CHAPTER 19

Language Comprehension and Production

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INTRODUCTION

In this chapter, we survey the processes of recognizing and producing words and of understanding and creating sentences. Theory and research on these topics have been shaped by debates about how various sources of information are integrated in these processes, and about the role of language structure, as analyzed in the discipline of linguistics.

Consider first the role of language structure. Some of the research we discuss explores the roles that prosody (the melody, rhythm, and stress pattern of spoken language) and the phonological or sound structure of syllables play in the production of speech and the comprehension of written and spoken words. Other research is based on linguistic analyses of how some words are composed of more than a single morpheme (roughly, a minimal unit of meaning), and asks how the morphological makeup of words affects their production and comprehension. Much research on sentence comprehension and production examines the role of syntactic structure (roughly, how a sentence can be analyzed into parts and the relations among these parts). As we hope to make clear, interest in linguistic rules and principles remains strong. However, theorists are exploring the possibility that some or all of our knowledge of our language is more continuous, less all-or-none, than traditional linguistic analyses propose, as well as the possibility that our experience of the probabilistic patterns of our language affects comprehension and production.

Although there is broad agreement that a wide range of linguistic and nonlinguistic information is used in comprehending and producing language, there is debate about how different information sources are coordinated. Early psycholinguists tended to see language as an autonomous system, insulated from other cognitive systems (see J. A. Fodor, 1983). This *modular* view was motivated in part by Chomsky's work in linguistics and by his claim that the special properties of language require special mechanisms to handle it (e.g., Chomsky, 1959). It holds that the initial stages of word and sentence comprehension are not influenced by higher levels of knowledge. Instead, information about context and about real-world constraints comes into play only after the language module has done its work. This gives most modular models a *serial* quality, although such models can also resemble *cascade* models, in which information flows more or less continuously from one module to another as soon as it is partially processed.

Parallel models contrast with modular and many cascaded ones in that knowledge about language structure, linguistic context, and the world are processed all at the same time in the comprehension of words and sentences. Most commonly, a parallel view is also *interactive* rather than modular, claiming that different sources of information influence each other in arriving at an interpretation of language. This influence can happen in different ways. For example, different sources of information may compete with each other in arriving at a decision, or decisions made at one level of analysis (e.g., the word) may affect decisions at other levels (e.g., the letter or phoneme), via what is termed *feedback*. Views about production can also

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be either serial or parallel, or modular or interactive, but the direction of the main flow of information is opposite to that in comprehension: Speakers usually start with at least a rough idea of what they are going to say, and then generate syntactic structures and retrieve words and their elements.

In this chapter, we describe current views of fluent language users' comprehension of spoken and written language and their production of spoken language. We review what we consider to be the most important findings and theories in psycholinguistics, returning again and again to the questions of modularity and the importance of linguistic knowledge. Although we acknowledge the importance of social factors in language use, our focus is on core processes such as parsing and word retrieval that are not necessarily affected by such factors. We do not have space to say much about the important fields of *developmental psycholinguistics,* which deals with the acquisition of language by children, or *applied psycholinguistics,* which encompasses such topics as language disorders and language teaching. Although we recognize that there is burgeoning interest in the measurement of brain activity during language processing and how language is represented in the brain, space permits only occasional pointers to work in neuropsychology and the cognitive neuroscience of language. For treatment of these topics, and others, the interested reader could begin with two recent handbooks of psycholinguistics (Gaskell, 2007; Traxler & Gernsbacher, 2006) and a handbook of cognitive neuroscience (Gazzaniga, 2004).

LANGUAGE COMPREHENSION

Spoken Word Recognition

The perception of spoken words should be extremely difficult. Speech is distributed in time, a fleeting signal that has few reliable cues to the boundaries between segments and words. Moreover, certain phonemes are omitted in conversational speech, others change their pronunciations depending on the surrounding sounds (e.g., the /n/ in *lean* may be pronounced as [m] in *lean bacon*), and the pronunciations of many words differ depending on speaking rate and formality (e.g., *going to* can become *gonna*). Despite these potential problems, people seem to perceive speech with little effort in most situations. How this happens is only partly understood.

Listeners attempt to map the acoustic signal onto representations of words they know (the *mental lexicon*) beginning almost as soon as the signal starts to arrive. The *cohort model,* first proposed by Marslen-Wilson and Welsh (1978), spells out one possible mechanism. The first few phonemes of a spoken word activate a set or *cohort* of word candidates that are consistent with that input. These candidates compete with one another. As more acoustic input is analyzed, candidates that are inconsistent with the input drop from the set. This process continues until only one word candidate matches the input. If no single candidate clearly matches, the best fitting candidate is chosen. Each candidate in the cohort has a frequency associated with it, and these frequencies affect the time course of word recognition (Kemps, Wurm, Ernestus, Schreuder, & Baayen, 2005).

