Introduction

Current theories and research on the psychology of word- and sentence-level language processing generally posit two kinds of processes: associative, data-driven processes and symbolic, rule-based processes. Findings from behavioral studies suggest that we understand and produce language using a combination of both kinds of processing. To date, the majority of psycholinguistic evidence for a "dual-mechanism" theoretical perspective comes from word-level studies conducted with Germanic languages. Results from studies testing speakers of non-Germanic languages, however, point to an almost exclusive reliance upon rule-based processes.

This book was written to address two questions. First, can support for the dual-mechanism perspective be obtained using a non-Germanic language such as French, a language for which the findings to date do not support a dual-mechanism account of processing? Second, can behavioral studies simultaneously offer a view onto both word-level and sentence-

level, that is, morphological and syntactic, processing, thereby providing a new perspective on the processing debate?

A Challenge to Classical Models
of Mind: Connectionism

In 1986, Rumelhart and McClelland and the PDP Research Group reported that a computer (i.e., artificial intelligence, or AI) simulation of a neural network had modeled humanlike performance in its production of significant portions of the English past tense, and it had even correctly overgeneralized English past-tense forms from novel items, thereby mimicking the English past-tense acquisition behavior of infant learners. Amazingly, Rumelhart and McClelland's connectionist network had managed this feat without having recourse to anything resembling a rule for creating past-tense forms. Instead, the network had learned to model the English past tense purely on the basis of extensive training. This report was of tremendous significance; it challenged the classical view of mind, according to which all cognition proceeds from the application of algebraic rules that operate upon symbols or variables (see, e.g., Johnson-Laird, 1988; Newell, 1980; Newell and Simon, 1972; Pylyshyn, 1984). In this case the regular English past tense, a feature of grammar that has traditionally been described with reference to linguistic rules (i.e., "to form the past tense of *walk, open,* or any other regular English verb, add *-ed* to the verb's infinitival form"), had been learned without using such rules. According to classic, symbolic accounts of cognition, the statement corresponding to the linguistic rule is to be understood as a high-level description of the mental combinatorial process through which speakers of English compute the regular past tense. Rumelhart and McClelland's finding called this account into question; here was an instance of all-or-

nothing, rulelike behavior that did not have its source in a rule. Moreover, Rumelhart and McClelland's connectionist network had done what even Deep Blue could not do when it defeated Garry Kasparov eleven years later: it had learned from its mistakes and adjusted its output accordingly, much as humans do.

A second reason for the significance of Rumelhart and McClelland's report is that their network had also been reasonably successful in coping with semiregular patterns occurring among the English irregular past-tense forms. Thus, faced with irregular verbs with semiregular patterns such as *spring* and *sneak* and similar-sounding regular verbs such as *ding* and *tweak,* the network was often able to produce the correct forms *sprung* and *snuck* and *dinged* and *tweaked.* Purely symbolic accounts would have to posit separate rules for the semiregularities among the irregular verbs. Moreover, only phonological rules of an implausibly baroque nature could capture all the semiregularities. Nevertheless, Rumelhart and McClelland's network was often able to generalize correctly to make novel irregular past-tense forms from the semiregular irregular-verb patterns on which it had been trained, while keeping the novel irregulars separate from similar-sounding regulars, to which the network correctly added the regular past-tense inflection, *-ed.*

The Response to Connectionism: Words and Rules Theory

In response to Rumelhart and McClelland's study, Steven Pinker and colleagues have gradually elaborated a dual-mechanism model of language processing known as words and rules theory. In its most recent iteration (Pinker, 2000; Pinker and Ullman, 2002), it holds that all language processes belong to one of two computational systems: a symbolic, combinatorial mod-

ule (i.e., a grammar) and a linguistically structured word repository (i.e., a lexicon). With respect to the regular and irregular English past tense (e.g., *walked* vs. *went,* respectively), words and rules theory is thus neither exclusively symbolic nor exclusively associationist but instead posits roles for both kinds of processing. Specifically, the theory asserts that productive word-, phrase-, and sentence-building processes tend to be executed on an as-needed basis by the symbolic module. In contrast, simplex or idiosyncratic linguistic items are stored in and retrieved from the lexicon. In this view, the symbolic module is responsible for the on-the-fly formation of the English regular past tense; the lexicon is responsible for the storage and retrieval of English irregular past tenses.

