perception system did not. Logical argumentation cannot determine the nature of the mapping between the grammar and performance mechanisms -- only empirical study will reveal how a formal grammar might be integrated into a language processing system.

Nonetheless, type transparency provides a working hypothesis about how grammars and parsers may be optimally related. Although type transparency is not a logical necessity, it is a reasonable hypothesis about how the knowledge system contained in the grammar can be accessed in a straight forward way by the parser. The theory of grammar should at the very least be compatible with the theory of language processing. That the parser refers to grammatical knowledge is a natural assumption given that this knowledge can be shown to be

independently required to explain language acquisition. Again, an odd redundancy would result if the human parser did not make use of the system of linguistic knowledge that the child exploits in learning language (Berwick and Weinberg, 1984). However, claims about constraints on the form of grammar based on parsing requirements must be fairly tentative simply because our current understanding of human parsing is quite limited (Tanenhaus, Carlson, and Seidenberg, 1985; Berwick and Weinberg, 1984). As our knowledge of the mechanisms required for language comprehension increases such claims will gain more significance.

Type Transparency and Models of the Lexicon

In this thesis, I will argue for a type transparent mapping between the lexicon characterized by linguistic models and the lexicon proposed by models of lexical access and processing. All of the recent work cited above dealing with the link between grammars and processing systems has been concerned with syntactic representations and sentential parsing. In contrast, I am concerned here with morphological parsing and lexical representations.

First, a word must be said about "linguistic" and "psychological" models of the lexicon. As discussed at the beginning of this Chapter, linguistic models describe speakers' internalized knowledge of language -- in this case lexical knowledge -- and such models are "psychologically real" to the extent that they can account for what speakers know about the properties of words. "Psychological" models must also include representations of lexical knowledge, but proposed models have generally concentrated exclusively on lexical access

procedures for the recognition or production of words. One of the goals of this dissertation is to combine both types of models -- that is, to relate the lexicon as described by theoretical linguistic models and a lexical processing model. Ultimately to understand the mental lexicon these two types of models must be integrated. It is plausible to assume that the mind does not contain two lexicons, linguistic and psychological. The question of concern here is what role lexical knowledge plays in word recognition and on-line language processing.

Several issues arise with respect to the integration of linguistic and processing theories of the lexicon. One relevant question is whether the internal organization of lexical knowledge hypothesized within linguistic models is mirrored by lexical processing models. Most commonly, within linguistic theory all information about a lexical item (e.g., phonological, syntactic, semantic) is listed as part of a single entry in the lexicon. In contrast, many psycholinguistic models of the lexicon propose separate subcomponents containing phonological, orthographic, and semantic information about words (Forster, 1976; Allport and Funnel, 1981; Fromkin, 1985). Lexical knowledge about a word is therefore not stored in one "place," but is represented in different information-specific subcomponents. There is considerable evidence in support of this componential organization of the lexicon stemming from dissociations of function and knowledge which occur with neurological damage (Emmorey and Fromkin, in press; Fromkin, 1987). Although the information may be stored separately, evidence from processing experiments and speech

errors indicate that the subcomponents must be connected and integrated in a complex system (Seidenberg and Tanenhaus, 1979; Fromkin, 1985; 1987).

Given this evidence, what is the status of linguistic models which do not assume separate knowledge-specific subcomponents? Although the lexicon within a grammar is often presented as containing a separate entry for each word (or morpheme) that contains all the lexical information for that word, this information is conceived of as modular. That is, different formal mechanisms operate on the phonological, syntactic, and semantic aspects of words, and distinct principles are required to constrain the possible phonological and syntactic representations of the words of a language. Syntactic, semantic, and phonological information are listed and characterized separately within each lexical entry. Within both linguistic and psychological models, phonological, semantic, syntactic, and orthographic information must be integrated for each lexical item, but the information is in fact represented separately. It appears then that the general organization of lexical information within linguistic and psychological models are not in conflict but are quite compatible.

One of Fodor et al.'s (1974) conclusions was that syntactic representations described by the grammar were isomorphic to those constructed by the language processing system. Some controversy still surrounds their interpretation, but the evidence continues to indicate that listeners do in fact compute the syntactic representations characterized by formal grammar (Tanenhaus et al. 1985). In this thesis, I raise a parallel question: Are the lexical represen-

tations accessed during word recognition isomorphic to those proposed within linguistic theory?

The unit of representation in the lexicon is an issue that has not been resolved in either linguistic or psychological theories of the lexicon. The basic unit of representation can be defined as the structure that is listed in the lexicon and within linguistic theory the structure upon which lexical rules may operate. In linguistics both the morpheme (Kiparsky, 1982; Selkirk, 1982) and the word (Aronoff, 1976; Anderson, 1982) have been proposed as the basic unit of representation. Only relatively recently have processing models addressed the question of whether words or individual morphemes are stored in lexical entries. Some models assume that the morpheme is the basic unit of representation (Taft and Forster, 1975; Caramazza, Miceli, Silveri, and Laudanna, 1985), while others propose that all existing words rather than just morphemes are stored in the lexicon (Butterworth, 1983). Kempley and Morton (1982) and Morton (1981) argue that the lexical representations accessed during word recognition correspond to neither words nor morphemes but to a unit "more abstract than either". Kempley and Morton's hypothesis violates type transparency because the structures within the grammar are not mirrored by the processing model. I suggest that the lexical representations in the grammar are the same as those accessed by word recognition processes. There is no agreed upon theory of grammar, and controversy currently exists within linguistics as to whether the lexicon is word-based or morpheme-based, and different lexical access procedures may fit one model better than another. However, no

linguistic model proposes the type of representations that Kemply and Morton (1982) hypothesize underlie word recognition. In Chapter six, I present evidence against Kempley and Morton's hypothesis and argue for a word-based lexicon.

Word Formation Rules

Word Formation Rules (WFRs) comprise a component of the lexicon found only in linguistic models. Word Formation Rules indicate how the morphemes of a language are concatenated to form the actual words of that language. WFRs generate all of the well-formed words of a language (e.g. un-break-able) and exclude all of the ill-formed words (e.g. break-un-able) (Halle, 1973). WFRs specify the syntactic, morphological (i.e. type of affixation), and semantic relation between a base (e.g., sad) and the complex word output (e.g., sadness). For example, a WFR specifies that a noun can be derived from the adjective sad by suffixation of -ness. What (if anything) corresponds to WFRs in models of lexical processing? Aronoff (1976) explicitly states that WFRs are not used in the production of a word or sentence -- they are not on-line. Perhaps WFRs are simply stored in the lexicon, and these rules are only referenced to analyze new or unfamiliar words; that is, WFRs are not used for normal word recognition but can be used to interpret unfamiliar strings.

WFRs also relate already existing words when a word-based lexicon is assumed. Both sad and sadness have lexical entries in this type of model. According to Aronoff's view, WFRs are "once only" rules, and when a new complex word is formed it is immediately stored in the lexicon. Perhaps, a WFR can then be characterized as the

connection between the base and the complex form. That is, if both roots and their derived forms are listed as separate lexical entries, these representations may be related by a connection that is purely morphological (as opposed to semantic or phonological). Network models have also been proposed to account for the semantic relation between words. These issues are explored in more detail in Chapter six.

It may be, contrary to Aronoff's proposal, that WFRs are used on-line in the interpretation of morphological structure. In contrast to Aronoff, Halle (1973) presented Word Formation Rules that operate on a dictionary of morphemes rather than only on existing words. If roots and affixes are stored separately in the lexicon as in a morpheme-based lexicon, complex words might have to be parsed into their component parts to be recognized. WFRs may also play a role in morphological parsing algorithms by specifying the allowable affixation processes and phonological alterations of root and/or affix.

The experiments presented in the Chapters that follow addressed two issues: 1) whether morphological parsing occurs and 2) the nature of stored lexical representations. If type transparency is a viable hypothesis, then the nature of the processing mechanisms that interpret lexical structure can argue for a particular kind of lexical representation. In addition, the lexical properties of words discovered by linguistic investigation may help reveal the type of processing mechanisms required for lexical access and word recognition. The experimental findings discussed below should therefore be

of interest to both linguists and psychologists.

Chapter 2

The Nature of Lexical Entries, Lexical Rules, and Lexical Access

In this chapter, I will review some of the current linguistic and psycholinguistic models of the lexicon as background for the experiments discussed in the remaining chapters. As discussed in Chapter one theoretical models of the lexicon developed within linguistics and psychology differ in emphasis and content. Linguistic models describe the nature of lexical rules and representations that account for speakers' knowledge about words, whereas psychological models are concerned with how words are recognized during speech perception or reading. Different theories within both linguistics and psychology propose different lexical representations and organizations. Within the last decade interest in morphology and the lexicon has increased tremendously in linguistics. I will review only a small part of this new research, the models proposed by Lieber (1980), Jackendoff (1975), and Aronoff (1976). These models illustrate some of the concepts and problems that are shared by linguistic and psychological models of the lexicon and are relevant to the experiments described in the following chapters.

Linguistic Models

The lexicon is one component of the linguistic grammar. A lexical entry is a representation of lexical knowledge that is listed (i.e. stored) in memory rather than generated by lexical rules. In some models only morphemes are stored in the lexicon, and complex words are computed by lexical rules and are not listed. Early models

(e.g. Bloomfield, 1933) assumed that the only criteria for lexical listing was idiosyncrasy and unpredictability. For example, the morpheme green would be listed because English speakers must learn the arbitrary meaning associated with the phonological string /grin/. However, the word greener is not listed because its meaning and structure is predictable if the meaning of green and the bound morpheme -er are known. In Bloomfield's model the lexicon is a list of the morphemes of a language.

After Chomsky's introduction of Transformational Grammar, the research emphasis in linguistics shifted from morphology to syntax (Anderson, in press; Scalise, 1984). Morphology seemed to get lost somewhere between phonology and syntax; in 1976 Aronoff rejuvenated the study of morphology and the lexicon with his dissertation on word formation. Since Aronoff, a fair amount of research within theoretical linguistics has been concerned with lexical rules and representations. Recent models can be broadly divided into morpheme-based and word-based models of the lexicon.

Morpheme-Based Models

Lieber (1980) presents a detailed proposal for the organization of lexical entries and the internal structure of the lexicon itself. In Lieber's model all unanalyzable morphemes (e.g. break but not breaks or breakable) are stored in a permanent lexicon. Lexical entries contain idiosyncratic information about morphemes such as their category (noun, verb, adjective), phonological representation, semantic representation, subcategorization, diacritics, and insertion frames. Diacritics are features idiosyncratic to particular mor-

phemes that constrain their affixation possibilities. For example, the English suffix -ive can only attach to verbs marked [+Latinate], e.g. restrictive, but not *givive. The lexical entries for both restrict and the suffix -ive must contain the diacritic [+Latinate]. In Lieber's system, subcategorization information only refers to affixes and specifies what category of item an affix can attach to and what category it can produce. For example, un- attaches to adjectives and forms an adjective. Its subcategorization frame is represented as $[_A$ ____$[_A$. Insertion frames specify the syntactic frame into which a lexical item can be inserted, e.g. hit requires an NP object (Lieber assumes Bresnan's functional structures to represent insertion frames.)

Lieber's model is morpheme-based because complex words are not listed in the lexicon, and lexical rules operate on morphemes as well as words (see below). Lexical entries for affixes are identical to lexical entries for non-affix morphemes except for the presence of subcategorization information in affix entries. Selkirk (1982) also proposes that both roots and affixes have lexical entries. In Selkirk's model the only difference between affix and nonaffix morphemes is that the former are always bound and are labeled with the category "affix". Lieber's model does not contain the categories "stem" or "affix" because the subcategorization information stored in their lexical entries distinguishes between them. There are several types of formatives that are stored in the permanent lexicon according to Lieber's model. Bound roots such as -ceive have lexical entries as well as "cran" morphemes which do not have clear meanings (e.g.

cranberry, huckleberry). Lieber also proposes that inflectional stem allomorphs which fall into conjugation and declension classes are listed as lexical entries. It is with this proposal that Lieber departs from models which treat inflectional morphology as part of the syntactic component of the grammar (Anderson, 1982; Aronoff, 1976; Allen, 1978). Lieber, along with Selkirk (1982) and Williams (1981), include all inflectional processes within the lexicon.

Relations between lexical items in the permanent lexicon are expressed by morpholexical (ML) rules. Lexical items are organized by lexical classes which correspond to their declension or conjugational classes and are defined by ML rules. For example, unproductive German plurals (e.g., Geist sg., Geister, pl., "spirit") are listed as separate items and related by a morpholexical rule (Lieber, 1980: p. 26):

Morpholexical Rule 9: $C_oVC_o \sim C_o\ddot{V}C_or$

roots: Geist, Mann, Buch

stems: Geister, Männer, Bücher

Unlike Word Formation Rules (see below) ML rules cannot add new formatives to the lexicon. They do not combine morphemes into a word structure and can only refer to phonological form and not syntactic or semantic information. The function of ML rules is purely for classification.

In Lieber's model the lexical entry for a particular noun will list its class membership as defined by a Morpholexical rule, as well as the roots and stems related by the morpholexical rule defining the class. The stem allomorphs which are related to roots by ML

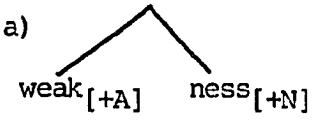
rules are listed in the lexicon as part of the lexical entry for the root forms. Note that only unpredictable stem allomorphy is listed in the permanent lexicon; for example, nothing in the form of the root Geist or Mann can determine that the correct plural forms are Geister and Manner.

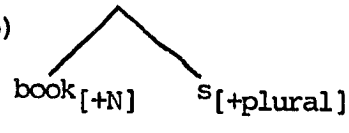
Lieber further proposes a second component in the lexicon -- the lexical structure component -- in which complex forms are generated by lexical structural (LS) rules. LS rules insert morphemes from the permanent lexicon into unlabeled binary branching tree structures. Insertion is subject to subcategorization restrictions, and only items from the permanent lexicon may be inserted. Furthermore, LS rules do not distinguish between inflectional and derivational morphology. In Lieber's model complex words have a hierarchical structure similar to phrases. These word structures are labeled by Feature Percolation and Labeling Conventions. For example, an LS rule first generates a binary branching tree without labels:

a) 

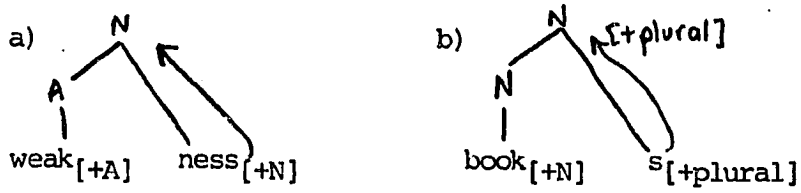
b) 

Insertion rules then insert stem and affix morphemes:

a) 

b) 

Finally, feature percolation and labeling conventions assign category labels to the structure:



Lieber proposes several percolation conventions which essentially ensure that potentially contradictory features do not clash and that the appropriate features percolate to the highest node.

The lexical models proposed by Selkirk (1982) and Williams (1981) also contain context free rewrite rules that generate lexical tree structures. However, in these models the nodes are generated with labels. The categories <u>root</u>, <u>stem</u>, and <u>affix</u> are primitives of this system. For example (from Williams, 1981):

root --> af root, root af
stem --> root
stem --> af stem, stem af
word --> stem
word --> word word

The differences in the rule systems proposed by Lieber (1980), Selkirk (1982), and Williams (1981) are not relevant to the questions addressed here. They differ in detail and explicitness with Selkirk providing the most elaborate theory of "word syntax". The relevant point is that these three lexical models contain rewrite rules and feature percolation conventions rather than Word Formation Rules (discussed below) to generate morphologically complex forms and posit separate lexical entries for stems and affixes unlike word-based models.

Lieber also argues for a third component in the lexicon which contains String Dependent rules which perform nonconcatenative mor-

phological operations such as reduplication, infixation, ablaut, and umlaut. These rules differ from Morpholexical (ML) rules in that they are productive, and unlike Lexical Structure (LS) rules, they must refer to the segmental properties of the base form to which they apply.

Note that none of the lexical rules proposed by Lieber play a role in determining the meanings of morphologically complex words. Although semantic representations are stored with lexical entries in the permanent lexicon, there is no mechanism for deriving complex semantic representations. Lieber assumes that lexical semantics is autonomous and not part of the morphological component of the lexicon.

Word-Based Models

In contrast to the morpheme-based models of Lieber, Selkirk, and Williams, Jackendoff (1975) and Aronoff (1976) propose models in which only words are stored in the lexicon. Bound morphemes like un-, -ive, or cran- do not have lexical entries. Jackendoff (1975) argues against what he calls an "impoverished entry" theory in favor of a "full entry" theory. The impoverished entry theory is similar to Lieber's in that only base forms (including bound roots) have lexical entries; for example, decide has a fully specified entry, and decision is not stored but rather derived by rule from its base form decide. In contrast, according to the full entry theory both decide and decision have lexical entries containing semantic, syntactic, morphological and phonological information. To account for the similarities between morphologically related words, Jackendoff proposes

Redundancy Rules which contain all of the information shared by the related words (see also Bybee, 1985).

Jackendoff (1975) presents two arguments in support of his full entry hypothesis: first, many derivational words are related idiosyncratically; that is, their semantic and/or morphological relationship cannot be easily predicted or described by rule. For example, the idiosyncratic meaning of transmission as a part of a car is not predictable from its component morphemes (Aronoff, 1976). Secondly, some derived forms have no base form from which they can be derived. For example, the forms aggression and retribution have "roots" that never appear on the surface, i.e. *aggress, *retribute. If stored in the lexicon these "roots" would have to be marked [-lexical insertion] to prevent them from appearing on the surface. Jackendoff argues against lexical entries that never appear as words, and he also argues against storing one complex form and deriving the other forms from it because problems arise in deciding which form is basic. For example, there is no nonarbitrary way to decide whether aggression, aggressor, or aggressive is more basic. Under the full entry theory one is not forced to choose a basic form because all complex forms would be listed. The full entry theory accounts for "rootless" forms and idiosyncratic semantics by listing the nonpredictable information with each entry, and the shared information between entries is accounted for by redundancy rules.

Aronoff's (1976) model maintains some aspects of Jackendoff's full entry theory, but he replaces redundancy rules with Word Formation Rules (WFRs). WFRs are similar to redundancy rules in that one

of their functions is to relate fully specified already existing words. In this capacity, WFRs analyze the structure of words listed in the lexicon. Unlike Jackendoff's redundancy rules, however, WFRs also account for the generation of new words. Furthermore, WFRs are unidirectional, whereas redundancy rules are bidirectional; that is, a redundancy rule expresses the symmetrical relation "is lexically related to". A WFR, on the other hand, operates on a base and produces an output. The base of a WFR is the set of words to which the rule can apply, and these words must be existing words; therefore, a possible but nonexistent word could not be the input to a WFR. Each WFR specifies the syntactic class to which its base belongs, and unlike Lieber's lexical rules, WFRs relate semantic aspects of words as well as their forms. The output of a WFR is a structure with labeled brackets in which the syntactic category of the base as well as the output are specified. WFRs may be subject to conditions on the form of the base to which they apply, and only items which meet the conditions may serve as bases for the WFR. For example, the WFR that attaches the suffix -able to transitive verbs to form derived adjectives such as breakable is formulated below:

$[X]_V$ --> $[[X]_V\text{able}]_A$

Condition: $[X]_V$ is transitive.

Syntax: object of $[X]_V$ corresponds to the subject of $[[X]_V]\text{able}]_A$

Semantics: $[[X]_V]\text{able}]_A$ = capable of being X-ed

As mentioned in Chapter one, WFRs are "once-only" rules. That is, once a new complex form is generated by a WFR, it is stored in the lexicon. By storing derived words in the lexicon after their

formation, Aronoff can account for semantic drift, that is, the ability of derived words to take on unpredictable meanings, e.g. transmission. Furthermore, WFRs are not operative in the on-line generation of a sentence, WFRs merely analyze existing words and add new words to the lexicon. However, Aronoff claims that not all new words are listed in the lexicon. The output of very productive WFRs are not stored in the lexicon. Aronoff's (1976) model differs from morpheme-based systems in that affixes do not have lexical entries. Affixes instead are represented as the Word Formation Rules that attach them to their bases.

A further difference between these models is the place of inflectional morphology in the grammar. Aronoff (1976; 1978) proposes that only derivational morphology should be represented in the lexicon and that WFRs involve only derivation. All inflected forms of a given lexical item are represented by a single lexical entry, and the allomorphs of that entry are spelled out in the syntax according to the configurational and agreement properties of the structure in which it appears. Only irregular inflectional allomorphs such as the forms of be are listed in the lexicon. In the models of Lieber, Selkirk, and Williams both inflectional and derivational operations take place in the lexical component of the grammar. Lieber (1980) and Williams (1981) maintain that inflectional and derivational morphology are essentially the same type of process and therefore should be represented in the same component. Anderson (1982), on the other hand, proposes that inflectional morphology is represented in several places in the grammar: the lexicon (idiosyncratic morphology), the

syntax (configurational and agreement phenomena), and the phonology (regular inflectional rules which may interact with phonological rules). Whether to separate derivational and inflectional morphology in the grammar and how to do so still remain controversial questions within linguistics.

By allowing irregular inflection to be listed in the lexicon, both Lieber (1980) and Anderson (1982) can account for the presence of irregular inflected stems in compounds and inside derivational morphology. In their models irregularly inflected stems can serve as bases for further word formation processes. For example, the inflected stem Männer feeds the German compounding rule which forms Männerkleidung "man's dress" (Lieber, 1980). Lieber (1980) can account for recent data from Slave, an athapaskan language, (Rice, 1985) and from Yiddish (Bochner, 1984) which indicate that regular inflectional rules can apply before derivational rules. However, neither Anderson (1982) nor Aronoff (1976) can account for these facts because in their models all regular inflection occurs after the operation of derivational rules. On the other hand, by allowing rules that spell out inflectional categories to mix with rules of phonology, Anderson can explain forms which result from a morphological rule feeding a phonological rule which in turn feeds another morphological rule. Anderson (1975) provides several examples in which inflectional rules must interact with phonological rules. Lieber's model cannot account for these facts since all inflection occurs in the lexicon prior to the operation of phonological rules.

The models proposed by Jackendoff (1975) and Aronoff (1976) are

capable of explaining the idiosyncratic semantics of derivational morphology. Lieber (1980) avoids the problems of unpredictable semantics by placing lexical semantics in a separate component but does not further elaborate this component; she offers no account of how complex lexical semantic structure is generated or represented.