A key part of the original cohort model was the idea of a *uniqueness point,* the point at which only one word remained consistent with the input. However, many words in English are so short that they do not have uniqueness points (Luce, 1986), and for a time the uniqueness point construct fell from favor. However, there is strong evidence of uniqueness point effects in words that are long enough to have them. Studies have shown that versions of the uniqueness point that take linguistic structure into account predict the time that listeners take to recognize words (Balling & Baayen, 2008; Wurm, Ernestus, Schreuder, & Baayen, 2006).

A classic paper by Zwitserlood (1989) supported the idea that listeners activate multiple word candidates by showing that the semantic information associated with each was activated early in the recognition process. This conclusion is supported by recent research measuring what listeners look at while hearing speech (see F. Ferreira & Tanenhaus, 2007, for a useful introduction). For example, listeners who are instructed to "pick up the candle" are initially likely to look at a piece of candy before picking up the candle (Allopenna, Magnuson, & Tanenhaus, 1998). This observation suggests that multiple words beginning with /kæn/ are briefly activated. Listeners may glance at a handle, too, suggesting that the cohort of word candidates is not limited to those that start with the same sound as the target. Indeed, later versions of the cohort theory (Gaskell & Marslen-Wilson, 1997; Marslen-Wilson, 1987) relaxed the insistence on perfectly matching input from the very first phoneme of a word. Other models (McClelland & Elman, 1986; Norris, 1994) also advocate continuous mapping from spoken input to known words, with the initial portion of the speech signal exerting a strong but not exclusive influence on the set of candidates.

Listeners map the acoustic signal onto their mental representations of words or *lexical representations* in a way that is sensitive to fine details of the signal. For example, small differences in the duration of phonemes (e.g., the fact that vowels are longer before voiced consonants such as /d/ than voiceless consonants such as /t/) can influence listeners' expectations about the ending of the current word (Kemps et al., 2005; Salverda, Dahan, & McQueen, 2003) and the beginning of the following word (Shatzman & McQueen, 2006).

Listeners also make perceptual adjustments to certain characteristics of speech, such as the way in which /s/ (as in *sip*) is distinguished from /ʃ/ (as in *ship*; Goldinger, 1998; Samuel & Kraljic, 2009). However, they make these adjustments only when the characteristics can be interpreted as having something to do with the talker (e.g., a foreign accent, or a peculiar way of pronouncing one sound; Kraljic, Samuel, & Brennan, 2008). Researchers used to consider variations like these to be problematic sources of noise that had to be overcome so that the signal could be matched against an idealized representation of a word. The current view, instead, is that many such sources of variation contain valuable information, which can be used to optimize performance (Clayards, Tanenhaus, Aslin, & Jacobs, 2008; Goldinger, 1998).

One persisting debate in language research, as we have mentioned, has to do with whether processing is interactive or modular and autonomous. In interactive models of spoken word recognition, higher processing levels have a direct influence on lower levels. In particular, knowledge of what strings of phonemes are words in one's language affects the perception of phonemes. Samuel (1997) used the phenomenon of *phonemic restoration*, in which people still report hearing a sound (e.g., the middle /s/ in *legislature)* if it is removed and replaced by noise, to show that knowledge about words affects how much information listeners need about a sound to identify it. However, autonomous models, which do not allow *top-down processes* (an effect of word-knowledge on phoneme perception is one example of such a process), have had some success in accounting for such findings in other ways. One autonomous model is the race model of Cutler and Norris (1979) and its descendants (e.g., Norris, McQueen, & Cutler, 2000). The model has two routes that operate in parallel. There is a pre-lexical route, which computes phonological information from the acoustic signal itself, and a lexical route, in which the phonological information associated with a word becomes available when the word itself is accessed. The route that most quickly results in identifying the word is said to win the race. When lexical information appears to affect a lower-level process, it is assumed that the lexical route won the race. Importantly, though, higher-level lexical knowledge never influences perception at the lower (phonemic) level. The issue of interactivity continues to drive a great deal of research and seems to defy resolution, and there is even disagreement about whether putatively autonomous models are in fact autonomous (see Norris et al., 2000).

Although it is a matter of debate whether higher-level linguistic knowledge affects the initial stages of speech perception, it is clear that our knowledge of language and its structure affects perception of a familiar language in some ways. For example, listeners use *phonotactic* information such as the fact that initial /tl/ doesn't occur in English to help identify phonemes and word boundaries (Halle, Segui, Frauenfelder, & Meunier, 1998). In addition, listeners use their knowledge that English words tend to be stressed on the first syllable to segment the continuous speech stream into discrete words (Norris, McQueen, & Cutler, 1995).