Although words and rules theory has been supported by linguistic, behavioral, and neuropsychological data from English and German, questions still remain with respect to the scope of the theory. For instance, psycholinguistic support for words and rules theory has been found primarily through studies examining the comprehension or production of isolated words. However, people produce and understand utterances that are longer than single words and that often embody complex syntactic relations. (In mainstream theories of syntax, such relations include traces and various kinds of coreferenced, moved elements.) Although words and rules theory holds that syntactic processing is symbolic, and online studies of sentence processing (that is, studies using tasks that measure changes in sentence processing load in very small time increments) suggest that this is true, there is to date no online behavioral evidence that addresses the nature of the relation between words-and-rules-theory-type word-level processing and sentence-level, syntactic processing. Moreover, the isolated words examined in past studies have often been limited to English infinitives and their inflected forms; few studies, with the

notable exception of Harald Clahsen and colleagues' work with German (see, e.g., Clahsen et al., 2001; Clahsen, Sonnenstuhl, and Blevins, 2003), have sought to establish whether the words-rules distinction exists among derived linguistic forms as well. Finally, there have been relatively few studies of non-Germanic languages that have found support for words and rules theory, prompting some researchers (e.g., Marslen-Wilson and Tyler, 1998) to suggest that the regular-irregular basis of words and rules theory might simply reflect idiosyncratic properties of the English past-tense system. Indeed, the results of the published studies that have examined word-level regular-irregular verb contrasts in French (Meunier and Marslen-Wilson, 2000; Meunier and Marslen-Wilson, 2004; Royle, Jarema, and Kehayia, 2002) do not unequivocally support a words-and-rules-theory-type account of language processing.

Outline of This Book

This book reports upon an empirical investigation of the preceding discussion. Using French language items and French native speakers, it contributes to the symbolic- and associative-processing debate through both word- and sentence-level psycholinguistic studies. The book is organized as follows. Chapter 1 will provide an overview of current theories of language processing, with special reference to words and rules theory and connectionist models. The overview will also serve to highlight the rulelike versus idiosyncratic nature of the linguistic items tested in the literature. A review of behavioral studies conducted with English regular and irregular verbs and native speakers of English will reveal that a verb's morphological status (that is, whether the verb is regularly or irregularly inflected) will have the most influence on the manner in which the item is processed.

The preponderance of evidence to date that suggests the relative efficacy of associative and symbol-manipulating theories of language has been collected in the context of online behavioral studies. In many of these studies, participants take part in what appear to be ordinary visual lexical-decision tasks (i.e., a participant must decide whether a string of letters is or is not a word in their language); however, such studies can involve more than what consciously meets the eye. Some of the most exciting findings in language-processing research have been obtained through masked-priming experiments, in which certain visual-stimulus events are presented so rapidly that the participant remains completely unaware of their presence. Nevertheless, research has shown that these subliminal-stimulus events do affect participant performance in online experiments. Accordingly, chapter 2 will review findings from the priming literature in experimental psychology and cognitive science, both generally and with respect to studies investigating word-level regular-irregular verb contrasts in Italian and French, thereby setting the stage for discussion of the primed lexical-decision tasks used in the experiments that constitute the core of this book. Also developed in chapter 2 is the idea that morphological *productivity* (that is, the extent to which a linguistic item such as a suffix has spread in use) is the concept upon which the words-rules distinction turns in French.

Chapters 3–6 will discuss four priming experiments, all of which were conducted with French language items and French native-speaker participants and which were designed to investigate the role of morphological productivity at both the word and the sentence level. More generally, the experiments were designed to explore whether the processing facts they revealed would be more in accordance with the partly

symbolic, partly associative words and rules theory or with the exclusively data-driven theory of connectionism.

The two word-level priming experiments examined the real-time comprehension of both inflected verbs and derived (i.e., suffixed) nouns. The two sentence-level priming experiments investigated the real-time processing of inflected verbs and derived nouns within syntactic movement operations, specifically *wh*-movement and lexical verb raising. Taken together, the results of the four experiments suggest that certain noun suffixes in French appear to be "dying out" in that the number of nouns in which they can be found has been steadily decreasing over the last three centuries, while other suffixes have shown increasing evidence of productivity during the same time period. Moreover, the results suggest that these differing patterns of productivity have processing consequences: productively suffixed French nouns bear the behavioral signatures of a rulelike, root-suffix combinatorial process, while unproductively suffixed French nouns do not. Also, in line with a well-supported theory of sentence processing (the trace reactivation account; Nicol and Swinney, 1989), the sentence-level studies point to the psychological reality of syntactic traces (that is, silent, syntactically active "remnants" of displaced sentential elements). The sentence-level studies are innovative in that they also afford a glimpse of the interaction between syntactic and morphological processing in the online context.

In chapter 7, the book discusses the implications of the findings from experiments 1–4 with respect to current theories of language processing. The overall findings are interpreted as supporting words and rules theory. Moreover, it is argued that the results of the two sentence-level experiments also support words and rules theory at the syntactic level. The book concludes with suggestions for further research.