In summary, I have discussed two major differences between word-based and morpheme-based models: 1) the unit of representation and 2) the place of inflectional morphology within the grammar. These issues are relevant to psychological models and will be addressed by the experiments presented in the following chapters. Some of the differences among the various models that I have presented will not be addressed directly by the experiments and do not bear directly upon processing models. For example, whether morphological rules should take the form of Word Formation Rules, redundancy rules, or rewrite rules will probably be best decided by linguistic data. It is unlikely that a processing experiment will be able to choose between these hypotheses; rather, further work on languages with complex morphological systems and arguments based on the ability of each rule type to account for the observed data are needed.

Psycholinguistic experiments may be relevant to the question of whether derivation and inflection should be separated in the grammar. In the experiments presented in the next chapters, I will examine whether this distinction is relevant to processing mechanisms at the level of word recognition. If inflection and derivation are distinguished by processing mechanisms, then linguistic models which also separate them would be supported under the type transparency

hypothesis.

The other issue I will investigate is the nature of lexical entries, i.e. the unit of representation in the lexicon. As stated above, word-based models assume that only words are listed in the lexicon and bound morphemes (in particular affixes) do not have lexical entries. The nature of the lexical rules within word-based models reflect these constraints on lexical representation because the rules only apply to words, not morphemes. In morpheme-based models, bound morphemes and affixes do have lexical entries, and the lexical rules proposed within these models reflect this fact. The priming experiments in Chapter six investigate whether affixes and words (or rather roots) have the same lexical status. Priming which is discussed in detail below is a technique that has been used to study the nature of lexical entries for psychological models of word recognition. If we find evidence that both roots and affixes exhibit the same priming effects, it would argue for a morpheme- over a word-based system.

The type of rules posited within linguistic models affects the nature of the lexical entries, and conversely the nature of the entries constrains the nature of the lexical rules. Similarly, within psychological models, the types of lexical access mechanisms can determine (in part) the nature of lexical entries and vice versa. In the following sections, I will describe and discuss some current models of auditory and visual word recognition and the lexical representations and access mechanisms that these models propose. As with the linguistic models, I will only discuss a few of the relevant

models, namely those that are representative of auditory or visual word recognition models with special attention to those that refer to the morphological properties of words.

Psychological Models

Auditory Word Recognition Models

The Cohort Model. Throughout the dissertation I will be most concerned with auditory word recognition, and the cohort model proposed by Marslen-Wilson and colleagues is one of the major models of auditory word recognition (Marslen-Wilson and Welsh, 1978; Marslen-Wilson and Tyler, 1980; Marslen-Wilson 1984; Marslen-Wilson, 1987). According to this model, word recognition is achieved in the following manner: the first one or two phonemes that are perceived serve to "activate" all words in the listener's lexicon which begin with that initial sequence, and these words form the "word-initial cohort". A word is recognized (in isolation) by matching the word candidates in this cohort with the incoming sensory information. When a mismatch occurs between the sensory input and a word candidate, that word drops out of the cohort[1]. This matching process continues until only one candidate remains which is consistent with the sensory input. At this point the listener is claimed to have recognized the word. When the word is heard in the context of an utterance, semantic and syntactic constraints are assessed along with the sensory input. Word recognition occurs when a single word candidate matches both the sensory and the contextual information. According to the cohort model, a word can be "recognized" even before the end of the word is heard if it is uniquely defined by context and

sensory information prior to the end of a word. For example, dwindle can be recognized when the [I] is heard since at this point it is uniquely distinguished from dwell and dwarf and all other English words.

Whether base forms or complex affixed forms in addition to base forms are stored in the lexicon will affect the size of the word-initial cohort and the point at which a word becomes distinct. For example, Emmorey and Fromkin (in press) observe that if the word Robert is heard in isolation, the candidate base morphemes compatible with the first syllable are robin and rob; Robert will be recognized at [ɚ] where it is the only remaining candidate compatible with the incoming stimulus. However, if affixed forms are also compared, the cohort will include robber, robins, robbing, robbed, and robbery. In this case, Robert will be recognized at [t] where it is distinguished from robber and robbery. If only base forms are accessed, recognition can occur earlier, thus how morphemes are stored will influence the recognition process.

Tyler and Wessels (1983) present some evidence suggesting that only base morphemes are contained in the cohort set used for recognition. As stated above, the cohort model predicts that at the point where subjects can uniquely identify a word (e.g. at [I] in the dwindle example above), only one candidate (i.e. dwindle) should remain in the cohort set. This prediction was best satisfied if only base forms were considered in a count of the possible cohort set for a given word in Tyler and Wessels' experiments. If all possible derived and inflected forms of a word were considered as part of the

initial cohort, the predictions of the model were not met; that is, when subjects were able to correctly identify a target word, more than one word candidate remained from the initial cohort set. If only base forms were included in the cohort set, then only one candidate (the correct one) remained at the point where subjects were able to uniquely and correctly identify the word. Tyler and Wessels suggested that "words were represented in the mental lexicon as base morphemes with inflectional and derivational markers attached to them (p. 418)." They further speculated that "when the base morpheme was accessed, all inflectional and derivational variations of that morpheme were also accessed (p. 418)."

These hypotheses about the representation and access of morphologically complex words are interesting, but the explanation of Tyler and Wessel's results rests solely upon the strength of the model; that is, the evidence is entirely theory internal. The experiments presented in Chapters three and four investigate the role of morphological complexity in auditory word recognition with particular emphasis on the predictions of the cohort model and the hypotheses put forth speculatively by Tyler and Wessels (1983).

The Logogen Model. The logogen model of Morton (1969; 1979) is one of the earliest models of word recognition and is proposed to account for both visual and auditory word recognition. The model is based on the concept of logogens which are passive recognition units that correspond to lexical items. A logogen contains semantic, syntactic, and phonological information and monitors for the sensory and contextual information appropriate to a given lexical item. When

enough information is collected, the logogen "fires" and becomes available to other processing systems. A logogen has a threshold which is affected by the number of times it has been activated. Frequency effects are accounted for by assuming that high frequency words correspond to logogens which have low response thresholds. According to the logogen model, word recognition is achieved when the activation threshold of a logogen is reached (and surpassed). Recently, Morton and his colleagues have proposed that separate logogens exist for visual and auditory word recognition (Morton, 1982; Jackson and Morton, 1984).

The logogen model is vague about the nature of the logogen representations and their functions. Pisoni and Luce (1987) remark that the logogen theory "says very little, if anything, about precisely how acoustic-phonetic and higher-level sources of information are integrated, the time-course of word recognition, the nature of the perceptual units, or the role of the lexicon in word recognition (p. 40)." Nonetheless, the notion of recognition units with activation thresholds has remained a major hypothesis concerning the representation of lexical items. Assuming that some type of recognition unit exists, one question raised here is whether recognition units correspond to words or to morphemes. The priming experiment presented in Chapter six was designed in part to address this question.

This dissertation is primarily concerned with auditory word recognition, but it is nevertheless necessary to discuss models of visual word recognition. Although the lexical access mechanisms of visual and auditory processing must of necessity differ, many have

argued that the lexical representations that are accessed during reading and listening are essentially the same (Bradley and Forster, 1987). Furthermore, more attention has been paid to the role of morphology in visual word recognition. In Chapter five, visual and auditory word recognition are compared directly using the same stimuli in an effort to explore the nature of these two recognition procedures and to investigate whether the same representations are accessed.

Visual Word Recognition Models

The Addressed Morphology Model. Caramazza, Miceli, Silver, and Laudanna (1985) propose a lexical model which contains two access procedures for reading morphologically complex words -- a morphological parsing address procedure and a whole word address procedure. These two procedures comprise the Lexical Address System which is distinct from the orthographic lexicon. The orthographic lexicon stores words in a morphologically decomposed form with root morphemes represented independently of affixes, although the root morpheme representations include specifications for permissible affixes.[2] The whole word address procedure operates directly on whole words in a passive, logogen-like activation manner (see above). The activated whole word address specifies a morphologically decomposed root morpheme and affix representation in the orthographic lexicon. The other process, the morphological parsing procedure, operates in parallel with the whole word procedure and also functions by passive activation. The parsing procedure is assumed to be more complex and slower than the whole word procedure, but is required explain how new

morphologically complex words are read. Known words are processed by activation of a whole word entry in the Lexical Address System which serves to address the morphologically decomposed orthographic lexicon. The Lexical Address System does not need to ascertain beforehand whether a word is new or known because the whole word procedure (for known words) and the morphological parsing procedure (for new words) operate in parallel. A simplified version of the Addressed Morphology Model is given in Figure 2.1:

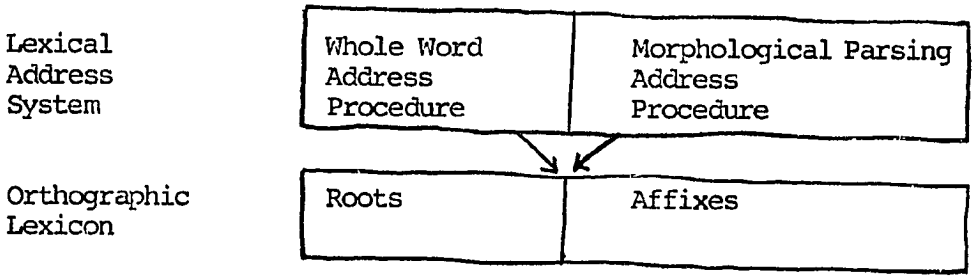


Figure 2.1. A simplified illustration of the Addressed Morphology Model.

Since the effects of the morphological parsing procedure for words are masked by the more efficient whole word procedure, support for the morphological parsing procedure is based on evidence from the processing of nonwords. Laudanna and Burani (1985) report that Italian subjects took significantly longer to reject nonwords that contained real root or suffix "morphemes" in a lexical decision task. For example, nonwords made up of two morphemes (e.g. cantevi: cant- "to sing") and an inappropriate inflection -evi) took longer to reject than nonwords with only one morpheme (e.g. canzevi; canz is not a real root.) Both of these nonword types took longer to reject than nonwords which contained neither a root nor a suffix (e.g.

canzovi). Laudanna and Burani explain this pattern of results as attempts of the morphological parsing system to analyze the nonwords as words. Caramazza et al. (1985) present a similar explanation for the errors of a dyslexic patient reading the same nonword types.

Caramazza et al. (1985) propose that known words are processed by activating a whole word entry which addresses the morphologically decomposed orthographic lexicon. For example, the word walks activates an address unit corresponding to the whole word walks which serves to access the root walk and the verbal suffix -s in the orthographic lexicon. However, if this whole word procedure is how words are normally accessed, more must be said about how the whole word units access the stored decomposed representations. In addition, such a procedure means that words are represented twice in the processing system -- once as a whole word unit in the address system and once in a decomposed form in the orthographic lexicon. In Chapter five, I will discuss the Addressed Morphology Model in more detail and present an alternative to the whole word address procedure.

The Addressed Morphology Model contains parallel processing systems and logogen-like representation in the lexicon. The following model proposes a serial search system and an active affix stripping process rather than the passive activation of recognition units.

The "Affix Stripping" Model. Taft and Forster (1975) propose a a model of the lexicon in which prefixed words do not have separate entries but are accessed by their root. According to this model, prefixed words are recognized in the following manner:

1. Recognize that a prefix is present and remove it for lexical search.
2. Search the lexicon for the root.
3. When the root is found recombine it with the prefix to form the word -- at this point recognition occurs.

This procedure is based on evidence which indicates that nonwords derived from prefixed words (e.g. vive from revive) take longer to reject in a lexical decision task than nonwords derived from pseudo-prefixed words (e.g. lish from relish). Taft and Forster (1975) argue that the root vive is initially found in the lexicon but rejected with post access checking of the combination of the root and prefix. The nonword lish can be rejected immediately since there is no root lish represented in the lexicon. Taft and Forster (1975) are not explicit about how the prefix string itself (e.g. re-) is recognized prior to being removed. Presumably, prefix representations are stored separately and matched with the initial string of a word, and when a match occurs the prefix is stripped and the root accessed. If no match occurs (i.e. the word is neither prefixed nor pseudoprefixed), the root is accessed directly.

Taft (1979) further proposes that suffixed words are also accessed by their root morphemes and undergo the same "affix stripping" analysis as prefix words. However, if the lexicon (or in this model the peripheral file, see Forster, 1976) contains base forms which are found by stripping off the affixes, what happens when suffixation changes the form of the base? For example, when accessing destruction, -ion is stripped off, but what base form is acces-

sed, destruct or destroy? If destruct is accessed, the processor gains no efficacy with morphological decomposition because both destruct and destroy must be stored. If destroy is stored, it is not clear how the processor would compute the base from its derived form destruction. It can be argued that the affix stripping process is only economical for derived (and inflected) words in which the phonological form of the base has not been changed. The experiment presented in the following chapter investigates whether some type of affix stripping might occur with auditory word recognition.

Summary

The purpose of this chapter was twofold. The brief discussion of some of the lexical models proposed in linguistics and psychology was included to provide some background to recent work concerning the role of morphology in processing and linguistic models. The second goal of this chapter was to investigate some issues common to the two fields. An important question that has not been resolved by any of the models proposed to date is whether the unit of representation in the lexicon is the word or morpheme or some combination of both. Linguistic models differ as to whether affixes are listed as lexical entries; psychological models have not addressed this question, although it would appear to be significant to them.

Another issue is whether morphologically complex words are computed by rule. If only roots are stored in the lexicon, then complex words must be analyzed morphologically by some process in order to be recognized. Determining whether or how morphological parsing might occur has implications for both processing and linguis-

tic models. Although linguistic models are not proposed as performance models, they must account for speakers knowledge of words. This knowledge is most likely used during word recognition and may determine what type of morphological analysis procedures operate when complex words are recognized.

Finally, the organization of lexical entries and the representation of morphologically related words is of importance to both linguistics and psychology. How much lexical information is accessed when a word is recognized? What is the role of semantics in determining morphological relationships? The experiments presented in the following chapters are designed to answer these questions and to help resolve the other issues discussed above. It is hoped that by bringing together linguistic and psychological models of the lexicon, a better understanding of the lexicon and lexical processes will be achieved.

Chapter 3

Evidence for On-Line Morphological Parsing

There is considerable evidence that the linguistic processing system differentiates between affixes and word stems. Fromkin (1971) presents speech error evidence which indicates that stem morphemes and affixes operate as independent speech units. For example, stem morphemes can be exchanged leaving behind a suffix -- "a floor full of holes" becomes "a hole full of floors". Garrett (1980) shows further that affixes and word stems exhibit different speech error patterns. Word stems often participate in exchange errors (as in the above example), but affixes seldom if ever do. Affixes, on the other hand, often participate in shift or movement errors (e.g. "that would be the same as adding ten" --> "... add tening") but word stems (of major grammatical categories) rarely do.

Aphasia data also indicate that affixes and base forms are processed differently. Buckingham (1981) discusses patients who produce jargon forms which are appropriately inflected:

a) The leg [vIltəd] from here down.

b) This is the [kreibəkaeks] where the [frəǰəz] get out after the [čuw].

In these examples nominal suffixes attach to "nouns" in noun phrases and verbal suffixes attach to "verbs". The jargon primarily affects the lexical or root morphemes. In addition, Broca's aphasics classically have difficulty producing grammatical suffixes but can produce the correct root morpheme (Goodglass and Kaplan, 1972). These patterns of performance again indicate that grammatical affixes and

lexical morphemes function differently within the linguistic system.

However, the representation of morphological structure and how it is accessed in the mental lexicon remain unclear. In Chapter two I described a model proposed by Taft and Forster (1975) and elaborated by Taft (1979) for the recognition of visually presented morphologically complex words which I termed the Affix Stripping Model. If the recognition of bimorphemic words takes longer than monomorphemic words, this would support the Affix Stripping Model because the increased duration could be due to the additional processing time required for affix stripping (cf. Caramazza et al. 1985). If no difference between these word types is found, however, we cannot conclude that affix stripping does not take place since parallel processing may occur.

A second question investigated was Taft and Forster's predication that pseudoaffixed words (e.g. invite; temper) take longer to process than true affixed words (e.g. insane; winner) because the pseudoaffixed words are initially misparsed as affix+root (or root+affix). Since the "root" of a pseudoaffixed word (e.g. *vite) is not in the lexicon, a second search must occur for the whole word (invite); thus, recognition of pseudoaffixed words would be delayed. In the experiment reported below both true and pseudoaffixed words were included to test this hypothesis. Note that recognition of pseudoaffixed words should be delayed in comparison to both monomorphemic and bimorphemic words because pseudoaffixed words require a second search of the lexicon which is not required for monomorphemic or bimorphemic words. If these results are observed, it will argue

for mandatory morphological decomposition prior to lexical access.

A third question addressed by the experiment was whether the linguistic distinction between derivational and inflectional morphology is relevant to processing mechanisms at the level of word recognition. Other psycholinguistic studies have treated inflectional and derivational morphology as a single category, using both derived and inflected words as stimuli (Manelis and Tharp, 1977; Henderson, Wallis, and Knight, 1984). As discussed in Chapter two, whether inflectional and derivational morphology are distinguished in a processing model has implications for linguistic models of the lexicon.

Finally, word recognition of both prefixed and suffixed words was also investigated. Cutler, Hawkins, and Gilligan (1985) propose an explanation for the purported "preference" for suffixation in the world's languages based in part on processing constraints. They argue that roots are processed prior to affixes, and thus roots are favored to be in the most salient position of the word -- the beginning. In determining the entire meaning of the word from its parts, the root has computational priority over the affix. In prefixed words the root is not in the most salient initial portion of the word, and the point at which the root may be recognized will be delayed. Based on this proposal, I hypothesize that recognition of prefixed words will be delayed compared to suffixed words.

To summarize, the following questions are addressed in the attempt to determine the role, if any, played by morphological complexity in linguistic processing:

1. Does internal word structure influence recognition time? That is,

do bimorphemic words take longer to recognize than monomorphemic words? If words are parsed into root and affix prior to accessing the root in the lexicon, this procedure might require some processing time slowing the recognition of bimorphemic words.

2. Is parsing "misled" by pseudoaffixed words like invite or temper? If these forms have to be reanalyzed, we would expect longer recognition times for pseudoaffixed words compared to monomorphemic words.

3. Is there a distinction between derivational and inflectional morphology present in processing at the level of word recognition?

4. Do we find a difference between prefixed and suffixed words in recognition time? If the root must be accessed prior to word recognition, then prefixed words might take longer to recognize because the root follows the prefix.

Method

144 words and nonwords were recorded by a male native Californian on one channel of a tape, and a tone which began a reaction time counter and corresponded to the beginning of the stimulus was recorded on the other channel. The interstimulus interval was 4 seconds. 20 Subjects wearing headphones heard the channel with the stimuli binaurally, decided if a given stimulus was a word, and pressed a telegraph key marked "yes" or "no" which stopped the timer.

Stimuli

The words formed the following categories (see Appendix A):

Words		Example
1. Suffixed (24)	inflected (12)	chosen
	derived (12)	winner
2. Pseudosuffixed (12)	"inflected" (3)	garden
	"derived" (9)	temper
3. Prefixed (12)		insane
4. Pseudoprefixed (12)		invite
5. Control Monomorphemic (12)		rabbit

There was an equal number of words and nonwords. All words were matched for spoken word frequency (Dahl, 1979), number of syllables, and number of phonemes. Although the words were not matched for written word frequency, there was no significant difference in written frequency between word categories ($F(5,66)=.92$, $p>.1$) using Carroll, Davies, and Richman (1971). A pseudoaffixed word was defined as a word containing a phonological string which resembles an affix but is not an affix (e.g. temper in which the final -er is the pseudosuffix) or a word that contains an historical affix which carries no semantic weight (e.g. the im- of imply). The pseudosuffixed words were generally of the former type and the pseudoprefixed of the latter. The roots of all affixed forms were free morphemes. Syllable structure was controlled to the extent that no word (or nonword) began with a consonant cluster (except for prestige). The stress pattern was held constant within a word category. It was impossible to control for stress placement across categories because prefixed (and pseudoprefixed) words almost always have second syllable stress. Cutler and Clifton (1984) found that the reaction time difference between words with first and second syllable stress is due

to acoustic length, and the effect of word length can be compensated for by using regression techniques.

The nonwords were constructed by changing one or two phonemes of a real word. The number of nonwords with first or second syllable stress was the same as for the words. Nonwords did not contain affixes.

Subjects

20 unpaid volunteers from undergraduate linguistics courses at UCLA participated in the experiment. Half of the subjects heard the stimuli in one order and half heard the stimuli in the reverse order.

Procedure

There were 18 initial practice items followed by the actual (randomized) list of stimuli with no break between the practice stimuli and the test stimuli.

Results

Errors and extreme reaction times (above 3000) were excluded from the analysis. A one-way covariate analysis[1] was conducted with word length as the covariate. A significant difference was found between the word categories ($F(5,1297)=2.49$; $p<.03$), and reaction time was significantly correlated with acoustic word length ($r=.22$; $p<.001$). Although words were matched for number of phonemes and syllables, acoustic length varied between word categories. With the covariate analysis, however, any effects of acoustic length were factored out. Mean reaction times for each category are presented in Figure 3.1.