The question of interactivity extends to the question of whether meaning affects word recognition. There is evidence that it may (Wurm, 2007; Wurm & Seaman, 2008; Wurm, Vakoch, & Seaman, 2004). However, no model has been fully spelled out that incorporates semantic information as a fundamental part of the recognition process. Research to be discussed in the section on sentence comprehension, however, carries suggestions that meaning and context affect comprehension, and future research may show that it affects word recognition itself.

Printed Word Recognition

Although speech is found in all human civilizations, reading and writing are less widespread. It seems plausible that readers use their knowledge of spoken language to comprehend written text. Indeed, a great deal of evidence shows that knowledge of spoken language plays an important role in reading a word (see Frost, 1998, for a review of research examining the role of sound structure in reading). We take the position that it matters little whether the initial input is by eye or by ear. The principles and processes of comprehending language are much the same.

In one kind of study that shows how important the spoken language is in reading, readers are asked to quickly decide whether a printed sentence makes sense. Readers were found to have more trouble reading sentences such as "*He doesn't like to eat meet*" than sentences such as "*He doesn't like to eat melt*" (Baron, 1973). The printed word *meet* apparently activated the spoken form /mit/ and thus the plausible word *meat.* Interestingly, people who were born deaf and lacked full command of the spoken language did not show a difference between the two sentence types (Treiman & Hirsh-Pasek, 1983).

A second reason to believe that phonology plays a critical role in recognizing words comes from the study of beginning readers. One of the best predictors of a child's reading ability is *phonological awareness*, the knowledge of the sound structure of spoken words that is at least partly accessible to awareness (Ehri et al., 2001; Mattingly, 1972). A child who has the ability to count or rearrange the phonological segments in a spoken word is likely to be successful in learning to read.

There is debate, however, about just how spoken language plays a role in identifying a printed word. One idea, which is embodied in *dual-route* theories of reading such as that of Coltheart, Rastle, Perry, Langdon, and Ziegler (2001), is that two different processes are available for converting spellings to phonological representations. A lexical route is used to look up the meanings and phonological forms of known visual words in the mental lexicon. This procedure yields correct pronunciations for familiar *exception words,* or those such as *love* that deviate from the typical spelling-to-sound correspondences of the language. A nonlexical route accounts for the productivity of reading: It generates pronunciations for novel letter strings (e.g., *tove*) as well as for regular words (e.g., *stove*) on the basis of smaller units, even if the words haven't previously been encountered. This nonlexical route gives incorrect pronunciations for exception words, so that thesewords may be pronounced slowly or erroneously (e.g., *love* said to rhyme with *cove*) (e.g., Glushko, 1979). Other theories, in particular connectionist approaches (e.g., Harm & Seidenberg, 2004; Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989) deny the existence of two different ways of recognizing words, and claim that a single set of connections from orthography to phonological forms can account for performance on both regular words and exception. In some languages, such as Dutch and Spanish, there is a nearly one-to-one mapping between letters and phonological segments. With such a simple mapping, the nonlexical route posited by dual-route theories could work in a very straightforward manner. However, some languages, including English, have more complex writing systems. In English, for example, *ea* corresponds to /i/ in *bead* but /ɛ/ in *dead*; *c* is /k/ in *cat* but /s/ in *city.* Such complexities are particularly common for vowels in English, leading some to suggest that a nonlexical route would not work very well for this writing system.

However, consideration of the consonant that follows a vowel often helps to specify the vowel's pronunciation in English (Kessler & Treiman, 2001; Treiman, Mullennix, Bijeljac-Babic, & Richmond-Welty, 1995). The /ɛ/ pronunciation of *ea,* for example, is more likely before *d* than before *m.* Such considerations have led to the proposal that readers of English often use the context in which a letter appears to help determine its pronunciation. Indeed, readers appear to use various types of context, including probabilistic patterns as well as all-or-none rules (Kessler, 2009). In many cases, the relevant context for a vowel involves the linguistic unit known as the *rime* (the vowel nucleus plus an optional consonant or cluster following it) (Treiman, Kessler, & Bick, 2003). Readers even seem to pick up this context-sensitive information out of the corner of their eye or *parafoveally* (see Rayner, Pollatsek, & Schotter, this volume). Parafoveal previews have been shown to facilitate word recognition if they share letters or sounds with the target word (Pollatsek, Lesch, Morris, & Rayner, 1992; Rayner, 1975). A parafoveal preview even facilitates word recognition if it has the right consonant-sensitive vowel sound. For example, the preview *strean* facilitates reading the target *streak* more than *stread* does (Ashby, Treiman, Kessler, & Rayner, 2006).