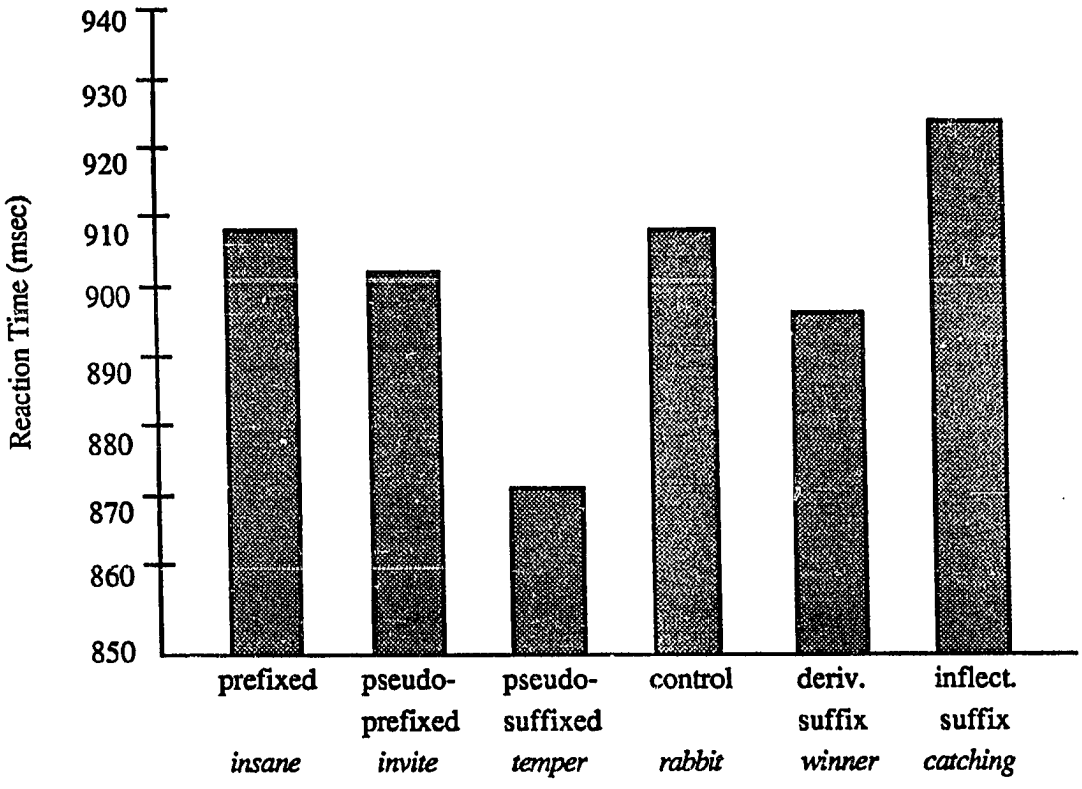


Figure 3.1. Lexical decision times when RT is measured from word onset.

Bimorphemic vs. Monomorphemic Words

Planned Comparison analyses revealed no significant difference between bimorphemic and monomorphemic words (F(1,867)=.11, n.s.). Pseudoaffixed words were not included in this analysis although they are monomorphemic because they may influence reaction time due to their structure, and the goal was to compare monomorphemic words with bimorphemic words uncontaminated by such possible effects. The mean reaction time for monomorphemic words was 906 msec;[2] and the mean reaction time for bimorphemic words was 911 msec.

Pseudoaffixed vs. True Affixed Words

Pseudoaffixed words were not recognized more slowly than true

affixed words but were in fact recognized more quickly ($F(1,1085)=4.49$; $p=.03$). The mean reaction times were 887 msec for pseudoaffixed words and 911 msec for true affixed words.

When the pseudoprefixed and pseudosuffixed results are considered separately, we find no difference between pseudoprefixed and true prefixed words ($F(1,435)=.14$, n.s.) and pseudosuffixed words are recognized faster than true suffixed words ($F(1,647)=11.99$, $p<.001$).

Inflected vs. Derived Words

There was no significant difference in reaction time between inflected and derived words ($F(1,433)=1.72$, n.s.). The mean reaction time for inflected words was 920 msec and 897 msec for derived words.

Prefixed vs. Suffixed Words

No significant difference in reaction time was found between prefixed words ($\bar{x}=919$ msec) and suffixed words ($\bar{x}=911$ msec) ($F(1,652)=.27$; n.s).

Discussion

The results from the pseudoaffixed words will be discussed first. Recall that Taft and Forster (1975) hypothesized that any string resembling a prefix is stripped off prior to lexical access; thus, pseudoprefixed words (e.g. invite) should take longer to recognize than true prefixed or monomorphemic words because the "prefix" is erroneously stripped off. That is, according to their model, when no root is found (*vite is not a root) a second search must occur for the recombined form (invite) which should cause a delay in recognition time. The results of this experiment do not support this serial search process for auditory word recognition -- the recognition of

pseudoprefixed words was not delayed in comparison to true prefixed words or control (monomorphemic) words.

However, Taft and Forster (1975) and Taft (1979; 1981) in their experiments considered historically prefixed words as prefixed words. They made no distinction between words whose morphological analysis resulted in syntactic or semantic information relevant to the meaning of the word and those words whose morphological structure was an historical relic. For example, Taft (1981) considered deprive and replica as prefixed bimorphemic words which were compared to devout and regime which were considered pseudoprefixed monomorphemic words.

The pseudoprefixed words used in the experiment discussed here are all historically prefixed (Klein, 1966), but of the pseudosuffixed words only motive is historically suffixed. If we assume that historically prefixed words are stored in the lexicon by their root, then our results do not disconfirm the Affix Stripping model. Instead, the results suggest that neither semantic compositionality nor the boundedness of the root affect word recognition time. No difference in lexical decision time was observed between semantically compositional prefixed words with free roots (e.g. insane) and semantically noncompositional prefixed words with bound roots (e.g. invite).

However, if word recognition mechanisms distinguish between historical prefixes and phonological strings that simply resemble prefixes as the Taft (1981) results suggest, it is not clear how the child comes to store the roots of historical prefixes in the lexicon but not "pseudoroots" of words that sound/look as if they begin with

prefixes. That is, how does the speaker/hearer learn that prive (from deprive) is a root in the lexicon but vout (from devout) is not?

As for the pseudosuffixed words, these were recognized faster than any other word category. The Affix Stripping model predicts that these words should be recognized more slowly than both control (monomorphemic) words and true suffixed words. On the other hand, a model in which affixes are not stripped predicts no difference between pseudosuffixed words and control monomorphemic words. The results of this experiment, however, show control words as the most different from pseudosuffixed words!

The Cohort model for auditory word recognition proposed by Marslen-Wilson and colleagues (Marslen-Wilson and Tyler, 1981; Marslen-Wilson, 1984) may provide an explanation for this result. This model is described in more detail in Chapter two. The aspect of the model that is relevant here is the hypothesis that a word can be recognized quite early before the end of the word is heard. According to this model, a word can be recognized when it becomes unique and is distinguished from its initial cohort. The example given earlier was dwindle whose initial cohort consists of dwarf, dwell, and dwindle. At the vowel dwindle becomes unique and is distinguished from dwarf and dwell.

If the uniqueness point for the pseudosuffixed words occurs earlier in the word than in the control words this might account for the results. That is, the pseudosuffixed words might have been recognized faster not because of their morphological structure, but

because they were distinguished from their cohort earlier than the control words. This is not necessarily a property of pseudosuffixed words, but may have happened by chance in selecting these particular stimuli.

To investigate this possibility, the uniqueness points of the stimuli were estimated using Kenyon and Knott (1953). The duration from the beginning of the word to the beginning of the phoneme which distinguished the word from the rest of the cohort was then subtracted from subjects' total reaction time. In this manner, reaction time from when the word became unique could be determined. For example, lobster becomes unique at /s/ where it is distinguished from lobby and lob; the duration from the beginning of the word to /s/ was subtracted from the reaction time of each subject. For suffixed words, the uniqueness point was determined for the root. For example, the root of jumpy becomes unique at the /p/ where it is distinguished from jumbo and jumble. Tyler and Wessels (1983) present evidence suggesting that only base forms are included in the cohort set used for recognition, therefore, we did not consider jumpy to become unique at /i/ when it is distinguished from jump. This is a logical assumption since if suffixed words become unique when they are distinguished from the root (i.e. jumpy from jump), then all other words must become unique word finally where the root is distinguished from possible suffixed forms, e.g. insane from insanely or rabbit from rabbits.

In addition, to discover whether the remaining duration of the word after the uniqueness point was a factor, a correlation between

reaction time and remaining duration was performed.

Results of Uniqueness Point Analysis

Reaction time was significantly correlated with remaining word length ($r=.40$; $p<.001$). A one-way covariate analysis with remaining duration as the covariate showed a significant difference between word categories ($F(5,1297)=10.13$; $p=.001$). Mean reaction times for each category are shown in Figure 3.2.

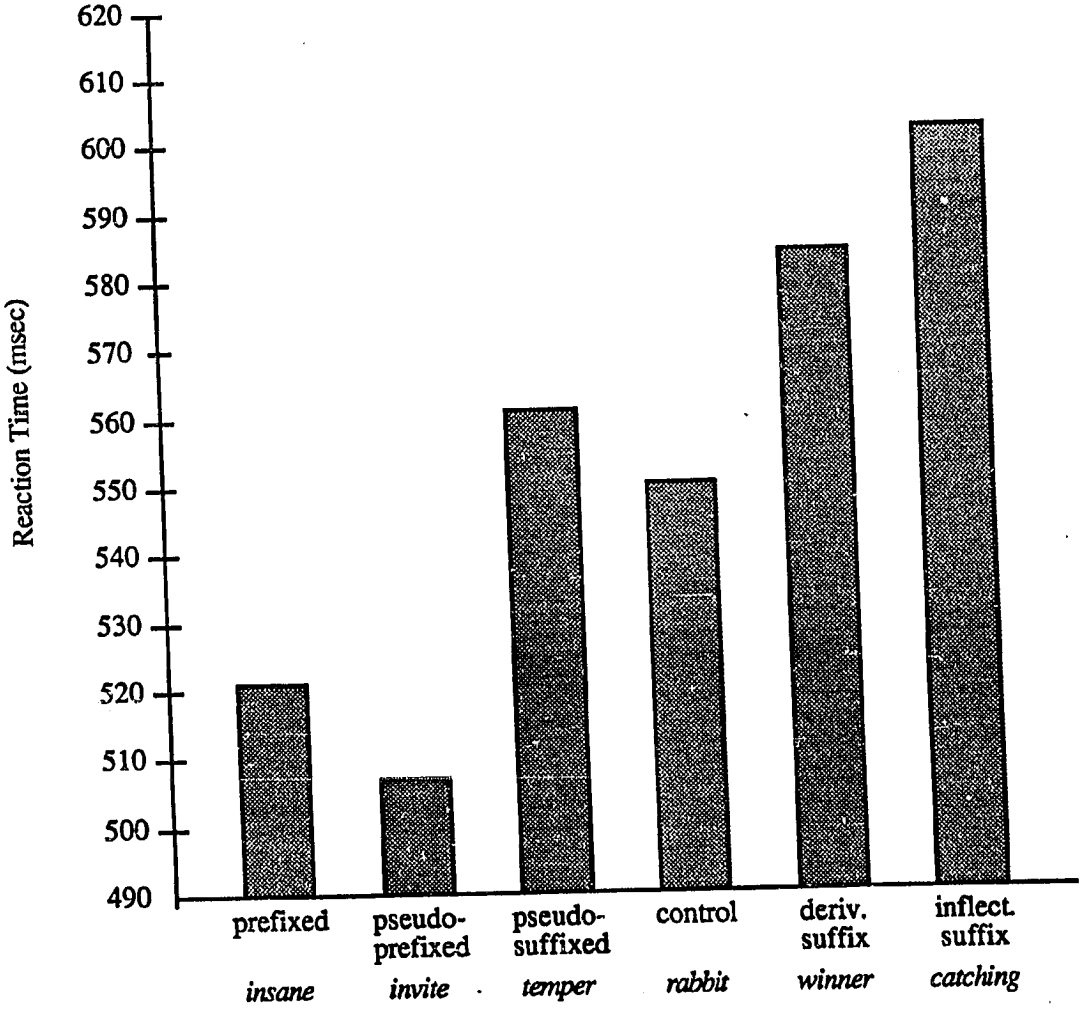


Figure 3.2. Lexical decision times when RT is measured from uniqueness point.

The results suggest that the reaction time difference between the control words and the pseudosuffixed words (both of which are monomorphemic) was due to the pseudosuffixed words becoming unique earlier than the control words. Pseudosuffixed words were distinguishable an average of 71 msec earlier than control words. When this factor is adjusted by measuring reaction time from the uniqueness point the difference in recognition time disappears.

Furthermore, when reaction time is measured from the uniqueness point, several effects of word internal structure are observed.

Suffixed Words

Suffixed words took longer to recognize than both control words ($F(1,649)=16.57$; $p<.001$) and pseudosuffixed words ($F(1,647)=6.27$; $p<.01$). Again, no lexical decision time difference was found between words with inflectional and derivational suffixes.

Prefixed Words

Both prefixed and pseudoprefixed words were recognized faster than control words ($F(1,651)=9.37$; $p<.002$). In fact, prefixed and pseudoprefixed words were recognized faster than all other word categories. Again, no reaction time difference was observed between the prefixed and pseudoprefixed words themselves.

Discussion and Conclusion

The fact that pseudoaffixed words were not recognized more slowly than monomorphemic words (under either analysis) is evidence against Affix Stripping model as proposed by Taft and Forster (1975) and Taft (1979). Furthermore, these results agree with those found by Henderson et al., (1984) using visual lexical decision. Henderson

et al. also found no difference between pseudoaffixed words and control words and proposed that the Affix Stripping model be revised such that both the unanalyzed form (e.g. massive; motive) and the root of the decomposed form (e.g. mass; mot) are searched for in parallel. The model proposed by Taft and Forster (1975) assumed that a serial search occurred first for the root, and if this search failed the entire word was searched for in the lexicon. Parallel processing predicts no difference between pseudoaffixed and control monomorphemic words. If a parallel search occurs, one analysis may fail (e.g. mot+ive), but the other (whole word) search will succeed (e.g. motive), and no processing cost for misanalysis will be incurred. However, these negative results also support a model in which no affix stripping occurs at all -- such a model also predicts no difference between pseudoaffixed and control monomorphemic words. Other evidence must be presented before an affix stripping model can be adopted for auditory (or visual) word recognition.

Recognition time was delayed for bimorphemic suffixed words, but I propose that the response delay for these words was not due to affix stripping prior to lexical access; rather I suggest that the delay was due to the on-line morphological analysis of suffixed words. Suffixed words only took longer to recognize when reaction time was measured from the uniqueness point of the root. Under this analysis, what was being measured was the time to confirm the expected word for monomorphemic words compared to the time to recognize the suffix in suffixed words. That is, if only roots are contained in the cohort set used for recognition (as Tyler and Wessels' (1983)

results suggest), then suffixes must be accessed and recognized after the root is identified. Once the root is identified, the incoming sensory information is matched with the stored suffixes. This additional matching procedure delays recognition for suffixed words compared to monomorphemic words. For monomorphemic words (e.g. lobster, rabbit), the word is potentially recognizable at the uniqueness point (e.g. at /s/ for lobster), and the access mechanism merely matches the remainder of the word with the incoming stimulus.

For example, the monomorphemic word lobster is recognizable at /s/ where it is distinguished from lobby and lob. No other word begins "lobs". From that point on, subjects simply match the remaining incoming stimulus /tər/ with the expected stored representation (i.e. [labstər]). For suffixed words, the root is first distinguished from the cohort set containing roots, but then the suffix must be recognized and accessed. For example, as mentioned earlier the root of jumpy is recognizable at the /p/, but after this point there are several suffixation possibilities which are not predictable in isolation, jumping, jumps, jumper, etc. Lexical decision times for suffixed words were longer than for monomorphemic words because after the uniqueness point, monomorphemic words only needed to be confirmed, whereas a second recognition task was required for suffixed words. Recognition of the suffix is a separate process which could take longer than the simple confirmation of the rest of an expected word.

Suffixes may be stored with the root as suggested by Tyler and Wessels (1983) or in a separate subcomponent in the lexicon. Several

investigators have proposed that affixes are stored separately in the lexicon (Bradley, Garrett, and Zurif, 1980; Garrett, 1980; Caramazza et al. 1985), and some computational models of the lexicon also contain separate sublexicons for suffixes and roots (Karlsson and Koskenniemi, 1985; Hankamer, 1986). If suffixes have representations that are stored in a separate component, this organization implies that the same representation is accessed each time a suffix is heard. If this is the case, we would expect to find priming effects for words that share the same suffix, e.g. blackness should prime shortness. If each root entry contains the suffixes that are allowable for that root, no priming should occur because the suffix representation is not shared. That is, the same suffix representation is not accessed when blackness and shortness are heard because both roots store a separate representation of the suffix ness. These two possible lexical organizations are represented in Figure 3.3.

Suffixes Stored with the Root

black -ness, -ish -er, -en short -ness, -er -en, -ly

Suffixes Stored in a Separate Component

black short	-ness -ish -ly -er -en

Figure 3.3. Two Possible Representations of Suffix Morphemes.

Note that even if suffixes are stored with there roots, there may still be a separate affix component that is not used during on-line word recognition. This affix component would account for our ability to create and interpret new morphologically complex words. These

possible representation systems will be discussed in more detail in Chapter six.

Finally, access to either the suffix component or the suffixes stored with the root may be constrained by the temporal order of speech perception. A root must first be distinguished from the cohort set before access to suffix representations is possible. This constraint prevents misanalysis of some pseudosuffixed words because the root (i.e. the pseudosuffixed word itself) is encountered first, preventing access to any suffix representations. For example, the entire root heaven is initially found in the lexicon which prevents the misanalysis heav+en. No root heav ([hEv]) exists which might cause the parsing mechanism to search for a suffix. However, of the 12 pseudosuffixed words 8 contained an initial string that corresponds to a word root (e.g. lob in lobby and lobster). The parser may be misled by a "false" root and attempt to locate a suffix, but should this misparse cause a delay in recognition? If analyses were attempted serially, one might predict a delay -- for example, lob in lobster can be parsed as a root, and when no appropriate suffix is heard, the incoming stimulus may be then reanalyzed as a monomorphemic root.

However, the recognition of pseudosuffixed words was not delayed in comparison to control monomorphemic words as is predicted by such an analysis. Therefore, I propose, along the lines of Henderson et al., that parallel analyses are conducted, one fails (lob+ster) and one succeeds (lobster). The search conducted in the root component succeeds, but the parsing analysis fails. For true suffixed words

only the parsing analysis succeeds by accessing the root jump in the root component and subsequently identifying the suffix y. The parallel search in the root component for a root "jumpy" fails because jump not jumpy is stored there. Pseudosuffixed (monomorphemic) words and control monomorphemic words can both be recognized when they are distinguished from other possible roots in their cohort set; thus, when reaction time between these words is measured from uniqueness point no difference in recognition time is observed. Lexical decision times to suffixed words are longer because suffixed words must be recognized by the slower parsing procedure. The root must first be identified, and then the suffix can be accessed and recognized. The parse traces for jumpy and lobster are shown in Table 3.1.

TABLE 3.1. Parse Traces for jumpy and lobster.

Suffixed Word: jumpy			
Incoming Stimulus:	ǰʌm[a]	ǰʌmp	ǰʌmpi
Cohort Set:	jump jumble jumbo	jump	-y -s -er -ing
Process:	No root matches full incoming form [ǰʌm], continue matching.	jump is only remaining candidate consistent with input, check for suffixes.	Suffix -y matches input.[b]

Pseudosuffixed word: lobster				
Incoming Stimulus:	lab	labs	labst	labstɚ
Cohort Set:	lobby lobster lob	lobster	lobster	lobster
Process:	lob matches full incoming form, check for suffixes.	lobster is only remaining candidate consistent with input. lob + suffix analysis fails.	Continue to match incoming form with remaining candidate	

[a]For the sake of illustration, the input stimulus begins with the first three segments rather than with the very beginning of the word. Also, phonemes are given as the incoming stimulus to simplify the illustration, although the matching process may operate upon a more phonetic representation.

[b]The data do not allow us to determine whether all suffixes are accessed or only those appropriate for the root.

Finally, although prefixed words are bimorphemic, response times to both prefixed and pseudoprefixed words were faster than for any

other word category. Subjects may have been biased to respond "word" when they recognized the prefix. None of the nonwords contained prefixes, thus when the subject heard a prefix he/she may have been more biased to respond "word" compared to the other word types.

This advantage for the prefixed words may have been masked when the uniqueness point of the word was not considered because prefixed (and pseudoprefixed) words became unique later than other word categories (by about 75 msec). This delay may have obscured the bias to decide that the item was a word. I hypothesized in the introduction that prefixed words might be recognized more slowly because their roots may have to be accessed first, thus slowing the identification of prefixed words. The potential identification of the prefixed words used here was delayed by about 75 msec, but this was compensated for by a lexical decision strategy. The data suggest that prefixes must have been recognized before the entire word was heard in order to bias the response. Apparently, subjects did not wait until the end of the word before analyzing it morphologically. However, the data do not allow a choice between a model of the lexicon which stores prefixed words separately from their roots (with their morphological structure marked in some way, e.g. in+sane) and a model which contains a prefix stripping process prior to access of the root in the lexicon. In both models, prefixes can be recognized early and thus bias the subject to respond "word".

Additional support for the hypothesis that listeners do not wait until the end of the word to begin the recognition process is found in the correlation data from reaction time and word duration. Reac-

tion time was positively correlated with word duration when measured from word onset ($r=.22$, $p<.001$) indicating that the longer the word, the longer the decision time. However, reaction time was negatively correlated with word duration when measured from word offset ($r=-.52$, $p<.001$). Jarvella and Meijers (1983) found the same pattern of correlations for Dutch. When recognition time is measured from word offset longer words produce faster decision times. This can be accounted for if listeners begin processing words before their offset since they would have more time to process longer words.

Note also that reaction time was not constant from the point at which the word could be recognized (i.e. the uniqueness point) but varied with the remaining duration of the word. Apparently subjects waited to confirm that the stimulus was in fact the word they expected. That is, reaction time from the uniqueness point was correlated with remaining word duration because subjects waited to confirm the rest of the word before making their lexical decision. This result is not surprising in light of the requirements of the lexical decision task. Words may "become nonwords" with a change in the final segments of the word. When subjects were asked informally about their false-positive errors, they often replied that they expected a particular word and had decided too quickly.

This finding does not disconfirm the cohort model but reflects the nature of the task demands for lexical decision. Marslen-Wilson (1984) using a nonword detection task found that reaction time was constant after the "rejection" point and did not correlate with the remaining duration of the stimulus. In a nonword detection task,

subjects indicate when a given stimulus becomes a nonword. For example, shimderence becomes a nonword at /d/ where it deviates from shimmer. Lexical decision differs from this task in that subjects have reason to delay their response after a word has been distinguished from the cohort because it may turn out to be a nonword, whereas in the nonword detection task subjects need not delay their response after a deviation from possible words is detected. The explanation offered here for the difference in correlation results for these two tasks makes a specific prediction about the correlation between reaction time and duration for words and nonwords. The correlation should be weaker for nonwords than for words because once a nonword deviation is detected (i.e. when the stimulus deviates from all possible words) subjects can make their lexical decision confidently -- the stimulus once deviated cannot then "become a word". However, a word may still become a nonword after the uniqueness point, thus subjects may delay their response. Reaction time was not measured for nonwords in this experiment, but it was measured in Experiments 2 and 3. The results from both experiments support the prediction.

In summary, the results of the experiment reported here suggest a model of auditory word recognition which parses the morphological structure of words on-line. Evidence was found indicating that the internal structure of prefixed words is determined during lexical access. Lexical decision times to prefixed words were faster than for other word types suggesting that subjects were able to recognize prefixes before the word offset and use this knowledge to bias their

lexical decision. There was no evidence suggesting that the parsing procedure was misled by pseudoaffixed words. I hypothesized that if misparses occur during auditory word recognition, they occur in parallel with the correct parse. Finally, lexical decisions to suffixed words were longer than monomorphemic words when reaction time was measured from the uniqueness point of the word. Under this analysis, what is essentially being measured (in addition to decision time) is the time to recognize the suffix in suffixed words compared to the time to match the end of the expected word with the remaining stimulus for monomorphemic words. Suffix recognition appears to be a separate process which takes longer than confirming the rest of an expected word. The evidence suggests that only roots are contained in the cohort set used for recognition, and the recognition of the suffix occurs after the root has been identified.

However, some suffixed words became unique at the suffix, for example the root harm in harmful cannot be uniquely identified at the root, but at /f/ where it is distinguished from harmony. Because the uniqueness point for the root of suffixed words varied, another experiment was designed in which the roots of all suffixed words become unique prior to the suffix (e.g. droop in drooping becomes unique at /p/ where it is distinguished from drool and druid). With this control we can be sure that the root is uniquely identifiable prior to the suffix and thus that the recognition time for the suffix is measured. The results of this experiment are presented in the next chapter.

Chapter 4

Derivation and Inflection

In Experiment 1 lexical decision times were shown to be influenced by the uniqueness point of each word. In the experiment which follows this variable was explicitly controlled by choosing complex words that become unique at the end of their roots. The aim of this experiment was to replicate Experiment 1 with more controlled stimuli and to test further predictions about the proposed parsing procedure. The results of response times to the word stimuli are presented as Experiment 2a, and those to the nonword stimuli as 2b, although the stimuli of both categories were presented to the same subjects and formed the word and nonword stimuli of a single experiment. The results are presented in this manner because the variables manipulated in the word and nonword stimuli address different questions about morphological parsing.

Experiments 2a

Method

Stimuli

30 suffixed words (15 inflected, 15 derived) and 15 monomorphemic words were selected for the properties described below and are listed in Appendix B. The nature of the nonwords is described in the section concerning Experiment 2b. Words were controlled for uniqueness point such that the same number of phonemes preceded and followed the unique segment. All suffixed words became unique at the root final consonant -- e.g. the root of bragging becomes unique at /g/ where it is distinguished from brass, brat, etc. In addition,

the total acoustic length of the words was similar ($\bar{x}$=562 msec for inflected words; $\bar{x}$=567 msec for derived words; $\bar{x}$=541 msec for monomorphemic words). The acoustic length preceding and following the uniqueness point was also similar for all word categories. Finally, words were matched for root frequency, and suffixed words were chosen such that the surface (i.e. suffixed) form had approximately the same frequency as the root form.

A tape was constructed in the same manner as in Experiment 1, and the same speaker was recorded.

Subjects

20 unpaid volunteers from undergraduate linguistics courses at UCLA participated in the experiment. Half of the subjects heard the stimuli in one order, and half heard the stimuli in the reverse order.

Procedure

The procedure was the same as in Experiment 1.

Results

As in the previous experiment, reaction time was measured from uniqueness point which was determined by the procedures discussed in Chapter three. A one-way covariate analysis was conducted with remaining duration as the covariate.[1] Reaction time was significantly correlated with remaining duration ($r=.22$; $p<.001$). The over-all F test was marginally significant ($F(2,810)=2.73$; $p=.06$). However, planned comparisons revealed that derived words were recognized faster than inflected and monomorphemic words ($F(1,811)=5.42$; $p=.02$); but lexical decision times were not significantly different for monomor-

phemic words and inflected words (F(1,556)=.16; n.s). Mean Reaction times for each category are given in Figure 4.1.

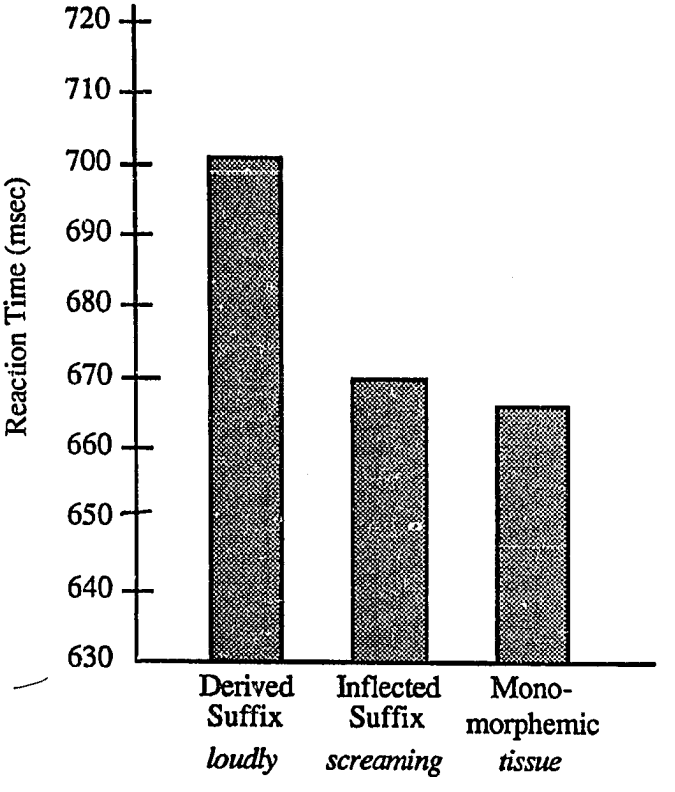


Figure 4.1. Lexical Decision Times for Suffixed and Monomorphemic words.

Discussion

The results of Experiment 1 were only partially replicated -- lexical decision times to derived words were longer than for both monomorphemic and inflected words, but no difference between inflected and monomorphemic words was observed. In the first experiment both derived and inflected words took longer to recognize when reaction time was measured from uniqueness point. It was hypothesized that the recognition and access of the suffix added processing time compared to monomorphemic words. This explanation must be elaborated

or replaced. In this more controlled experiment, recognition of the inflectional suffix did not take additional time. Therefore, we cannot conclude that the delay in decision time for the derived words was simply due to parsing the suffix since decision time varied with the type of suffix. Lexical decisions were made in the same time for monomorphemic words and inflected words, but when the word contained a derivational suffix lexical decision times were slowed.

There are at least three possible explanations for this result: 1) the parsing procedure for inflectional and derivational morphology is different, 2) inflectional and derivational morphology are represented differently in the lexicon which affects processing time in some specifiable way, and/or 3) the locus of the delay for derived words is at the decision stage and not in lexical access or representation. I will explore each of these possibilities in turn.

That different computational or lexical parsing procedures may exist for different word types is not a new hypothesis. Bradley (1978) and Bradley, Garrett, and Zurif (1980) propose that function words (closed class vocabulary) are recognized by a mechanism which is independent and separate from that serving lexical content words (open class vocabulary). Bradley and her colleagues suggest that because function words play a crucial role in determining the syntactic structure of a sentence, these words have a special recognition device. The evidence for this hypothesis derives from lexical decision experiments which show that function word recognition is not sensitive to the same variables as content word recognition. Lexical decision times were found to vary with word frequency for content

words but not for function words. In addition, nonwords containing content words (e.g. worderty) interfered with (or slowed) lexical decisions, but no interference effects were observed for nonwords containing function words (e.g. sucherty). Furthermore, Bradley et al. (1980) propose that agrammatism, a form of aphasia in which the production and comprehension[2] of function words are impaired, is due to the loss of this special lexical retrieval mechanism for function words. Bradley et al. found that agrammatic aphasics do not exhibit differential frequency effects for function and content words and appear to treat function words as content words.

In agrammatism inflectional morphology suffers a greater loss than derivational morphology.[3] If Bradley's proposal is correct, we might hypothesize that because inflectional morphemes contribute information relevant to syntactic structure and are also lost with agrammatic aphasia, they too have a separate computational mechanism perhaps tied in some way to the function word recognition device. However, questions have been raised about the experiments on which Bradley et al. (1980) base their differential access proposal.

Neither Gordon and Caramazza (1982) nor Segui, Mehler, and Morton (1982) were able to replicate the differential word frequency effects for function and content words using normal subjects; therefore, it is unclear whether function and content words are recognized differently by normal subjects. Furthermore, Kolk and Blomert (1985) show that the difference in nonword interference effects for function and content words found by Bradley (1978) may have been due to an artifact in the composition of the word list used in the lexical decision

task. Bradley's word list contained only content words, and when both function and content words are included, equal interference effects are observed for nonwords containing function words (such-erty) and those with content words (worderty).

Although separate lexical access mechanisms have been proposed for function and content words which might have been extended by rough analogy to inflectional and derivational morphology, support for the original hypothesis is now lacking. The psycholinguistic literature therefore provides no indication that inflectional and derivational morphology have different access routes into the lexicon.

Linguistic theory may offer some insight into whether separate parsing procedures are plausible for inflection and derivation. I have proposed that a morphological parser interprets word structure on-line during word recognition. The parser must be able to derive the underlying morphological form stored in the lexicon from the incoming acoustic signal which contains the surface form. The underlying and surface forms may be related by morphophonemic rules, although it is an open question how the parser might make use of these linguistic rules. If inflection and derivation are characterized by different types of morphological rules, different parsing procedures for inflection and derivation may also exist. However, the same formal mechanisms are needed to describe both inflectional and derivational processes (Lieber, 1980; Williams, 1981). Inflection and derivation can both be characterized by the same sorts of word formation rules (e.g. prefixation, reduplication, vowel umlaut,

etc.), and there appears to be no morphological process that is the sole domain of either inflection or derivation, regardless of whether they apply at different points in the derivation of a sentence (Anderson, in press). The implication for parsing is that whatever lexical access mechanisms interpret morphological structure they will have to analyze the same types of surface forms for both inflection and derivation. Therefore, there is no reason to expect that the parsing procedure for inflectional or derivational morphology should differ since the same types of morphophonemic surface structures must be parsed.

If the observed asymmetry between inflected and derived words is not due to distinct lexical parsing procedures, the difference may lie instead in their lexical representations. Miceli and Caramazza (1987) present some strong evidence that inflection and derivation constitute autonomous subcomponents of the lexicon. They describe an Italian patient who makes morphological errors in spontaneous speech and in the repetition of single words. The great majority of these errors are substitutions of inflectional affixes. Their patient was presented with 1832 words to repeat over several sessions, and he produced 50% of these words incorrectly. About 70% of his errors are morphologically based; that is, he repeated the root correctly but substituted an incorrect affix. The striking feature of the morphologically based errors is that they are essentially all inflectional errors (97%) -- very few are derivational (3%). Miceli and Caramazza (1987) propose that this categorical distinction between inflection and derivation can be explained by assuming that the two classes of

affixes compose autonomous subcomponents within the lexicon, and their patient shows a selective impairment in his ability to select specific affixes within the inflectional subcomponent of the lexicon.[4]

Miceli and Caramazza's case study provides evidence that there is a fundamental distinction between derivation and inflection at a lexical level. How might this distinction produce the asymmetry in recognition time observed in the experiment presented here? To answer this question we must examine more closely the nature of lexical representations for inflected and derived words and how different lexical structure might come to produce the observed behavioral differences. The derived words in both Experiment 1 and Experiment 2a contain category changing suffixes, whereas inflectional suffixes do not change the lexical category of a root. For example, the verb hunt is transformed into a noun by adding the agentive suffix -er; in contrast, the verb scream does not change category when the inflectional suffix -ing is added. The derivational suffixes in these experiments are the heads of the words in which they appear in part by virtue of their category-changing status (Williams, 1981). Selkirk (1982) argues that inflectional suffixes are not heads in English.

I propose that the change in lexical category of the derived words may have delayed either word recognition or lexical decision (or both). During lexical access the root along with its semantic and subcategorization information is initially accessed. The suffix is then accessed, and for derived words the suffix changes the ini-

tial lexical category of the word. For example, for the word hunter, the root hunt is initially recognized as a verb.[5] On encountering the derivational suffix -er, the original category assignment must be revised. Such revision is not required for inflected words. I hypothesize that the morphosyntactic information about a word is extracted on-line, and the delay in lexical decision time for derived words may be due to a revision in lexical category.

Furthermore, I wish to argue that the processing delay is not due to the revision of an on-line semantic analysis. First, the semantic change caused by the derivational suffix for these stimuli is intuitively not great. Half the words (8) are adverbs derived from adjectives by -ly (e.g. glumly, loudly), and the rest are derived nouns or adjectives (e.g. broiler, perilous). Although all the stimuli are semantically decomposable, I suggest that meaning is not constructed on-line. The semantics associated with derivational morphology are notoriously idiosyncratic (Jackendoff, 1975; Aronoff, 1976). For example, we might be able to devise a rule or procedure to interpret the semantics of hunt+er or glum+ly, but such a procedure would fail for breathe+er or hard+ly which are not semantically decomposable. The semantic relation between the word root and its derived word form tends to shift unpredictably over time. It seems unlikely, therefore, that semantic structure is constructed on-line during word recognition. I suggest that lexical meaning for the root and the derived form are stored and accessed separately. For example, when the word hunter is recognized, the semantics associated with hunter are accessed -- the semantic representation is not constructed by

combining the root semantics (of hunt) and the semantics of the suffix (-er). If the delay in lexical decision is due to a semantic change when a derivational suffix is encountered, the mechanism for the delay is not the revision of a semantic representation that is being built on-line.

I have argued thus far that the lexical access and parsing procedures themselves do not differ for inflection and derivation, but that the lexical representations of these words differ in ways which might slow parsing for derived words. The syntactic and/or semantic changes that are induced by adding a derivational suffix may cause a delay in parsing because either the lexical category must be reassigned or the semantics of the derived word must be newly accessed. For inflected words, no change in lexical category or semantics occurs.

Another possibility is that these differences in lexical structure between inflected and derived words exert their effect not during lexical access and recognition, but during lexical decision. The nature of the nonwords differed between Experiment 1 and 2 and may have made the lexical decision in Experiment 2 more complex. Experiment 1 contained simple nonwords like molid, whereas Experiment 2, in addition to simple nonwords, contained nonwords created by an illegal or nonoccurring combination of root and suffix, e.g. crushly. In Experiment 2 subjects may have made a well-formedness judgment in addition to a lexical decision. Well-formedness judgments may be more complex for derived words because both the lexical category and the semantics of the root are affected by the suffix. In Chapter

five I will suggest a way of determining the locus of the reaction time delay for the derived words -- that is, whether the delay occurs during lexical access or decision.

In sum, I have discussed three possible explanations for the asymmetry found between inflection and derivation -- differing parsing procedures, differing representations, and differing degrees of difficulty for lexical decision. However, still to be explained is the lack of difference between inflected and monomorphemic words. Apparently, recognition of the inflectional suffix did not require more processing time compared to confirming the rest of an expected word for monomorphemic words. Note that for both inflected and monomorphemic words once the root is isolated, the remaining stimulus adds no further relevant information. That is, for monomorphemic words the expected word is confirmed. For inflected words, the suffix does not change the semantics or lexical category assigned by the root and adds no syntactic information that is relevant in isolation.

Experiment 1 led us to hypothesize a particular method of lexical access for auditory word recognition. Experiment 2 partially replicated the results of Experiment 1, but the precise nature of the parsing mechanism remains somewhat unclear. We now turn to the nonword results which further illuminate the possible parsing procedures implemented in the recognition of morphological structure during auditory processing.

Experiment 2b

Three categories of nonwords were designed to test some of the

hypotheses that are implicit in the model of auditory word recognition and lexical access I have been developing based on Marslen-Wilson's cohort model. As I have implied, nonwords are rejected in a lexical decision in a manner similar to how real words are recognized. A word becomes unique when it deviates from all other words in the lexicon. A stimulus becomes a nonword when it deviates from all words in a listener's lexicon. In the previous Chapter, I developed an hypothesis about how morphological structure might be parsed and represented within the framework of a cohort model. Stems are recognized first, followed by the access and recognition of suffixes using the same matching procedure. This model makes certain predictions about how the system deals with nonwords that have internal structure.

I designed the nonwords such that they are distinguished from real words at the same segment, but they vary as to whether they contain no morphological structure e.g., sulfack [sʌlfaek], a nonword "root" with a real suffix, e.g. garnly [garnli], or an illegal or nonexisting[6] combination of a real root and suffix, e.g. crushly [krʌšli]. In these examples, sulfack [sʌlfaek] becomes a nonword at /ae/ where it is distinguished from sulphur. Garnly can be rejected at the /l/ where it is distinguished from garnet and garnish, and finally crushly also becomes a nonword at the /l/ -- no word begins [krʌšl]. In the first two examples, no root is recognized since sulf and garn are not roots. Both these word types can be rejected in the cohort set containing roots. This model predicts no difference in lexical decision time between sulfack and garnly because they can

both be rejected at the same point -- the suffix in garnly should never get analyzed as such on-line because no root has been encountered that would cause the parsing procedure to check for a suffix. However, subjects should take longer to reject nonwords like crushly because a root can be (uniquely) identified, thus the parser can check for a suffix. This category of nonwords was designed such that the root becomes unique at the final segment (thus we can potentially ensure root access), e.g. crushly is unique at the /š/ where it is distinguished from crumb, crust, etc. Lexical decision for these nonwords should take longer because it is the illegal (or nonoccurring) combination of root and suffix that causes the rejection, not simply deviation from possible words. Note that if no morphological parsing occurs at all, then no difference between any of these nonword categories should be observed because they all deviate from possible words at the same segment.

Method

Stimuli

The nonwords (see Appendix C) formed the following categories as described above: a) 15 simple nonwords (e.g., sulfack, clussig), b) 15 suffixed nonwords (e.g., garnly, gending), and c) 15 root-suffix illegal combinations (e.g. crushly, mirthing), hereafter referred to as pseudowords. The frequency of the root in this last category was matched with the frequency of the words described in Experiment 2a. As noted above, all nonwords could be rejected at the same segment. The nonwords had the same number of phonemes and syllables, and the mean acoustic duration of the nonword categories was similar ($\bar{x}$=536

msec for a), x=566 msec for b), and x=551 msec for c)). The same suffixes that appeared on the words also appeared on the nonwords.

Subjects and Procedure

The subjects and procedures were the same as in Experiment 2a.

Results

Reaction time was measured from the rejection point for a better comparison with the word results, but the findings remain the same if reaction time is measured from stimulus onset.[7] A one-way covariate analysis was conducted with remaining duration as the co-variate. Reaction time was not significantly correlated with duration ($r=.05$, n.s.). A significant difference was found between the nonword categories ($F(2,849) = 3.57$, $p<.03$). Planned comparisons revealed that lexical decision times for pseudowords (e.g. crushly) were longer than for both simple nonwords ($F(1,573) = 6.59$; $p<.01$) and suffixed nonwords ($F(1,558) = 4.87$; $p<.03$). No difference in reaction time was observed between simple nonwords and suffixed nonwords ($F(1,566) = .24$; n.s.). The mean reaction times are shown in Figure 4.2.

Discussion

The results support the predictions -- nonwords that do not contain real word roots (e.g., sulfack and garnly) are rejected faster than nonwords that contain illegal or nonoccurring combinations of root and suffix. Furthermore, as predicted, suffixed nonwords did not slow lexical decision compared to simple nonwords, suggesting that during auditory processing the suffix in the nonword (e.g. -ly in garnly) is not analyzed as such on-line.

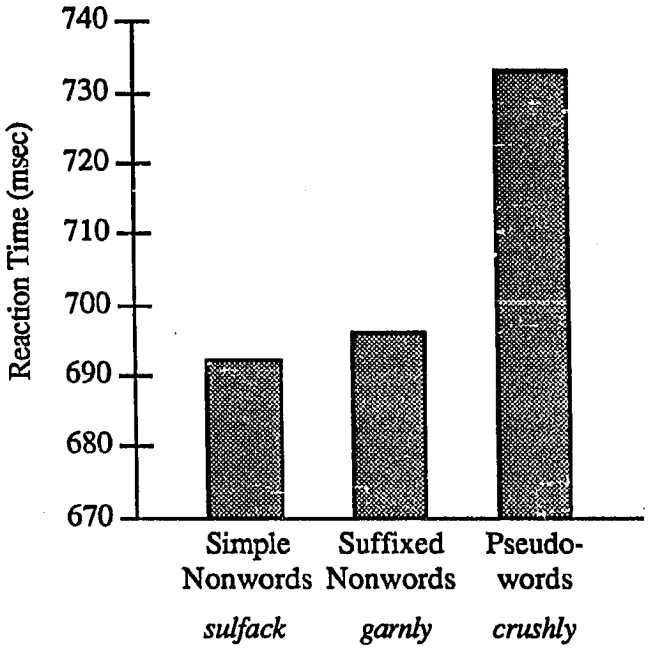


Figure 4.2. Mean Lexical Decision Times for Nonwords.

These results suggest several properties that are attributable to lexical access and morphological parsing. The matching mechanism that operates during lexical access determines when a nonword deviates from stored lexical roots and at this point the system can reject the item as a word. Both simple and suffixed nonwords can be rejected at the point where they deviate from stored roots. No unique root is encountered that would trigger the mechanism to look for a suffix, thus response times to suffixed nonwords are not slowed. The parse trace for each nonword type is illustrated in Table 4.1.

Table 4.1. The Parse Traces for sulfack, garnly, and crushly.

Nonword:	sulfack			
Incoming Stimulus:	sʌl	sʌlf	sʌlfae	
Cohort Set:	sulphur	sulphur		
sulfate	sulk	sulfate[a]		
sultry	sullen			
sultan	sulcus			
Process:	No root matches full incoming form, continue matching	No root matches full incoming form continue matching	No remaining candidates, CAN REJECT	
Nonword:	garnly			
Incoming Stimulus:	gar	garn	garnl	
Cohort Set:	garb	garnish		
garment	garden	garnet		
garter	garnet	garner		
garner	garnish			
garlic	Gardenia			
garland	gargantua			
gargoyle	gargle			
Process:	No root matches full incoming form, continue matching	No root matches full incoming form continue matching	No remaining candidates, CAN REJECT	
Nonword:	crushly			
Incoming Stimulus:	krʌ	krʌš	krʌšl	krʌšli
Cohort Set:	crush	crush	-s, -ly	-ly
crux	crust		-less, -ed	
crutch	crumb		-ing, -y	
crunch	crumble			
Process:	No root matches full incoming form, continue matching	crush is only remaining candidate consistent with input, access suffixes.	No suffix fully matches remaining input, continue matching.	Suffix -ly matches input, REJECT AS ILL-FORMED

[a] It is possible that these two words (and others e.g. sulferous) are not contained in the cohort set used for recognition. Instead, the bound root sulf may be in the cohort set.

Note that there are at least two possible reasons why lexical decisions for pseudowords like crushly were delayed. One hypothesis is that the delay was due to a well-formedness decision; that is, determining that the combination of root and suffix is illegal/nonoccurring. This additional analysis may have complicated and delayed the lexical decision. Another possibility is that simply accessing a unique root in the lexicon slowed the rejection time. No lexical root could have been uniquely identified during lexical access for the simple or suffixed nonwords. The experiments presented in the following chapter investigate which hypothesis is correct and also explore the difference between auditory and visual processing.

Finally, these results indicate that the morphological analysis of an incoming stimulus is intricately intertwined with the mechanisms of lexical access. If morphological analysis were independent of lexical access or occurred after lexical access, we would predict that response times for suffixed nonwords should be longer because the suffix could be recognized as a potential morpheme and should therefore slow rejection of the item as a nonword. However, morphological analysis appears to be constrained by the temporal nature of lexical access and speech perception.

Chapter 5

Auditory and Visual Word Recognition

In the experiments presented in this Chapter, I explore further how lexical access mechanisms deal with nonwords which have internal structure and examine the relation between auditory and visual word recognition. Experiment 3 investigates the type of lexical information that interferes with lexical decisions for auditorily presented nonwords. Experiment 4 presents the same word and nonword stimuli visually to a different set of subjects in an effort to directly compare the effects of morphological structure on auditory and visual word recognition processes.

Experiment 3

In Experiment 2b presented in Chapter four, lexical decision times for pseudowords like crushly were longer than for simple nonwords (e.g. sulfack) and suffixed nonwords (e.g. garnly). Two possible reasons for this effect were presented: 1) a word root interferes with rejection time and 2) illegal combinations of two English morphemes slows rejection time by requiring a well-formedness judgment. In the following experiment, the same words and nonwords from Experiments 2a and 2b were presented to a different group of subjects with the addition of a fourth nonword category: nonwords which begin with a real word root but are followed by a "false" suffix, e.g. cagelo [kejlo]. If lexical decision times for these nonwords are slower than for simple nonwords, it will indicate that the recognition of a possible root interferes with lexical decision. If response times to these root-initial nonwords (cagelo) are de-

layed, response times to the pseudowords (crushly) should be delayed as well because the pseudowords also begin with a word root. If no difference is observed between the root-initial nonwords and the pseudowords, it will suggest that the suffix -ly is not recognized as a suffix on-line. Both crushly and cagelo become nonwords at the same segment, thus if lexical decision is not slower for crushly, one can argue that the suffix is not recognized as such on-line and therefore does not interfere with lexical decision. If pseudowords take longer to reject than root-initial nonwords, it would indicate the suffix in these forms is recognized as an English morpheme on-line and interferes with lexical decision. In this case, the delay for pseudowords would be due to the well-formedness judgment that must be made for these forms.

Method

Subjects

20 unpaid undergraduates from introductory linguistics courses at UCLA volunteered to participate in the experiment.

Stimuli

The word and nonword stimuli from Experiments 2a and 2b were used along with 15 additional root-initial nonwords as described above (see Appendix D). The frequency of the initial roots (e.g. cage in cagelo) was matched with the word roots in the pseudowords. They were also matched for number of phonemes and syllables, and the mean acoustic duration was similar to the other nonword categories ($\bar{X}$=543 msec). As with the pseudowords, the roots in the root-initial nonwords become unique root finally (e.g. cage is unique at /ʤ/ where

it is distinguished from case, cake, cape, etc.)

Results and Discussion

I will present the word results first. A one-way co-variate analysis was conducted with remaining duration as the co-variate.[1] Reaction time was significantly correlated with duration ($r=.25$; $p<.001$). A significant effect of word category was found ($F(2,781) = 3.32$; $p<.04$). Planned comparisons revealed that lexical decision times to derived words were significantly longer than to inflected words ($F(1,508) = 4.50$; $p<.04$) and monomorphemic words ($F(1,519) = 4.75$; $p<.03$). Reaction time to inflected words was not significantly different from monomorphemic words ($F(1,532) = 0.0$; n.s.). Mean reaction times for each category are presented in Figure 5.1:

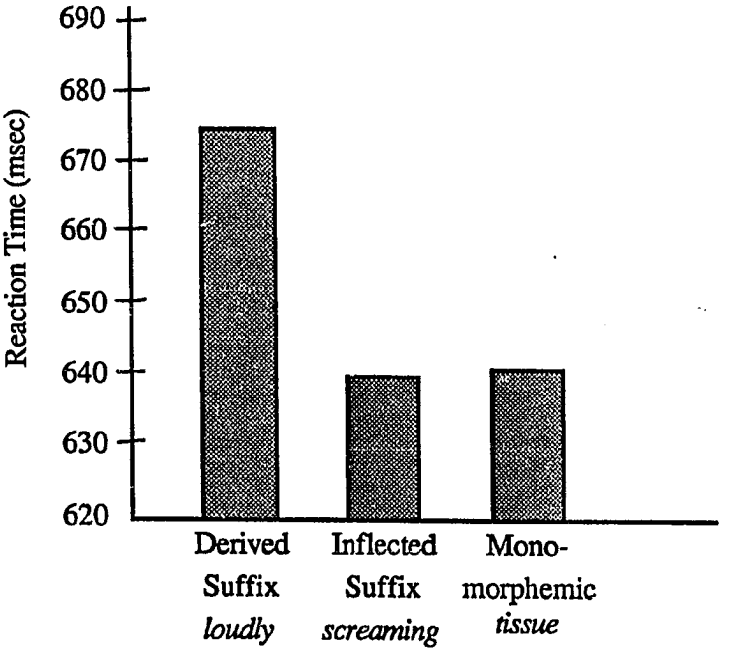


Figure 5.1. Mean Lexical Decision Times for Suffixed and Monomorphemic Words Presented Auditorily.

This experiment replicates Experiment 2a with a different group

of subjects. Response times to derived words were slowed in comparison to inflected and monomorphemic words. I argued in Chapter four that this delay was due to the category-changing nature of the derivational suffix. The parsing procedure may have been slowed for the derived words because the category of the root and the category assigned by the suffix differ. I further suggested that the locus of the delay may have been either during lexical access or during the lexical decision stage. Because pseudowords were included with the nonwords, subjects may have been making a well formedness decision for the complex words which is more complicated for the derived words since the suffix affects the lexical category as well as the semantics of the root. As in Experiment 2a, the presence of an inflectional suffix did not slow response time in comparison with monomorphemic words. Again, I propose that inflectional suffixes add little information relevant to the recognition of words in isolation, and therefore response to inflected words is similar to monomorphemic words.

As in Experiment 2b, reaction time for the nonwords was measured from the rejection point, and again the results are not altered if RT is measured from stimulus onset.[2] Reaction time was not significantly correlated with duration ($r=.04$, n.s.). A significant effect of nonword category was found ($F(3,1129 = 6.75$; $p<.001$). Planned comparisons revealed that pseudowords took longer to recognize than all other nonword categories ($F(1,1130) = 17.69$; $p<.001$). No significant difference was found between root-initial nonwords and simple nonwords ($F(1,582) = 0.02$; n.s.). The means for each category are

presented in Figure 5.2.

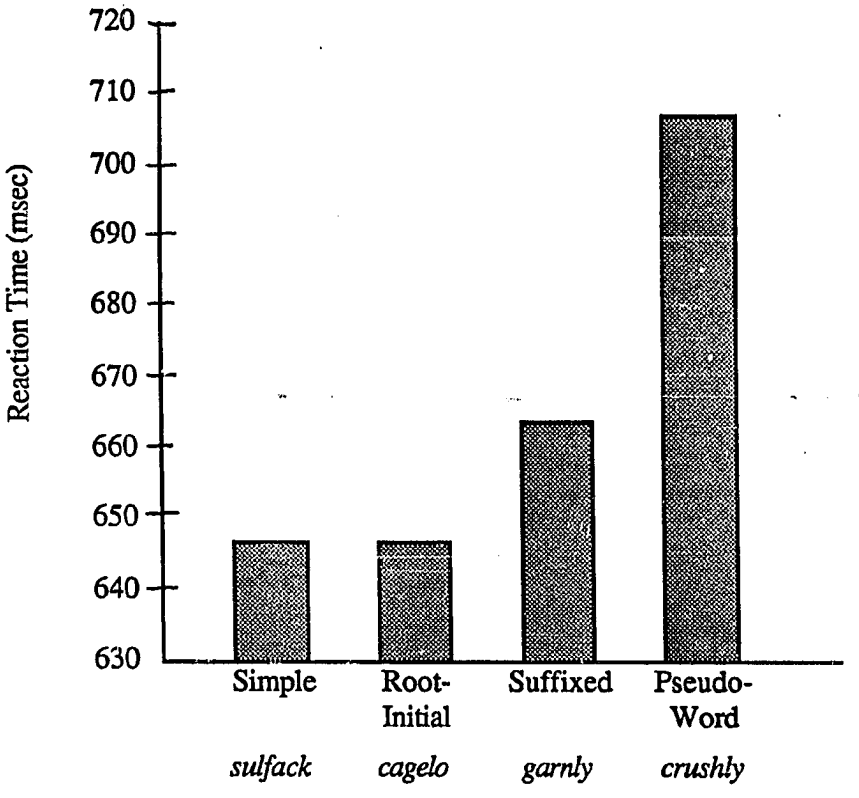


Figure 5.2. Mean Lexical Decision Times for Nonwords Presented Auditorily.

The results indicate that the presence of an initial root in a string that becomes a nonword does not interfere with lexical decision. The response delay for pseudowords cannot be due to simply encountering a unique root during lexical access, but must be due to a well-formedness judgment. These results provide additional clues as to the nature of morphological parsing of real words.

First, let us examine how each of these nonword types is processed according to the hypothesized lexical access and parsing procedures presented here. As when the stimulus is a word, the first few segments of a nonword "activate" the roots stored in the listener's

lexicon. For simple nonwords (e.g. sulfack) no root is uniquely identified, and when the stimulus deviates from stored root representations (e.g. at /ae/), subjects can reject the stimulus as a word. Again note that RT is not correlated with duration after the rejection point -- subjects can readily make their decision without waiting until the end of the stimulus. After the rejection point a nonword cannot "become" a word. This is not the case for words -- a uniquely identified word can still "become" a nonword. RT is therefore correlated with remaining duration for words but not for nonwords. The suffixed nonwords (e.g., garnly) can be rejected in the cohort set containing roots in exactly the same manner as the simple nonwords, i.e. at the point where it deviates from stored roots. I hypothesized that the morphological parser does not look for a suffix until a possible root has been identified. This analysis explains why response times for simple and suffixed nonwords do not differ.

In the case of root-initial nonwords like cagelo, a unique initial root is encountered during lexical access. I hypothesized that after a root is recognized, the possible suffixes are automatically accessed. Identifying cage as a root in cagelo should cause the parser to access possible suffixes.[3] The form could then be rejected due to a mismatch between stored suffixes and the incoming stimulus (i.e. lo). The fact that response times to these root-initial nonwords were not slowed argues against my hypothesis that accessing stored suffixes requires additional processing time. The roots in these nonwords (i.e. cage in cagelo) become unique root finally; thus, only one candidate remains in the cohort set (i.e.

cage). The parsing mechanism then accesses stored suffixes, and the item can be rejected. The parse trace for root-initial nonwords is given in Table 5.1:

Table 5.1. The Parse Trace for cagelo

Nonword: cagelo				
Incoming Stimulus:	ke	keǰ	keǰl	keǰlo
Cohort Set:	case cage cape cake came[a]	cage	-s, -ly -ed, -less -ing, -y	----
Process:	No root matches full incoming form [ke], continue matching.	cage is the only remaining candidate consistent with input, check for suffixes.	No root matches [keǰl], REJECT [keǰl] as a root No suffix fully matches remaining input.	No suffix matches [lo], CAN REJECT

[a] Not all of the candidates in the cohort set for /ke/ are listed because the set is quite large.

Apparently, simply accessing stored suffixes did not interfere with the lexical decision for the root-initial nonwords. However, the access/recognition of suffixes must be tied in some way to the identification of a possible root morpheme -- otherwise we could not explain the lack of response delay for suffixed nonwords like garnly. If the recognition of suffixes operates independently of root identification we would expect suffixed nonwords to take longer to reject than simple nonwords.

The results of Experiment 3 indicate that the response delay for

pseudowords (e.g. crushly) is not caused by encountering a potential root in initial position. Rather they suggest that both the root and the suffix are recognized as existing English morphemes whose combination is illegal or nonoccurring. The presence of just a root (as in cagelo) or just a suffix (as in garnly) does not cause a delay in lexical decision. Only when both root and suffix are possible English morphemes that combine to form a pseudoword is lexical decision delayed. This delay is apparently due to an additional well formedness judgment that must made for this category of nonword.

These results differ in an interesting way from those of Taft and Forster (1976). Taft and Forster presented nonword "compounds" in a lexical decision task, and the compounds varied as to whether the first constituent was a real word (e.g., footmilge) or a nonword (e.g., mowdflisk). These stimuli were presented visually, and subjects were found to take longer to reject nonwords with initial word constituents compared to initial nonword constituents. The results with auditory stimuli presented here showed no interference effect due to an initial word root. These conflicting results may reflect different lexical access procedures for visual and auditory processing. We now turn to Experiment 4 in which auditory and visual processing are compared directly by presenting the same word and nonword stimuli in both modalities.

Experiment 4

The explanations for the results of Experiments 3 and 2a,b rely heavily on the temporal nature of speech perception. Do we find the same pattern of results for visual word recognition when processing

is not as constrained by serial order? Are the effects of morphological structure observed in Experiment 2a due to the nature of auditory processing or to the nature of the lexical representations themselves? I have argued that the effects of word internal structure on lexical decision were due to the nature of the lexical representations, therefore I hypothesize that if auditory and visual word recognition processes share lexical representations, we should find the same pattern of response times for words. On the other hand, nonwords do not have lexical representations, and therefore response time differences may reflect differences in access procedures. Furthermore, I predict that because word recognition in the visual domain is not constrained by temporal order as strongly as auditory word recognition, we should find a different pattern of results for the nonwords only.

Method

Subjects

20 unpaid undergraduates from introductory linguistics courses at UCLA volunteered to participate in the experiment.

Stimuli and Procedure

The words and nonwords were printed on white cards in black ink and presented for 500 msec in central vision using a box tachistoscope. The interstimulus interval was 6 seconds. Reaction time was measured from stimulus onset. As in the previous experiments subjects pressed a telegraph key marked "yes" or "no" which stopped the reaction timer. Half the subjects viewed the stimuli in one order and half in the reverse order.

Results and Discussion

The word results will be presented first. A one-way ANOVA revealed a significant difference between word categories ($F(2,833) = 6.43$; $p<.001$). Planned comparisons showed that lexical decision times to derived words were longer than for inflected and monomorphemic words ($F(2,833) = 6.43$; $p<.002$). No significant difference was observed between inflected and monomorphemic words ($F(1,567) = 1.17$; n.s.). Mean reaction time for each word category is shown in Figure 5.3:

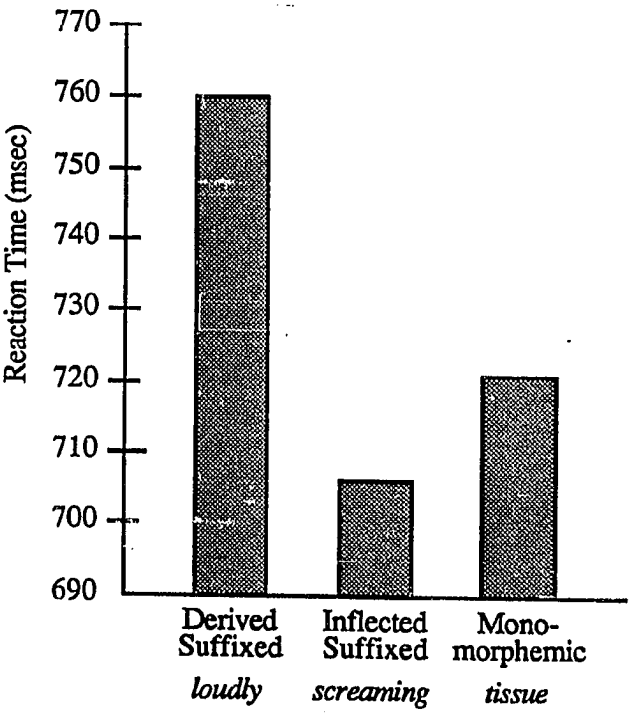


Figure 5.3. Mean Lexical Decision Times for Words Presented Visually.

The pattern of response times for the visually presented word categories was the same as for auditory presentation. Recognition of derived words was delayed for both visual and auditory presentations.

As I argued in Chapter four, it is unlikely that this difference between derivation and inflection is due to separate parsing procedures or access mechanisms for each type of morphology. I suggested, instead, that the difference lay in their lexical representations. To find the same pattern of results for visual word recognition suggests that equivalent lexical representations are accessed for both auditory and visual word recognition. Morphological structure is marked similarly for orthographic and phonological representations. In Chapter four, I proposed that the locus of the delay for derived words might be at lexical access or later in the lexical decision stage. Interestingly, with visual presentation another paradigm is available that may help determine which explanation is correct.

Recently, "naming" experiments have been compared to lexical decision experiments (Seidenberg, Waters, Sanders, and Langer, 1984; Seidenberg, Waters, Barnes, and Tanenhaus 1984). In a naming experiment, subjects read aloud words presented on a computer screen as quickly as possible. In this task, no lexical judgment must be made -- there are no nonwords included in the reading task. However, lexical access still occurs; that is, subjects must access orthographic and phonological representations when they read a word out loud. If the time to initiate naming for derived words is longer than for inflected and monomorphemic words, then the processing delay can be argued to occur during lexical access (as long as other factors such as spelling regularity are controlled). If, on the other hand, the time to initiate naming is the same for derived words,

inflected words, and monomorphemic words, then the response delay observed for lexical decision must have occurred in the decision stage and not during lexical access itself. This experiment, however, is left for future work.

We now turn to the nonword results. A significant difference between nonword categories was found ($F(3,1110) = 48.54$; $p<.001$). Planned comparisons revealed that lexical decision times to pseudowords were longer than for all other nonword categories ($F(1,1102) = 115.73$; $p<.001$). Stem-initial nonwords took longer to reject than simple nonwords ($F(1,580) = 8.05$; $p<.005$), and suffixed nonwords took longer to reject than root-initial nonwords ($F(1,573) = 8.68$; $p<.005$) but were rejected faster than pseudowords ($F(1,520) = 30.34$; $p<.001$). Mean reaction times for each nonword category are shown in Figure 5.4.

In contrast to the word results, the nonword results from Experiment 4 differ greatly from those of Experiment 3. When simple nonwords, root-initial nonwords and suffixed nonwords are presented auditorily for lexical decision, no significant difference in reaction time is observed between any of these categories. However, when the same stimuli are presented visually, lexical decision time increases incrementally for each category (see Figure 5.4). Other studies have found similar results with visual lexical decision. As noted above, Taft and Forster (1976) found that the response times to nonwords which begin with a word root (footmilge) were longer than nonword "compounds" with a nonword initial constituent (mowdflisk). Furthermore, Henderson et al. (1984) found longer lexical decision

times for visually presented suffixed nonwords (e.g. fritable) compared to simple nonwords (e.g., garpod).

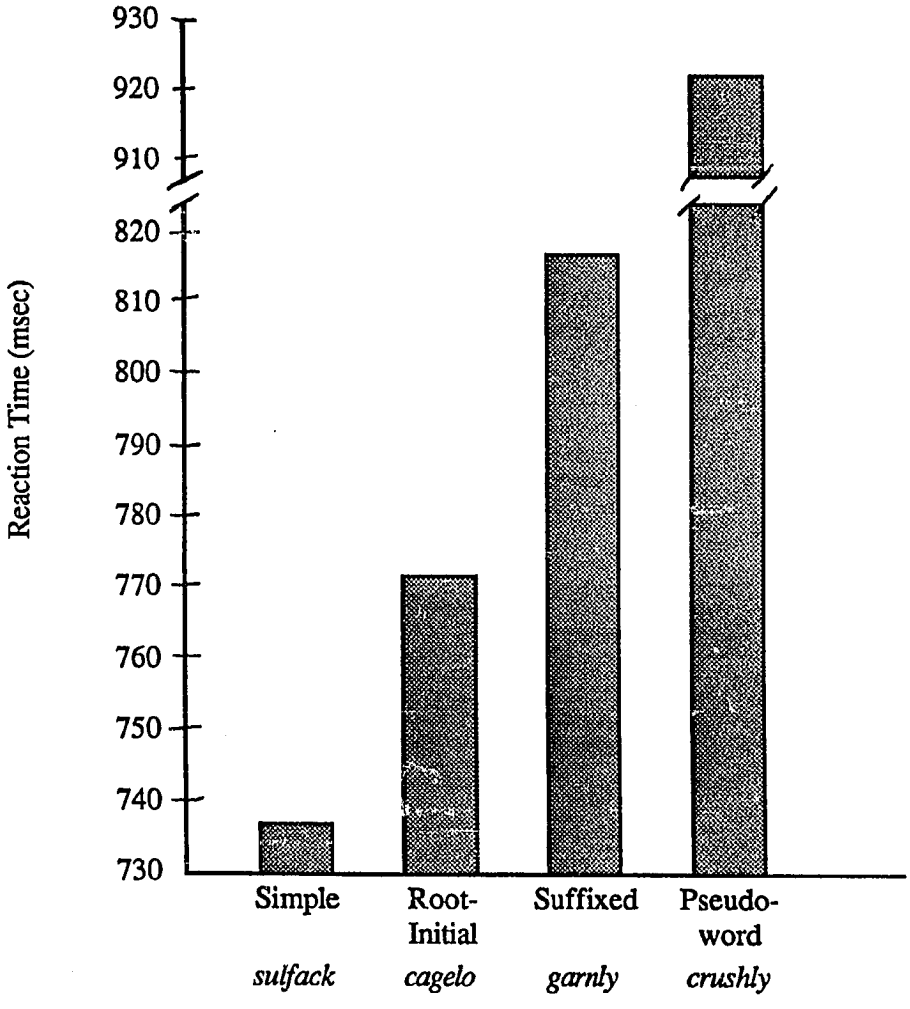


Figure 5.4. Mean Lexical Decision Times for Nonwords Presented Visually.

Why do subjects perform similarly under auditory and visual conditions when accepting a stimulus as a word, but differently when rejecting a stimulus as an existing word? I suggest that although auditory and visual word recognition procedures may differ, they access equivalent lexical representations. Word internal structure

is marked for both orthographic and phonological representations. Nonwords do not have lexical representations, and subjects' performance when "recognizing" a nonword may reflect the automatic access procedures used to recognize printed and spoken words under normal conditions. Visual processing is not constrained by temporal order to the same degree as auditory processing, and apparently recognition of roots and suffixes are somewhat independent. Recognition of either a word root in the initial position of a nonword or a suffix in final position slows response time.

If we assume that roots and suffixes have separate orthographic representations, we can account for the nonword interference effects. When part of a nonword matches an orthographic entry that representation is automatically accessed.[4] So for example, the orthographic representation for cage is accessed when cagelo is presented, and the orthographic representation for -ly is accessed when garnly is presented. Other evidence that suffixes may be read as separate units comes from letter search/cancellation experiments. Smith and Groat (1979), Drewnowski and Healy (1980), and Smith and Sterling (1982) have shown that in searching through prose for a target letter subjects are more likely to miss a target that is part of an inflectional suffix. Smith and Groat (1979) found that the rate of omission for e in -ed is higher than when e appears in a nonaffixed word (e.g., hundred). Drewnowski and Healy (1980) also found higher omission rates for the letter n in the inflectional suffix -ing compared to words ending in a nonaffix string (e.g. wing or sterling). Drewnowski and Healy (1980) explain the omission errors by

hypothesizing that suffixes are read as separate units and not broken down into letters.

The Addressed Morphology Model (Caramazza, Miceli, Silveri, and Laudanna, 1985, see Chapter two) also proposes that suffixes are stored separately in the orthographic lexicon as logogen-like recognition units. Recall that their model assumes two parallel lexical access mechanisms: 1) a whole-word address system that, in the case of known morphologically complex and monomorphemic words, accepts the entire letter string as input and matches it with its corresponding whole-word recognition unit, and 2) a morpheme address system whose recognition units correspond to morphemes instead of whole words. The morphemic address system is used to recognize new or unfamiliar polymorphemic words.

The Addressed Morphology Model can easily explain the nonword results presented here as attempts of the morphological address system to analyze the nonwords as words. That is, the morphological address system recognizes separately the possible root and suffix of crushly, the suffix in garnly, and the root in cagelo. The whole-word system fails equally for all these nonword types. The Addressed Morphology model accounts for the nonwords results in a similar manner as the logogen model if logogens correspond to morphemes.

However, the word results must be explained by the operation of the whole-word address procedure which operates in parallel with the morphological parsing procedure. Caramazza et al. assume that complex words are recognized more efficiently by the whole-word procedure since the parsing procedure is relatively slow. As the model

stands now, it cannot account for the difference between derived and inflected words. The whole-word address procedure was designed to account for results which showed no difference between monomorphemic and suffixed words (Manelis and Tharp, 1977; Henderson et al. 1984), but as noted earlier, these experiments mixed derivation and inflection in their stimulus sets.

However, the whole-word system may not be necessary. The evidence provided to support the whole-word access procedure is based on word frequency experiments. Results from Italian (Burani, Salmaso, and Caramazza, 1984), English (Taft, 1979), and Serbo-Croation (Lukatela, Gligorijerc, Kostic, and Turvey, 1980) indicate that the frequency of both the root and the frequency of the surface (i.e. inflected or derived) form affect reaction time in lexical decision tasks. Words with high frequency roots are recognized faster than words with low frequency roots, although their affixed forms are matched for frequency. However, if words are matched for root frequency, affixed words with high frequencies are recognized faster than affixed words with low frequencies. For example, thing and world have the same root frequency, but things is more frequent than worlds. Lexical decision time for things is faster than for worlds (Taft, 1979).

Burani et al. (1984) account for the frequency effect of affixed words by assuming that the whole-word address units are activated in a logogen-like fashion and that their response thresholds are influenced by the number of times these units have been activated. The response threshold for a whole-word unit is lowered each time the

affixed form of the word is encountered. Lowered response thresholds lead to faster recognition times (Morton, 1969). For example, every time the whole-word address unit for bragging is activated, it leads to a lowering of the unit's response threshold. A separate whole-word unit exists for bragged, and its response threshold is lowered whenever bragged is encountered. The effects of root frequency on reaction time are accounted for by the additional presence of the root representation (i.e. brag) in the orthographic lexicon.

An alternative account may be possible, however, which does not depend on separate whole-word units. The frequency effect for morphologically complex words may be due to the connection between roots and affixes in the lexicon. Caramazza et al. (1985) propose that information about permissible affixes is stored with the root, and I propose that this information takes the form of network-like connections between roots and their permissible affixes. With each encounter of a complex word, the connection between the root and the affix is strengthened, and the strength of these connections affects the lexical decision time for complex words. The effect of root frequency can be accounted for by assuming that each encounter of the root lowers the logogen response threshold.

Problems for this connectionist account (and especially for the whole-word address account) arise when languages with complex morphology are considered. When the number of possible root/affix orderings and combinations is large, a connectionist account becomes unwieldy. However, the spirit of the proposal may be salvaged in that the allowable root/affix combinations is what affects the speed

of word recognition. Therefore, the frequency effect should arise from the mechanism that provides this specification, not out of a separate address system in which all complex words are stored redundantly as whole word entries.

In sum, I propose that equivalent lexical representations are accessed during reading and speech perception but that these representations are accessed by different mechanisms. The fact that there was no difference in the pattern of response times for words with auditory or visual presentation suggests that morphological structure is marked similarly for phonological and orthographic representations. Nonwords do not have lexical representations, and I propose that the differing pattern of response times for the nonwords reflects how these stimuli were interpreted by modality specific access procedures. For auditory word recognition, identification of a final suffix is tied to the recognition of a root; thus, no difference in rejection time was found between simple nonwords and suffixed nonwords. For visual word recognition, on the other hand, recognition of suffixes is not tied to temporal order or to the recognition of a root. Therefore the presence of either a suffix or a root in the nonword slowed rejection time. Visual word recognition appears to operate more holistically that auditory word recognition. The results presented here argue strongly against Bradley and Forster's (1987) claim that the operations acting on spoken and written inputs do not differ in character.

Chapter 6

The Unit of Representation

Many introductory linguistics textbooks define the morpheme as "the minimal unit of meaning" (Fromkin and Rodman, 1983; Falk, 1978; Chao, 1974). Although this is the traditional definition, it does not apply to all elements we would like to label as morphemes (Matthews, 1972). Aronoff (1976) has argued that the definition of morpheme must be adjusted to include morphemes which have no constant meaning. For example, the words remit, commit, transmit, submit, permit, and admit all share the bound root mit, but mit does not have a constant meaning across these forms. Similarly, no meaning is shared by receive, deceive, conceive, or perceive -- although they all share the same root ceive. Aronoff points out that although these words do not share a similar meaning, they do undergo the same phonological rule. For example, words that contain the root mit undergo a morphologically conditioned palatalization rule which changes t to s before the suffix ion: permission, submission, admission, etc. This rule is morphologically conditioned because it only applies to the morpheme mit and not to words that simply end in the phonological string mit, e.g. vomit but not *vomission. Aronoff proposes that we broaden the definition of morpheme to include elements that share a phonological operation. He suggests that "...what is essential about a morpheme is not that it mean, but rather merely that we be able to recognize it. A morpheme is a phonetic string which can be connected [arbitrarily] to a linguistic entity outside that string" -- i.e. either to a constant meaning or to a morpho-

phonemic rule (p. 15).

Does this definition have any relevance for psychological models of the lexicon and lexical processing? That is, how crucial is semantics to the representation of morphological relationships? Although semantic relatedness within a linguistic model is not necessary to define morphological relations, for processing purposes semantic associations may be crucial to determining morphemic representations.

A large body of evidence indicates that semantic relations between words are represented in the lexicon. Early studies (e.g. Meyer and Schvaneveldt, 1971) show that subjects are faster at classifying a letter string (e.g. doctor) as a word if it is preceded by a word that is semantically associated (e.g. nurse) than if the preceding word is unrelated (e.g. butter). Such priming effects are generally interpreted as reflecting some form of association between the two related items, and this relation is argued to be represented within the lexicon (Forster, 1981). Some studies have investigated priming effects for morphologically related words, but these experiments have used words as stimuli which were semantically as well as morphologically related (Murrell and Morton, 1974; Stanners, Neiser, Hernon, and Hall, 1979; Kempley and Morton, 1982; Fowler, Napps, and Feldman, 1985). Although semantic priming has not been observed for the long delays between prime and target used in these experiments, the semantic relation between morphologically related words may be stronger than between words that are semantic associates and do not share the same root morpheme. In order to discover whether word

relations based on morphological structure are represented independently of semantics, the experiment described below used morphologically related words that do not share a constant meaning.

The implications of morphological priming data for the organization of lexical representations depends in part on how it is interpreted within a particular model. Within some models (e.g. Stanners et al., 1979; Morton, 1979) priming is interpreted as the lowering of recognition thresholds of lexical units due to previous activation. Two questions arise for these models with regard to the issues raised here: Do lexical units correspond to words or to morphemes, and if they correspond to morphemes is the psychological "definition" of morpheme the same as the one proposed by Aronoff? In these models, priming between morphologically related items indicates that the items share a single recognition unit. For example, Kempley and Morton (1982) found that prior presentation of words with regular inflections (looked, looking) facilitated auditory recognition in noise, but the prior presentation of words with irregular inflection (knelt, kneeling) did not. This result was explained by proposing that the recognition unit for looked and looking corresponds to the root morpheme look and is activated when either looking or looked is heard -- thus previous exposure to either form will facilitate later recognition due to the lowering of the response threshold for look. Two separate recognition units exist for kneeling and knelt. Kempley and Morton suggest that phonological structure rather than a syntactic or semantic relationship determines whether words correspond to one recognition unit or two since the same syntactic/semar-

tic relationship holds between kneeling and knelt as between looking and looked. However, Kempley and Morton's results do not allow us to determine if it is the conjunction of a semantic and a phonological relationship that determines the nature of the recognition unit. Experiment 5 below investigates whether semantic relations are crucial to defining lexical representations.

In other models, priming data is interpreted as reflecting the organization of lexical entries. Words that are related morphologically (or semantically) prime each other because they are connected in some way within the lexicon. The logogen model prohibits connections between word recognition units (Morton, 1969). The lexicon has recently been viewed as consisting of sub-components containing different information about lexical items (Emmorey and Fromkin, in press; Allport and Funnel, 1981; Fromkin, 1987). Within a componential lexicon, a lexical entry consists of information (phonological, orthographic, semantic) stored in separate information-specific components in the lexicon. Semantically associated words are connected in some form of network within a semantically organized subcomponent (e.g. Collins and Loftus, 1975). Phonological representations of words are stored in a subcomponent organized by initial segment structure or some other phonologically based structure. In the Fromkin model (1985; 1987) connections between subcomponents are represented as address tags that cross-reference entries in each component. But how are morphological connections between words represented in a lexicon that stores semantic and phonological information separately? The experiment below investigates whether morpho-

logical relations must be represented within the semantic component.

Experiment 5: Root Priming and the Role of Semantics

If morphological relations are present in the lexicon independently of semantic association, I predict that the recognition of morphologically complex words such as deceive will be facilitated when preceded by a semantically unrelated word sharing the same root (conceive). If semantics is essential to representing morphologically related words, no recognition facilitation should be observed. Note that if hearing conceive facilitates the recognition of deceive, this result could be due to the phonological similarity between the prime and target rather than to the morphological relation. Thus, monomorphemic words related solely by their phonological form must be included as a phonological control, e.g. balloon/saloon.

Method

A lexical decision task was used in which pairs of words were presented. The words were either morphologically related (submit/permit) or phonologically related (stockade/blockade).[1] The nonword pairs consisted of a word "prime" and a nonword target (e.g. convert, orake [orék]).

Materials

The morphologically related word pairs were not semantically associated, were prefixed, and in general could undergo the same morphophonemic rule. For example, conceive and deceive become conception and deception with the addition of the suffix ion. The morphologically related pairs shared the same number of phonemes as the phonologically related pairs, and all words had second syllable

stress. There were 16 word pairs of each type (see Appendix E).

Two tapes were constructed using the UCLA WAVES Speech Analysis System. The recording was made by a male native Californian, and the speech was sampled at 10 Khz. Tape 1 contained the morphologically related prime-target pairs (e.g. submit, permit) and the phonologically unrelated prime-target pairs (e.g. baton, saloon). Tape 2 contained the phonologically related prime-target pairs (e.g. balloon, saloon) and the morphologically unrelated prime-target pairs (e.g. abuse, permit). Subjects never heard the same target twice. The unrelated prime for each pair had the same word frequency as the related prime. The target words for the morphologically related and the phonologically related word pairs were matched for word frequency as well. The same recording of the target was used for both Tape 1 and Tape 2, and a tone was placed on a second channel corresponding to the beginning of the target word which started the reaction timer. The interval between word pairs was four seconds, and 50 msec separated the prime and target words.

In addition, there were 32 filler unrelated word pairs. All filler words had second syllable stress and the same word frequency as the target pairs. The filler pairs were the same for both tapes. There was an equal number of nonwords and words. The nonwords were constructed by changing one or two phonemes in a real word and all had second syllable stress. The first item of all pairs (a total of 128) was always a word, the second item was either a nonword or a real word. The word "primes" for the nonword targets were matched for frequency and morphological structure with the primes for the

word targets. Subjects were asked to make their lexical decision to the second item. Only 13% (16/128) of the pairs on each tape were related which minimized the possibility that subjects used a guessing strategy to anticipate a word response.

Subjects and Procedure

40 UCLA undergraduates from introductory linguistics classes volunteered to participate in the experiment. 20 subjects heard Tape 1, and 20 heard Tape 2. Subjects were tested individually in a sound-treated booth. The materials were presented binaurally through headphones, and subjects made their response by pressing telegraph keys marked "yes" or "no" which stopped a reaction timer.

Results and Discussion

Errors and extreme reaction times (above 3000 msec) were excluded from the analysis. Priming was observed for pairs that were morphologically related ($F(1,628)=108.76$; $p<.001$) but not for the phonologically related pairs ($F(1,569)=2.81$; n.s.). Mean reaction times are given in Table 6.1:

Table 6.1. Mean Reaction Times for Experiment 5.

	Mean Reaction Time (msec)		
	Unrelated Prime	Related Prime	Amount of Priming
Morphological Target	937 (abuse/permit)	792 (submit/permit)	145
Phonological Target	917 (baton/saloon)	884 (balloon/saloon)	33

Morphologically complex targets were responded to significantly fas-

ter when preceded by a morphologically related word ($\bar{x}$=792) than when preceded by an unrelated word ($\bar{x}$=937). Significant facilitation was not observed when the words were only phonologically related and did not share a root morpheme. These results indicate that the morphological relation between words is represented independently of semantics in the lexicon. A strong priming effect was observed between words that are morphologically but not semantically related; priming was not observed for words that simply share a final syllable, i.e. are phonologically related.

With respect to the logogen model, these results indicate that a semantic relationship is not essential for determining logogen representations -- morphophonemic information may be enough. However, Kempley and Morton (1982) found no priming between kneeling and knelt although they share a morphophonemic relationship. Their results in conjunction with those presented here suggest that only words which share the same phonological root correspond to a single recognition unit (e.g. looking and looked) -- this would be an odd state of affairs for languages which have very productive morphological processes that change the phonological shape of the root. All forms related by such processes (e.g. umlaut, vowel harmony) would require separate recognition units.

However, in contrast to Kempley and Morton's results, Fowler, Napps, and Feldman (1985) found priming effects between irregularly related words (e.g. health, healer) as well as between regularly related words using an auditory lexical decision task. Fowler et al. suggest that the absence of priming found by Kempley and Morton may

have been due to the long delay between prime and target used in their experiment. Priming between kneeling and knelt may have occurred but diminished before it could be effective in speeding recognition. If priming between irregular words does occur, then the logogen model must be further elaborated. At present, Morton (1981) proposes "a composite model in which an input stimulus word is first segmented into its component morphemes . . . and then recombined in a central part of the lexicon (p. 395)." However, even for regularly related words no hypothesis about how this segmentation occurs is put forward, and the problem is compounded if heal and health correspond to one logogen. What information does the recognition unit respond to if neither phonological, semantic, nor syntactic information defines a logogen unit?

Fowler et al.'s findings are also interesting with respect to the cohort model. If derived words are accessed via their root morpheme as suggested by Tyler and Wessels (1983), words in which the affix changes the phonological shape of the root could not be accessed. For example, the suffix -ity changes the vowel in sane from [e] to [ae] in sanity. The word-initial cohort for sanity consists of all words beginning with the initial sequence [sae] (e.g. sand, salamander, etc.) The root sane is not included and therefore could not be accessed. Sanity must have an entry distinct from sane. Again, interpretation depends on the hypothesized cause of priming. If priming represents the activation of lexical units (as proposed in the logogen model), then Fowler et al.'s results present a problem for the cohort model as it stands. Sane will not be activated when

hearing sanity because two separate units must be represented since they do not share initial segments, or if only sane is stored some sort of morphological preprocessing must be hypothesized to compute the root sane from sanity. If, on the other hand, priming reflects the activation of connections between two related units, no immediate problems arise for the cohort model since this model does not prohibit connections between lexical items. Irregularly related words may have separate representations and may be connected by a morphological relationship.

Finally, the results presented here suggest that within a componential model of the lexicon morphological connections between words need not be found in the semantic component. I hypothesize that morphological relationships are represented by connections between words in the phonologically ordered lexical subcomponent, and these connections can be defined by a morphophonemic rule. Heal and health may not be stored together in a phonologically ordered lexicon, but there is a morphological connection that is activated when either word is heard, and these words are also connected in the semantic component by virtue of their morphological/semantic relationship. Submit and permit are connected in the phonological component but not in the semantic component.

In summary, there are two possible interpretations of the priming results presented here. Priming facilitation between morphologically related words may have occurred because these words share a root which was accessed each time the word was heard. That is, the bound root (e.g. -mit) is stored in the lexicon, and this representa-

tion is activated each time a complex word is heard that contains that root (e.g. submit or permit). On the other hand, both submit and permit might both be stored in the lexicon. In this case, priming facilitation may be due to the morphological connection between the two entries. If only the bound root is represented in the lexicon, it would suggest that the unit of representation within the lexicon is the morpheme rather than the word. In the following experiment, this possibility is explored by conducting another priming experiment in which a suffix morpheme is shared by the word pairs rather than a root morpheme. If priming is observed between pairs such as drummer-thinker, then a morpheme-based model of the lexicon will be supported.

Experiment 6: Suffix Priming

The purpose of this experiment is to further investigate the unit of representation in the lexicon. The results of Experiment 5 are compatible with both a word-based and a morpheme-based lexicon. As stated above, root priming (e.g. between submit and permit) can be explained in a word-based model as the the activation of the connection between these words defined by a morphophonemic rule. Within a morpheme-based model, root priming can be explained as the repeated activation of the root representation. However, if suffix priming occurs it can only be explained as the repeated activation of a suffix representation -- a connectionist account would be implausible. If a morpheme-based model is correct, priming should occur between words that share a suffix because according to this model suffixes have lexical representations independent of root morphemes.

The suffix representations can be accessed each time they are heard regardless of the root morpheme to which they are affixed. A word-based model predicts no suffix-priming because in this model affixes do not have separate lexical entries that can be primed, and all words that share the same suffix are independent of each other.

Furthermore, in Chapter three I suggested that suffixes might be stored either with their roots or in a separate component. If suffixes are stored in a separate component, then the same suffix representations should be activated with each presentation of the suffix, and we should find priming between words that share a suffix. On the other hand, if each root entry contains the suffixes appropriate to it, then priming should not be observed because the same suffix representation is not repeatedly accessed.

Method

Materials

The word pairs shared either an inflectional suffix (smiling, breaking), a derivational suffix (blackness, shortness), or final segments (tango, cargo). There were 18 word pairs of each type (see Appendix F). The targets in each condition (i.e. inflected, derived, and phonological control) were matched for word frequency. The related prime for each pair had the same frequency as the unrelated prime, and the frequency of the primes was matched across conditions. All words were two syllables with initial stress.

The tape was constructed with the UCLA WAVES Speech Analysis System. The same speaker from Experiment 5 was used, and the speech was sampled at 14 Khz. Both the related pairs and the unrelated

pairs were included on the same tape, thus subjects heard the target word twice. However, the stimuli were balanced such that any repetition effects should cancel out. For each condition half of the related pairs (e.g. smiling, breaking) preceded the unrelated pairs (e.g. hurry, breaking) on the tape, and the other half of the related pairs followed the unrelated pairs. To further eliminate repetition effects, two tapes were constructed. One tape presented the stimuli in one order, and the other tape presented the stimuli in the reverse order. Half the subjects heard tape 1, and half heard tape 2. The same recording of the target word was used for both the related pair and the unrelated pair. A tone was placed on a second channel (inaudible to subjects) corresponding to the beginning of the target word. The interval between the word pairs was three seconds, and 50 msec separated the prime and target words.

There was a total of 108 word pairs. There was an equal number of words and nonwords. The nonwords were constructed by changing one or two phonemes of a real word and had the same stress pattern as the words. The total number of stimulus pairs was 216. As in Experiment 5, the first item of all pairs was always a word, and the second item was either a word or nonword. The word "primes" for the nonword targets were matched for frequency and morphological structure with the primes for the word targets. Subjects were asked to make a lexical decision to the second item of each word pair.

Subjects and Procedure

20 UCLA undergraduates from introductory linguistics classes volunteered to participate in the experiment. Response times were

measured as in Experiment 5.

Results and Discussion

Errors and extreme reaction times (above 3000 msec) were excluded from the analysis. Priming was observed for pairs that share a derivational suffix ($F(1,704) = 20.52$; $p<.001$) and for pairs that share final segments ($F(1,667) = 25.27$; $p<.001$). A small but significant amount of priming was also found for words that share an inflectional suffix ($F(1,687) = 4.55$; $p<.05$). Mean reaction times are given in Table 6.2:

Table 6.2. Mean Reaction Times for Experiment 6.

	Mean Reaction Time (msec)		
	Unrelated Prime	Related Prime	Amount of Priming
Derivational Target	875 (fertile/shortness)	812 (blackness/shortness)	63
Inflectional Target	841 (hurry/breaking)	812 (smiling/breaking)	29
Phonological Target	898 (fable/cargo)	819 (tango/cargo)	79

In contrast to Experiment 5, phonological priming was found between words that share final segments. It is possible that phonological priming was significant in this experiment because it was a with-in subjects design which has less subject variation and therefore may have been more sensitive to the experimental manipulations. Experiment 5 was a between-subjects design which inherently contains

more subject variation. Phonological priming may have occurred in Experiment 5 but was too weak to reach significance.

Note that the priming we observe in the inflectional and derivational conditions is probably not due to a shared suffix representation because priming was also present in the phonological condition. If suffix priming contributed to the results, we would expect at least more priming between words that share a suffix than between words that only share final segments, but this was not found. Apparently, the priming observed between words that share a suffix was not due to their morphology but to a phonological relationship.

The lack of suffix priming argues in favor of a word-based model of the lexicon over a morpheme-based model (see Chapter two for a detailed description of these models.) Suffixes apparently do not have independent representations that can be primed.[2] Furthermore, the results from Experiments 5 and 6 indicate that roots and suffixes have a different lexical status. Priming was found for root morphemes but not for suffix morphemes. This differential priming effect argues against affixes having lexical entries similar to roots as proposed by proponents of morpheme-based models of the lexicon (Selkirk, 1982; Lieber, 1980). Selkirk (1982) has proposed that a major difference between nonaffix and affix morphemes is that affix morphemes are always bound, but boundedness cannot be the reason for the priming differences observed here because the roots in Experiment 5 were bound morphemes (e.g. -mit).

It should be noted that my argument against the morpheme-based models within linguistics holds only if the lexical representations

listed in a linguistic model map directly to recognition units within a processing model. If the grammar is type transparent with the processing system, however, the representations accessed during word recognition should correspond to the representations listed in the lexicon of the grammar. The results from Experiments 5 and 6 suggest that words rather than morphemes are stored in the lexicon and accessed during recognition. A word-based model can be integrated more easily with a lexical access system that operates upon word representations.

Finally, we come to the difference in the amount of priming between derivational and inflectional conditions. Why do we find smaller priming effects for words that share an inflectional suffix? I suggest that this difference in priming is not due to morphological structure but to the phonological structure of the words in each condition. All but one of the word pairs in the phonological condition share a final syllable in addition to simply sharing final segments; all but four of the pairs in the derivational condition share a final syllable; however, only four of the word pairs in the inflectional condition share a final syllable. The number of shared segments were matched between conditions, but syllable structure was not controlled for. Less priming may have been found in the inflectional condition because most of these word pairs did not share a syllable, and priming due to shared syllables may be more robust than priming due to shared segments alone. Such a possibility is investigated in the following experiment.

Experiment 7: Syllable Priming

If the differential priming effect observed between words with derivational and inflectional suffixes in Experiment 6 was due to a difference in the syllabic structure of the items, we should be able to eliminate the difference by changing the syllabic structure of the inflected words. We should find stronger priming for words which share a final syllable regardless of the morphemic status of the syllable. In this experiment, inflected words that share a final syllable (e.g. poking, winking) were substituted for the word pairs in the derivational condition, thus we can directly compare these inflected word pairs with inflected pairs that do not share a final syllable (e.g. smiling, breaking).

Method

Materials

The word pairs from the phonological and inflectional conditions from Experiment 6 were used with some modifications. The one pair from the phonological condition which did not share a final syllable (panel [pae - nəl], temple [tɛm - pəl]) was substituted for a pair that did (stable [ste - bəl], noble [no - bəl). The word pairs from the inflectional condition of Experiment 6 constituted the condition in which no final syllable was shared. The four word pairs that did share a final syllable (e.g. flirted [flɚ - Dəd], stranded [straen - Dəd]) were substituted for word pairs that did not (e.g. filming [fIl -miŋ], choking [ʧo - kiŋ]). Finally, 18 inflected word pairs which share a final syllable (e.g. poking [po - kiŋ], winking [wiŋ - kiŋ]) were substituted for the 18 pairs in the derivational

condition. Thus, there were three word conditions in this experiment: phonological control, inflected with a shared final syllable, and inflected with no shared syllable (see Appendix G). The same frequency controls were implemented as in Experiment 6, and the same nonword pairs were used. Again, there was a total of 216 pairs. The same tape was used from Experiment 6 with the substitutions noted here.

Subjects and Procedure

20 UCLA undergraduates from introductory linguistics classes volunteered to participate in the experiment. Half the subjects heard the stimuli in one order, and half heard the reverse order. Response times were measured as in Experiment 6.

Results and Discussion

Errors and extreme reaction times (above 3000 msec) were excluded from the analysis. Priming was found for inflected pairs that share a final syllable ($F(1,689) = 17.89$; $p<.001$) and for phonological pairs that share a final syllable ($F(1,644) = 4.40$; $p<.04$). Significant priming was not observed for inflected word pairs that did not share a final syllable ($F(1,682) = 3.47$; n.s.). Mean reaction times are given in Table 6.3:

Table 6.3. Mean Reaction Times for Experiment 7.

	Mean Reaction Time (msec)		
	Unrelated Prime	Related Prime	Amount of Priming
Inflec. Shared Syll.	847 (whistle/shaping)	789 (dumping/shaping)	58
Inflec. No Shared Syll.	823 (hurry/breaking)	799 (smiling/breaking)	24
Phono. Shared Syll.	895 (fable/cargo)	837 (tango/cargo)	58

Phonological priming was found only when word pairs share a final syllable -- when the shared segments did not form a syllable, significant priming was not present.[3] Furthermore, the morphemic status of the final syllable did not influence the amount of priming facilitation. The results of this experiment reinforce the conclusions drawn from Experiment 6. No evidence of suffix priming has been found which indicates that suffixes do not have independent representations that are accessed during word recognition. A morpheme-based model in which affixes have lexical entries is not supported. A word-based model, however, is consistent with the lack of suffix priming.

Interestingly, Slowiaczek and Pisoni (1986) did not find evidence of phonological priming using an auditory lexical decision task. However, the primes and targets used in their experiment shared segments not syllables. Slowiaczek and Pisoni presented primes that shared one, two, or three phonemes with the target word (e.g.

target: black; primes: burnt, bleed, or bland). Significant priming was not produced by any of these primes. Slowiaczek and Pisoni may have failed to find phonological priming because the segment may not be a representation that is repeatedly accessed during word recognition. That is, there may not be phoneme representation, say /p/, that is activated each time a [p] occurs in the acoustic input. Syllables, on the other hand, may have representations within the lexicon that are accessed during word recognition such that repeated activation of these representations speeds recognition. Another possibility is that phoneme representations are activated during speech perception, but this activation fades too quickly to produce facilicatory priming. The activation of syllable representations may be more stable. Future experiments need to directly compare priming for words with shared segments and words with shared syllables controlling for the total number of shared segments.

As mentioned in Chapter one, a fair amount of controversy surrounds whether the syllable or the segment is the unit of segmentation for speech perception. Recently, Cutler, Mehler, Norris, and Segui (1986) have proposed that alternative segmentation routines are available to the human language processor. Based on evidence from monitoring experiments, the authors argue that French speakers tend to use a syllable-based segmentation procedure whereas English speakers do not exhibit syllabifying segmentation when listening to speech. The results presented here are not necessarily at odds with these results. Although the syllable may not be a unit of segmentation used by English speakers, the syllable may still be a unit of

representation that is activated. For example, Dell's (1986) network model of the lexicon contains a hierarchy of representations (nodes) which include syllable and phoneme representations. Segmentation may activate phoneme nodes which in turn access/activate syllable nodes. In contrast, the TRACE model (McClelland and Elman, 1986) does not contain a level of syllable representation, and it is not clear if this model, as it stands, could account for the presence of priming between words which share a syllable and the lack of priming between words sharing the same number of segments but not sharing a syllable.

In Dell's model, word nodes such as farming and farmer connect to a common root morpheme node. The lack of suffix priming evidenced by Experiments 5 and 6 in this Chapter indicates that word nodes do not connect to suffix morpheme nodes. Root morpheme nodes connect to syllable nodes which further connect to phoneme nodes. Fowler et al. (1985) observe that Dell's model has difficulty accounting for the priming between irregular words like heal and health because in this model these words do not share a morpheme node. In this model the syllable structure and phonemic constituents of a word are elaborated at hierarchical levels leading from morpheme nodes, thus morphemes sharing a node are required to have the same pronunciation. The model has a similar problem explaining priming between inflected words sharing a final syllable (e.g. farming, swimming) because it is the morpheme nodes that connect to the syllable nodes. Fowler et al. propose a modification to Dell's model that will account for the heal/health case as well as the syllable priming results presented here. They suggest that the model be adjusted such that the syllable

level and the levels below it connect directly to the word nodes and not to the morpheme level. Morphological structure would then be a hierarchical level independent of levels of phonological structure. Furthermore, the separation of morphological from phonological levels of representation receives independent support from linguistic theories of prosodic structure (e.g. Selkirk, 1984; McCarthy, 1981). In metrical theory, syllable structure forms a level of representation independent of morphological structure.

Finally, the fact that phonological priming occurred word finally has important implications for the cohort model which proposes that words are accessed only by their initial segments. In this model there is no mechanism for tango to prime cargo because when tango is heard only those words that begin with similar segments are activated. Furthermore, since lexical access is phonologically ordered, the cohort model implies that the end of a word should be least salient part of the word. However, recent experiments have shown that listeners are quite capable of recognizing spoken words on the basis of their final segments alone (Nooteboom, 1981). Salasoo and Pisoni (1985) also found that listeners could correctly identify words from information at the ends of those words. The cohort model as currently proposed cannot explain word recognition from final fragments or word final phonological priming.

The cohort model may have to loosen its constraint that words are accessed in a strictly "left-to-right" order. Additional phonological structure may need to be added that is independent of the temporal order of input if the model is to survive. This additional

structure may be sub-lexical; that is, activation of syllable or phoneme representations may occur prior to (or during) the activation of lexical representations. If this is the case, phonological priming should occur between nonwords which have no lexical representation (e.g. sengo) and words (e.g. cargo) because the priming facilitation occurs at a sub-lexical level. A recent experiment conducted by Slowiaczek, Nusbaum, and Pisoni (1987) suggest that such priming might occur. In their experiment subjects had to identify a target word in noise, and the probability of correct identification was increased when the target word was preceded by a nonword prime that shared three initial phonemes (e.g. prime: [plef]; target: place). Target identification was not aided when the nonword primes only shared one or two phonemes (e.g. prime: [pem] or [plik]; target: place). These findings suggest that phonological priming of some degree may occur at a sub-lexical level.[4]

In summary, the results for the experiments presented in this chapter provide evidence for the following assertions:

1. Morphological relationships are represented independently of semantic association within the lexicon.

2. Affixes do not have lexical representations that can be primed. A word-based model of the lexicon is more consistent with this finding than a morpheme-based model.

3. Syllable priming appears to be more robust than segment priming. Models of word recognition which include a level of syllabic representation are favored over those which do not.

4. Morphological structure may form a level of representation

independent of but related to phonological and semantic representations.

Chapter 7

Summary and Conclusions

A major assumption underlying this study is that language as a cognitive system can only be understood with an understanding of the relation between grammar and language processing mechanisms. One goal of this dissertation has been to elucidate how lexical models proposed as part of linguistic theory may be incorporated into lexical models proposed in psychology. I have suggested that the lexical representations in linguistic theory should be type-transparent with those accessed on-line during word recognition and language comprehension. The results from the various experiments presented here have been consistent with this proposal. We have found no evidence which indicates that the lexical representations accessed during word recognition are incompatible with those proposed in linguistic models. As was evident in Chapter two, linguistic models of the lexicon contain different types of rules and representations. The results of the experiments presented here cannot chose between many of the subtle proposals found in these models -- nor were they designed to do so. However, the results do support one type of lexical model over another, namely word-based over morpheme-based models.

This chapter will review the major experimental findings and their implications for the representation of morphological structure in the lexicon and how this structure might be parsed during word recognition. The model sketched here is preliminary and proposed only for auditory word recognition. Several important questions and

issues are not yet addressed, and the gaps and problems that must be resolved by future research will be indicated.

The Representation and Parsing of Morphological Structure

The research began with the question of how morphologically complex words are represented in the lexicon. As discussed in previous chapters, it is assumed that representation and processing inter-relate such that the nature of lexical access implies a particular type of representation and vice versa. Thus, both concepts will be discussed. I will present a first approximation of a morphological parsing model which interprets word internal structure on-line during lexical access. The model is based largely on the lexical access procedure proposed for the cohort model (Marslen-Wilson, 1987). I do not assume, however, the interactive nature of lexical access that this model proposes; all of my research was conducted with words presented in isolation. Additional experiments must be conducted with words in context to determine whether and/or how the morphological parsing procedure proposed here might be influenced by semantics or syntactic structure.

Prefixed Words

The results of Experiment 1 showed that prefixed words were recognized faster than monomorphemic words. This can be accounted for if subjects recognized the prefix early and were thus biased to respond "word" in the lexical decision task. The results from Experiment 1 are compatible with a model in which prefixed words are stored separately from their roots with their morphological structure marked (e.g. both in+sane and sane have lexical entries), and these

results are also compatible with a processing model which contains a prefix stripping process prior to accessing the root in the lexicon. However, recent experiments by Tyler, Marslen-Wilson, Rentoul, and Hanney (1987) indicate that prefix stripping does not occur for auditory word recognition. In three experiments using the gating, auditory lexical decision, and auditory naming (fast repetition) tasks, they compared the recognition points for prefixed words and their corresponding free roots. The results showed that the recognition-point for prefixed words was determined by the properties of the full prefixed form and not by the properties of its root. For example, miscount was recognized when it deviated from other prefixed words (i.e. from misconduct) and not at the point where the root count deviated from its cohort. That is, the uniqueness point for prefixed words was determined by a cohort containing prefixed words. Their results do not support the claim that lexical access is delayed until the root can be identified.

Tyler et al.'s (1987) results in conjunction with those of Experiment 1 suggest that prefixed words in English are listed in the lexicon with their morphological structure marked:

mis+cast
mis+count
mis+conduct
mis+construe

As shown, words that begin with the same prefix are stored together in the lexicon; word recognition is achieved when the prefixed word deviates from other words with the same prefix, e.g. miscount becomes unique at the vowel /aw/ where it deviates from the rest of the words

in its cohort.

Two questions arise in connection with this proposal: 1) How are newly coined English prefixed words recognized (e.g. debug, ex-hacker)? and 2) Does this proposal apply to languages with highly productive prefixation processes like the Bantu languages?

First, to account for morphological creativity as well as speakers' ability to understand new morphologically complex words, I suggest that independent prefix representations are stored in the lexicon but are not necessarily accessed during word recognition[1]. Such representations contain morphological, syntactic, phonological, and semantic information specific to particular prefixes. When new words are encountered or created, it is these representations that are used in conjunction with the speaker's knowledge of Word Formation Rules. I propose, like Aronoff (1976), that once a prefixed word is created or learned it is stored in the lexicon with the other words that begin with the same prefix. However, these rules and prefix representations are not accessed directly during on-line word recognition.

I hypothesize that for languages with very productive prefixation processes, prefixed words are not represented in their complex forms and are instead accessed by their roots. For languages in which almost every word is prefixed the initial cohort for prefixed words would be enormous (unlike for prefixed English words); therefore, some type of prefix-stripping process would be more efficient and economical than storing both the prefixed words and their roots in the lexicon. However, this speculative proposal waits confirma-

tion through psycholinguistic experiments using languages with productive prefixation.

Suffixed Words

The word and nonword results from Experiments 1-4 indicate that suffix recognition is a separate process that occurs after the root has been identified. The results from Experiment 1 and those of Tyler and Wessels (1983) suggest that only the roots of suffixed words are contained in the cohort set used for recognition and not fully inflected forms. Evidence from the nonword results of Experiments 2b and 3 further indicate that suffixes are not accessed/recognized until a root is identified. Response times to nonwords like garnly were not delayed in comparison to simple nonwords like sulfack. Both types of nonwords can be rejected at the same point. No possible root is identified, and thus the suffix in garnly is not recognized as such on-line. Suffixes are accessed only after a root has been identified. Furthermore, the lack of suffix priming is consistent with a model in which suffixes are stored with each root. A model in which suffixes are stored in a separate component that is accessed each time the suffix is heard is not supported.

The structure proposed here for the representation of suffixed words is similar to the "satellite entry" hypothesis put forth by Lukatela and his colleagues for Serbo-Croation (Lukatela et al., 1980; Katz, Boyce, Goldstein, and Lukatela, 1987). Lukatela et al. (1980) using visually presented Serbo-Croation words and Katz et al. (1987) using auditorily presented words found that lexical decision was not correlated with the frequency of the inflected forms. Re-

sponse times to oblique cases did not differ even though these forms differed in frequency, and the nominative singular form was recognized most quickly. To explain these results, a satellite theory was proposed in which each inflected form of a word has a separate entry in the lexicon. For nouns (in Serbo-Croation at least), the nominative singular entry functions as the nucleus around which the lexical entries of the remaining grammatical cases cluster. Figure 7.1 illustrates a partial satellite representation for the Serbo-Croation word zena ("woman"):

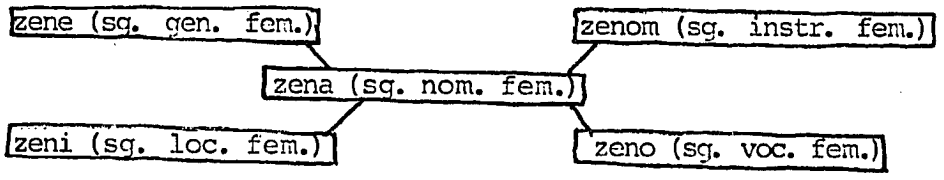


Figure 7.1. Satellite representation proposed by Lukatela et al.

I propose instead that these forms share a root entry and that suffixes are stored with the root as illustrated in Figure 7.2:

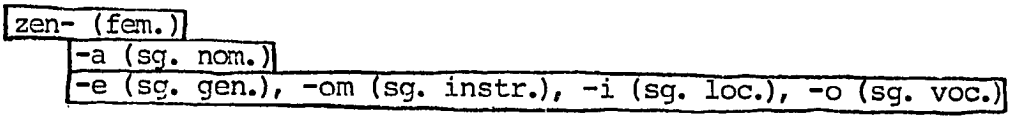


Figure 7.2. Representation of suffixed words proposed here.

According to this representation the speed of recognition for the nominative singular representation is due to the organization of the suffix representations attached to the root. That is, the singular nominative suffix has priority when the suffix representations are accessed. The representation of suffixed words proposed here simply

shifts the satellite hypothesis from listed inflected forms to suffix representations stored with the root.

The two questions that arose in connection with the representation of prefixed words are relevant here: 1) How are new suffixed words created/learned? and 2) Does this proposal apply to languages with highly productive suffixation processes? Again, I propose that for English independent suffix representations are stored in the lexicon and can be used creatively, but these representations are not normally accessed on-line during language comprehension. For suffixal languages like Turkish, suffixes may not be stored with each root. In these languages suffixes may be stored in a separate component that is automatically accessed after a root has been identified. This hypothesis can be investigated by conducting priming studies with languages which have highly productive and regular suffixation processes.

Inflection and Derivation

Miceli and Caramazza (1987) argue that if the satellite hypothesis is correct, the satellite representations cannot be unstructured. On the basis of data from a dyslexic patient (see Chapter four) Miceli and Caramazza argue that inflected and derived forms must cluster separately around the nuclear citation form. I propose, however, that the inflectional suffixes are stored separately from the derivational suffixes. This lexical organization can easily explain the pattern of morphological errors observed in Miceli and Caramazza's patient. As discussed in Chapter four the majority of this patient's repetition errors consisted of producing the incorrect

inflectional suffix; very few errors were made on the word root. According to the organization of entries proposed here, the patient was able to access root representations but access to inflectional suffixes was impaired. Under the satellite hypothesis, the patient's error pattern is explained as the misselection of an entire inflected form and not simply the misselection of a suffix as proposed here.

The results of Experiments 2a and 3 further support a distinction between derivation and inflection at the lexical level. In both these experiments, response times to derived words were delayed in comparison to inflected and monomorphemic words, and no difference in response time was observed between inflected and monomorphemic words. I suggested that the delay for derived words was due to the category-changing nature of the derivational suffix and that the parsing procedure may have been slowed because the category of the root differed from the category assigned by the suffix. I further hypothesized that because inflectional suffixes add little information relevant to the semantic/syntactic interpretation of words in isolation, response times to inflected words were similar to monomorphemic words. These proposals need to be further investigated using other stimuli as well as other psycholinguistic paradigms to establish whether the pattern of results found here is in fact due to the morphological properties I have suggested. For example, it would be interesting to compare response times for words with derivational suffixes that do not change the syntactic category of the root (e.g. violinist) with words that contain category-changing suffixes (e.g. player).

Finally, as we understand more about the recognition of morphologically complex words in isolation, it is important to investigate the recognition of complex words in context; after all, that is how these words are normally perceived and recognized. Anderson (1982) has proposed that the distinction between inflectional and derivational morphology is based on the relevance of inflectional morphology to syntactic structure, therefore the difference between inflectional and derivational morphology may become more apparent when sentential processing is considered.

Parsing Nonconcatenative Morphology

It is important to point out that the proposal for morphological parsing presented here fails when confronted with languages containing nonconcatenative morphology. The model assumes that words are represented in the lexicon as strings of morphemes -- prefixes precede roots and suffixes follow. Access to the lexicon is assumed to be "left-to-right" and phonologically ordered as in the cohort model. As mentioned in Chapter six, productive morphological processes that change the phonological shape of the root create problems for a phonologically ordered access procedure. The model must assume that words like sane and sanity have separate lexical entries because they cannot share the same initial cohort, sane is not contained in the cohort set for sanity. Because trisyllabic shortening is not very productive in English, words related by this rule could easily both be listed in the lexicon. However, many languages, like Arabic or Hebrew, exhibit highly productive nonconcatenative morphological processes. No linguistic model determines which items are listed in

the lexicon on the basis of whether a morphophonemic rule changes the initial segments of the root, and I suggest in accordance with the type-transparency hypothesis that no psychological model should make this distinction either. Productivity may determine which items are listed in the lexicon, but the nature of the morphophonemic rule relating lexical items should not be the deciding factor.

Morphological parsing and lexical access procedures need to be elaborated to account for the effects of allomorphy and morphophonemic processes such as umlaut, vowel harmony, reduplication, infixation, metathesis, etc. Lexical representations are no doubt more abstract than presented here, and the access procedure which matches the incoming sensory input with stored lexical representations must be more complex than previously suggested.

Linguistic theory can shed light on the nature of abstract lexical representations. Recently, autosegmental approaches to morphology have been advanced in which the morphological and phonological representations of a form are independent but coordinated. Rather than viewing morphemes as units composed of phonological material and concatenated to create words, the morphological elements of a word are represented on a morphological tier which is linked by lines of association to a phonological tier. This tiered approach to morphology pioneered by McCarthy (1981) has been quite successful in solving some of the classical problems of nonconcatenative morphology (see Anderson, in press). Can such representations be incorporated into a model of lexical access and word recognition? The answer will no doubt be found by future research on languages which exhibit the

morphological processes tiered representations were designed to explain. In fact, quite recently Boyce, Browman, and Goldstein (in press) have proposed that an autonomous morphological tier is necessary to account for priming data from Welsh. Welsh exhibits initial consonant mutations such that a word (e.g. pont "bridge") has different phonological forms (e.g. bont, font) depending on the syntactic context. Boyce et al. find that the mutated variants prime each other and explain this result (and others) by positing an independent morphological level and underspecified autosegmental phonological representations. The results from Experiment 5 also support the separation of morphological and phonological representations. Priming facilitation was found that was due solely to a morphological relationship and not to shared phonology or semantics.

Lexical Semantics

Throughout the dissertation I have been generally concerned with the representation of morphological structure without much regard to the lexical semantics of complex words. However, some of the experimental results presented here bear on the semantic representation of these words. For example, Experiment 5 showed that semantic association was not crucial to the representation of morphologically related words. Facilicatory priming was observed between morphologically related words that were not meaningfully related (e.g. submit, permit). Furthermore, Experiment 1 revealed no effect of the semantic decomposability of complex words. Prefixed words that were semantically decomposable (e.g. insane) were recognized as easily as those that were not (imply).

In Chapter four I argued against the hypothesis that the delay in recognition for derived words was due to the on-line construction of a complex semantic representation. In contrast, Miceli and Caramazza (1987) have proposed that the semantics of complex words are represented in the lexicon in a decomposed form. They argue that when a complex word is produced "a lexical semantic representation . . . serves as input to the phonological output lexicon. The semantic representation is articulated into distinct parts, each part specifying different aspects of the lexical form. That is, the semantic representation includes what we have called root semantic features, derivational semantic features (where present) and inflectional semantic features (p. 28)."[2] However, many linguists have pointed out that the semantics of derived words are often unpredictable and idiosyncratic (e.g. Aronoff, 1976; Jackendoff, 1975). Over time the meaning of derived words tends to drift away from the composite meaning they might have once had. For example, in English we find words like sizable, priceless, authority, or fellowship. If these words are accessed in a phonological lexicon on the basis of their "root semantics" in conjunction with their "affix semantics" as suggested by Miceli and Caramazza (1987), it is unclear how the root and affix semantics are determined. The meaning of these words cannot be derived from a straight forward combination of the meanings of their roots and affixes. I argue therefore that the phonological form of derived words is not retrieved on the basis of decomposed semantic representations.

I do not want to insinuate, however, that the semantic associa-

tion between morphologically related words is not rule-governed. Generally, a new word that enters the language is semantically decomposable, but after time the meaning of the derived word may shift. Models of the lexicon must be able to account for both the rule-governed aspects of lexical semantics and semantic drift.

Morphology in a Componential Model of the Lexicon

I have argued here and elsewhere (Emmorey and Fromkin, in press) that the lexicon consists of separate subcomponents which contain semantic, phonological, and orthographic information about words. Fromkin (1987) presents additional arguments for these separate lexical sub-components and provides a mechanism whereby entries within each component are connected. The question raised here is how morphological structure might be represented in this type of lexical model? In Chapter six, I suggested that morphological connections exist within the phonological component but not necessarily in the semantic component. I would like to revise that hypothesis here and suggest that a morphological component exists which interacts with both the phonological and semantic components.

A separate morphological component would allow priming between words which do not share a phonological root (e.g. heal, health) and priming between words related by a morphophonemic rule but which share no semantic relation (e.g. deceive, conceive). Furthermore, the separation of morphological from phonological representations coincides with current linguistic theory and brings us closer to incorporating a linguistic model of lexical representation into a model of lexical processing. The connections between the morpho-

logical and phonological representation of a lexical item may be defined by linguistic rules and principles. The further ramifications of this type of lexical organization for word recognition and language comprehension requires more psycholinguistic experimentation perhaps with languages that have more complex morphological systems than English.

Lexical Access for Visual and Auditory Word Recognition

On the basis of various data from dyslexic patients and psycholinguistic experiments, the proponents of several psycholinguistic models argue that orthographic and phonological representations of words are stored in separate components (e.g. Fromkin, 1987; Forster, 1976; Morton, 1979). Early proposals suggested that orthographic representations were not stored in the lexicon; rather, grapheme-to-phoneme rules converted printed words into phonological representations which were stored in the lexicon. However, new data indicate that this position is untenable (see McCusker and Hillinger (1981) for a review.)

If both orthographic and phonological representations are stored in the lexicon, how different is reading from listening? That is, what are the modality-specific and modality-free processes of word recognition? Experiments 3 and 4 shed some light on the answer to this question. In these two experiments, the same words and nonwords were presented visually and auditorily for lexical decision to two different groups of subjects. Response times did not differ for the word stimuli, but the pattern of nonword reaction times differed considerably depending on whether the nonwords were presented visual-

ly or auditorily.

The recognition of derived words was delayed for both visual and auditory presentation, and I have argued that this delay was due to the lexical representation of derived words and not to a different parsing procedure. This explanation suggests that the morphological structure of words is marked in the orthographic as well as phonological representations of words. Another possibility is that both orthographic and phonological representations connect to a morphological component. In either case, the results of Experiments 3 and 4 suggest that word internal structure has the same effect upon visual and auditory word recognition and therefore that the orthographic and phonological components of the lexicon do not differ with respect to the representation of morphological structure. Further research is required to determine whether this structure is represented in the phonological and orthographic subcomponents themselves or in a separate shared morphological component.

Nonwords do not have lexical representations, and I propose that their differing pattern of response times for visual and auditory presentation was due to the nature of the lexical access procedures for these modalities. Furthermore, I hypothesize that the morphological analysis of an incoming stimulus is dependent upon the mechanisms of lexical access. For auditory lexical access, identification of a final suffix is tied to the recognition of the root; hence, no difference in rejection time was observed between suffixed nonwords (garnly) and simple nonwords (sulfack). If morphological analysis for auditory word recognition is independent of lexical access or

occurred somehow after lexical access, we would expect longer response times for the suffixed nonwords. The suffix can be recognized as a morpheme and should slow the rejection of the item as a word. This is exactly the response pattern observed for nonwords presented visually. For visual word recognition, the suffix can be recognized independently of the root. The presence of either a real root or suffix in a nonword slows rejection time for visual word recognition. This pattern of results suggests that visual word recognition is not as constrained by temporal order as auditory word recognition.

A Parameterized Universal Parser

Psycholinguistic experiments with different languages raise important questions about natural language processing. For example, how do morphological processing systems vary as a function of the structural properties of their respective languages? For languages with complex morphology such as Eskimo or Turkish the morphological parsing mechanism may be quite complex and essential to word recognition; for isolating languages like Mandarin Chinese a parsing mechanism may not be employed at all. It is important to systematically study languages with different morphological properties to determine which aspects of human parsing are universal and which may vary with language type.

Analogous to Universal Grammar, children may come equipped with a parameterized Universal Parser, and UG may be implicit in the parser or may interact with the parser as a separate system. The morphological properties of a language may determine how the Universal Parser is implemented. A similar hypothesis has already been put

forth by Cutler et al. (1986) for segmentation procedures. Cutler et al. suggest that because English contains irregular syllable structure and unclear syllable boundaries, English speakers segment the acoustic signal on the basis of segmental structure, whereas French speakers rely on the syllable because French has a very regular and predictable syllable structure. The basic segmentation unit may be a parameter that is set during language acquisition on the basis of the phonological system being acquired. Setting this parameter would allow segmentation mechanisms to maximally interpret the acoustic cues provided by the language being acquired. The mechanisms involved in the interpretation of morphological structure may have similar parameters which are set during acquisition.

The default settings for the human morphological parser may be those required for isolating languages; that is, children may assume they are learning an isolating language until they receive evidence to the contrary. This default setting may explain in part why children first acquire a number of complex forms which are not analyzed into their component morphemes. Another possible parameter may be the types of morphological structures that the parser must interpret. For example, if a language has no prefixes, the morphological parser can search for a root without regard to possible prefixes. Although the parser may initially have the capacity to interpret prefixed items, this capacity is never utilized for this type of language. More sophisticated and interesting parameterized properties may be discovered by examining languages with different morphological systems.

Cross-linguistic studies will reveal the universal principles of language parsing as well as the parameters along which parsing may vary. For example, the distinction found here between roots and affixes may be universal; that is, roots may always have lexical entries, but languages may vary as to whether affixes have lexical entries that are accessed on-line. Another possible universal principle may be that the parser utilizes morphotactic information to constrain the possible interpretations of an incoming complex word. Idiosyncratic facts about the morphological structure of a given language may be very useful in constraining the number of word candidates and possible parses of an incoming string. I propose, similar to Marslen-Wilson (1987), that the parsing mechanism is optimally efficient; that is, any information that constrains the search space is used. Unlike Marslen-Wilson (1987), however, I suggest that the only information available to the morphological parser is language specific. Only facts about the morphological and phonological structure of the language may influence morphological parsing -- "real world" knowledge does not constrain the parser during the parse.

This last section has been presented primarily as a spring board for future cross-linguistic research. The major finding of experiments presented here is that morphological structure is analyzed on-line during word recognition. I have attempted to combine linguistic and psychological models of the lexicon. This dissertation forms an experimental and philosophical foundation upon which future studies concerning morphological structure and word recognition can build.

Notes to Chapter 1

1. "Processing" refers here to the mechanisms involved in both language comprehension and production).

2. It is interesting to note that the "lexical strategy" for discovering deep structure configurations based on the subcategorization constraints of the verb corresponds directly to the projection principle, a universal principle proposed by Chomsky (1981). The projection principle states roughly that the subcategorization properties (and thematic structure) of lexical items must be preserved at each syntactic level -- these representations are projected from the lexicon.

3. Bierwisch (1983) provides convincing arguments that this proposal is incorrect and that these authors themselves assume that separate syntactic and semantic representations exist.

Notes to Chapter 2

1. The cohort model has been modified recently (Marslen-Wilson, 1987) such that the drop out of words from the word initial cohort is not complete; that is, the matching process between the sensory input and the word candidates is not all-or-none; instead, when a mismatch occurs between a word candidate and the sensory input the level of activation of the word candidate is lowered. This modification allows the model to account for word recognition in noisy environments but does not greatly affect the issues discussed here.

2. In Lieber's (1980) model, subcategorization restrictions are specified for affixes not roots; for example, un- is marked as a prefix that can attach to adjectives, and roots are marked as to their syntactic category. In the Addressed Morphology model each root is specified as to what affixes it allows, such that roots would be marked as adjectives and would also be marked as allowing un- prefixation. Lieber's system of specification captures the generalization that the prefix un- attaches to adjectives and does not required every adjectival root to be marked for un- prefixation. Shifting subcategorization restrictions from roots to affixes does not appear to cause any problems for the Addressed Morphology Model, and therefore I suggest Lieber's specification proposal be adopted for this model.

Notes to Chapter 3

1. The conventional F statistic was employed here to avoid the substantial negative bias associated with quasi-F tests. Our materials were matched on a number of relevant dimensions (i.e. well balanced), and Wickens and Keppel (1983) have shown that balancing materials "is very effective in reducing the positive bias associated with a

[fixed-effect] F_1 statistic" (p. 307).

2. Means given in the planned comparison analyses vary slightly from the means given in the overall F because of the different covariate duration adjustments.

Notes to Chapter 4

1. The results are not altered if reaction time is measured from word onset ($F(2,810) = 2.96$ $p<.06$). To provide a better comparison with the previous experiment, results based on reaction time measured from uniqueness point are presented.

2. Kolk, and van Grunsven (1985) have described an agrammatic patient in which only the production of function words is affected.

3. All derivational morphology may not be spared -- Kean (1977) argues that only morpheme boundary (+) morphology is intact with agrammatism.

4. Miceli and Caramazza's data indicate that the patient's morphological errors are not due to an auditory perceptual impairment. The patient performed well on auditory lexical decision and auditory "same-different" tasks, although his performance on auditory sentence comprehension tasks was poor. The patient also appeared to have damage at some level of phonological processing because he was completely unable to repeat nonwords. Although Miceli and Caramazza's patient may have some perceptual and phonological impairments, the nature of these impairments cannot explain the morphological pattern of errors, i.e. the distinction between inflection and derivation.

5. Note that hunt may also be a noun. However, the verb is the base from which the noun is derived, and the verb form is also much more frequent. Therefore, I suggest that in isolation hunt is initially interpreted as a verb. Of the words used in Experiment 2a, 4 contained category ambiguous roots (hunt (V,N), shred (V,N), seep(V,N), and blunt (Adj, V) and 11 contained unambiguous roots (e.g. grim, tribe).

6. Because zero-derivation is so common in English, it is very difficult to find an illegal combination of roots and suffixes. For example, the pseudoword brooming is constructed by illegally combining a verbal suffix with a noun. However, it is fairly easy to imagine a verb "to broom" derived from the noun "broom". Therefore, it may be more appropriate to use the term nonoccurring than illegal to describe the root-suffix combinations that make up the pseudowords.

7. When reaction time is measured from stimulus onset, the results are as follows: Over-all F: ($F(2,849) = 3.69$; $p<.03$). The mean

reaction time for simple nonwords is 995 msec, 1005 msec for suffixed nonwords, and 1038 for word-suffix illegal combinations. Planned comparison analyses results are also the remain same.

Notes to Chapter 5

1. As for Experiment 2a, the results of Experiment 3 are not altered if RT is measured from word onset ($F(2,781) = 3.85$ $p<.03$). Results from planned comparisons also remain the same.

2. When RT is measured from stimulus onset the overall F statistic is $F(3,1128 = 6.14$; $p<.001)$. Results from planned comparisons remain the same as well.

3. Note that some monomorphemic words appear to begin with roots, e.g. pendulum contains pen. As stated in the text, I hypothesize that when a root is encountered suffixes are automatically accessed, so for example, when pen is heard, suffixes are accessed but none match the rest of the incoming stimulus, i.e. -dulum. Furthermore, matching of the incoming string with the remaining stored roots (e.g. pend and pendulum) continues in parallel with the matching of stored suffixes. Since no suffixes occur in pendulum only the root matching procedure succeeds. For a similar example, see the parse trace of lobster given in Table 3.1.

4. The exact nature of the matching process for visual input is not clear. I assume a pattern recognition process in which both root and affix representations are matched with the stimulus according to some "best-fit" algorithm. In this way, all possible partitions of the stimulus would be tested in parallel. Various constraints may operate on this procedure; for example, suffix representations may only be matched with the end of the stimulus.

Notes to Chapter 6

1. The phonologically and morphologically related words were also orthographically similar.

2. Suffix morphemes may still be listed in the lexicon but not accessed on-line, see Chapter seven.

3. The root priming effect found in Experiment 5 was not due to syllabic structure because both the phonologically related pairs (balloon/saloon) and the morphologically related pairs (submit, permit) share a final syllable.

4. Note that according to the cohort model, nonword phonological priming can occur at a lexical level because nonwords activate an initial cohort before they are discovered to be nonwords. For example, a nonword beginning with [ple] will activate a cohort con-

taining place. Therefore, the nonword [plef] should prime the lexical representation of place. However, this model also predicts that phonological priming by nonwords should be as strong as that produced by words (e.g. between plate and place) which was not found by Slowiaczek et al. (1987).

Notes to Chapter 7

1. This possibility was suggested to me by Victoria Fromkin.

2. It is not clear what is meant by inflectional semantic features.

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APPENDIX A

STIMULI FOR EXPERIMENT 1

Inflected	Derived	Prefixed
wasting	weakness	unfair
joking	vaguely	dislike
gambling	worthless	nonsense
curtains	safer	unsure
dining	shorter	insane
matches	jumpy	unlike
cookies	harmful	replace
tended	peaceful	unreal
lasted	filthy	renew
catching	winner	mislead
loosen	massive	distrust
chosen	thankful	unclear

Control Monomorphemic	Pseudosuffixed	Pseudoprefixed
rabbit	monster	invite
ticket	temper	retreat
victim	garden	reprieve
limit	bitter	release
soda	lobby	device
garbage	motive	reward
cancel	hunger	expense
campus	kidney	imply
cocktail	monkey	remote
hollow	token	discrete
robot	lobster	prestige
costume	heaven	design

APPENDIX B

WORD STIMULI FOR EXPERIMENTS 2a, 3, and 4

Inflected	Derived	Monomorphemic
drooping	glumly	grovel
blessing	bluntly	trophy
blooming	grimly	plasma
grudges	briskly	fresco
shaking	loudly	canvas
knitted	meeker	elbow
painted	rarely	tissue
paving	seepage	pigeon
blushes	snugly	stigma
gleaming	tribal	treasure
bragging	broiler	snorkle
menacing	perilous	caravan
loathing	tersely	fathom
screaming	hunter	walnut
peaches	shredder	kernel

APPENDIX C

NONWORD STIMULI FOR EXPERIMENTS 2b, 3, and 4

Simple Nonwords		Suffixed Nonwords		Pseudowords	
pardack	[pardaek]	bermly	[bɚmli]	broodly	[brudli]
sulfack	[sʌlfaek]	garging	[gargiŋ]	danking	[deŋkiŋ]
clussig	[klʌsIg]	tribber	[trIbɚ]	glober	[globɚ]
narrig	[nerIg]	vermly	[vɚmli]	lacely	[lesli]
grifna	[grIfna]	fulted	[fʌltId]	colted	[koltId]
oysko	[oisko]	nephly	[nɛfli]	chokely	[čokli]
symbit	[sImbIt]	hundage	[hʌndIǰ]	guestage	[gɛstIǰ]
harvame	[harvem]	garnly	[garnli]	roachly	[ročli]
faska	[faeska]	wobbing	[wabiŋ]	mirthing	[mɚθiŋ]
glistna	[glIsna]	jargly	[ǰargli]	crushly	[krʌšli]
drivna	[drIvna]	gending	[ǰɛndiŋ]	brooming	[brumiŋ]
victope	[vIktop]	traving	[traeviŋ]	creeding	[kridiŋ]
calvape	[kaelvep]	fungly	[fʌŋgli]	belchly	[bɛlčli]
orgit	[orgIt]	cassing	[kaesiŋ]	harshing	[haršiŋ]
cossote	[kasot]	sarder	[sardɚ]	fuzzer	[fʌzɚ]

APPENDIX D

ADDITIONAL NONWORD STIMULI FOR EXPERIMENTS 3 AND 4

Root-initial	Nonwords
cagelo	[keǰlo]
cuffack	[kʌfaek]
maplo	[maeplo]
beastig	[bistIg]
drainape	[drenaep]
duskorp	[dʌskorp]
gracelo	[greslo]
nudgeka	[nuǰka]
leakma	[likma]
lumpack	[lʌmpaek]
clogma	[klagma]
fraudig	[fradIg]
blobig	[blabIg]
snapna	[snaepna]
lagorp	[laegorp]

APPENDIX E

STIMULI FOR EXPERIMENT 5

Phonologically Related Pairs	Morphologically Related Pairs
balloon	submit
saloon	permit
unique	succeed
technique	proceed
tureen	conceive
careen	deceive
bamboo	reduce
taboo	induce
champagne	assume
campaign	consume
harpoon	refer
lampoon	prefer
duress	incur
caress	concur
bassoon	refuse
monsoon	confuse
spittoon	advise
cartoon	revise
stockade	assert
blockade	insert
harangue	apply
meringue	imply
charade	provoke
parade	invoke
mirage	object
garage	inject
cascade	infect
arcade	defect
canteen	pretend
routine	intend
salute	include
pollute	conclude

APPENDIX F

STIMULI FOR EXPERIMENT 6

Phonological Control	Inflectional Suffix	Derivational Suffix
shadow	smiling	badly
widow	breaking	lonely
shallow	seeming	tightly
yellow	walking	widely
drama	lifted	lovely
schema	looted	cheaply
ransom	joking	aimless
blossom	typing	careless
credit	speaking	careful
bandit	mending	blissful
eagle	blended	blackness
smuggle	dusted	shortness
panel	selling	dancer
temple	hunting	baker
splendid	greeted	endless
candid	welded	speechless
tango	chanting	drummer
cargo	dripping	thinker
stucco	baking	voter
fresco	crawling	winner
plasma	stopping	safely
dogma	scanning	bravely
robin	blouses	lawless
cabin	wishes	helpless
alto	banging	banker
pinto	chirping	loser
parcel	flirted	sleepless
cancel	stranded	fearless
crackle	peeping	harshness
buckle	tossing	kindness

camel	flipping	madness
formal	drinking	weaknesss
statue	pushing	vaguely
virtue	hoping	softly
rabid	dreaded	godless
morbid	glided	hairless

APPENDIX G

STIMULI FOR EXPERIMENT 7

Phonological Control	Inflectional Suffix No Shared Syllable	Inflectional Suffix Shared Syllable
shadow	smiling	swimming
widow	breaking	charming
shallow	seeming	gaining
yellow	walking	learning
drama	dancing	warning
schema	grazing	draining
ransom	joking	poking
blossom	typing	winking
credit	speaking	rising
bandit	mending	teasing
eagle	steaming	renting
smuggle	lisping	jolting
stable	selling	locking
noble	hunting	parking
splendid	sailing	shaking
candid	coughing	lurking
tango	chanting	hugging
cargo	dripping	clogging
stucco	baking	dumping
fresco	crawling	shaping
plasma	stopping	picking
dogma	scanning	shocking
robin	blouses	nailing
cabin	wishes	killing
alto	banging	hopping
pinto	chirping	napping
parcel	filming	banning
cancel	choking	signing
crackle	peeping	leaping
buckle	tossing	chopping

camel	flipping	groaning
formal	drinking	burning
statue	pushing	nursing
virtue	hoping	pressing
rabid	blaming	dodging
morbid	funding	forging