As discussed earlier, spoken words are spread out in time so that spoken word recognition is a sequential process. With short printed words, though, the eye takes in all the letters during a single fixation (Rayner, 1998). Some models of reading, including the connectionist models cited earlier (e.g., Plaut et al., 1996), maintain that all phonemes of a word are activated in parallel. Current dual-route theories, in contrast, claim that the nonlexical assembly process operates in a serial fashion such that the phonological forms of the leftmost elements, in a language that is read from left to right, are delivered before those for the succeeding elements (Coltheart et al., 2001). The process cannot be perfectly serial, however. Readers have a tendency to accept words in which two letters are transposed. They find it harder to decide that a string of letters is not a word if the only thing wrong with it is the order of its letters (*jugde*) than if it contains incorrect letters (*jupte*) (O'Connor & Forster, 1981; Perea, Rosa, & Gómez, 2005). But a warning: Don't be fooled by a widely circulated Internet message that said that resarceh at Cmabrigde Uinervtisy fuond that sentences in which letters weer transpsoed (or jubmled up) were as easy to read as normal text. In fact, there was no such research (see www.mrc-cbu.cam.ac.uk/people/matt.davis/Cmabrigde/), and experimental research has shown that jumbling letters in fact slows reading

(Johnson, 2009). The position of a letter in a word is encoded somehow, even if letters are not processed perfectly serially.

In addition to representing the sound segments of a word, the writing system of English and many other languages contains clues to the word's morphological structure. Consistent with the view that print serves as a map of linguistic structure, readers take advantage of these clues as well. For instance, skilled readers use the clues to morphological structure that are embedded in English orthography. They know that the prefix *re-* can stand before free morphemes such as *print* and *do,* yielding the two-morpheme words *reprint* and *redo.* When participants encounter *vive* in a *lexical decision task* (a task in which they must decide as quickly as possible whether a letter string is a real word), they may wrongly judge it to be a word because of their familiarity with *revive* (Taft & Forster, 1975; Wurm, 2000).

Even morphologically complex words that contain prefixes that are less familiar and productive than *re-* are not simply processed as whole units. Rather, the morphemes that make them up may be processed separately, at least to some extent. Pollatsek, Hyönä, and Bertram (2000, see also Hyönä, Bertram, & Pollatsek, 2004) measured eye movements during reading of Finnish sentences. Finnish is a language in which words are notoriously long and morphologically complex. The researchers manipulated the frequency with which the words, as well as the morphemes that they contained, occur in large samples of written language. They found that the frequency of the individual morphemes, as well as the frequency of the whole word, affected reading time. As is commonly found (see Rayner, Pollatsek, & Schotter, this volume), higher-frequency words (and here, morphemes) were read faster. Of particular interest, the earliest measures of processing difficulty only showed effects of the frequency of the first morpheme in a word, suggesting that this morpheme was the first to be processed. Kuperman, Schreuder, Bertram, and Baayen (2009) found similar results when Dutch readers' eye movements were measured while they made lexical decisions about morphologically complex Dutch words. Kuperman et al. (2009) proposed a new dual-route model that is based on parallel interactive use of all cues, including morphology-based ones, as soon as they begin to become available.

There is mixed evidence about whether the semantic relations between morphemes and the words they compose, or simply the orthographic forms of morphemes, affect visual word recognition (Feldman, O'Connor, & Moscoso del Prado Martín, 2009; Rastle & Davis, 2008; Rastle, Davis, & New, 2004). This work has used the technique of priming (see McNamara, this volume) to study semantically transparent words whose meaning is constrained by their component morphemes (*cleaner-clean; coolant-cool*), semantically opaque words (*rampant-ramp*), words which look like they could be related by morphology (*corner-corn*), and words that are merely related by form (*brothel-broth*). A brief presentation of the first member of any of these pairs primes (i.e., facilitates) recognition of the second member. Rastle and her colleagues have reported equivalent priming regardless of the semantic relation between the members of a pair, suggesting that morphological analysis is based on orthographic form. However, Feldman and colleagues have found a consistent, if small, advantage for words whose morphology is semantically transparent, suggesting that meaning relations between the components of a word and the word itself also play a role.

One important question is whether written word recognition is interactive. Does lexical knowledge exert a top-down influence on identifying letters? Whole words are recognized more quickly than isolated letters (Cattell, 1886), and a single letter is recognized more quickly when it occurs in a word than when it occurs in isolation (Reicher, 1969; Wheeler, 1970). This latter finding has been taken as evidence that activation of a word activates its component letters in a top-down fashion (McClelland & Rumelhart, 1981). However, various sorts of non-interactive models are able to account for this finding (e.g., Paap, Newsome, McDonald, Schvaneveldt, 1982) and many other results as well (Norris, 2006). Just as we saw in the discussion of spoken word recognition, the ultimate conclusion about top-down influences is far from certain in the case of written word recognition.

Comprehension of Sentences and Discourse

Although recognizing words is essential, understanding language requires more than adding the meanings of the individual words together. Readers and listeners must combine the meanings in ways that honor the grammar of the language and that are sensitive to the discourse context. Some psycholinguists have emphasized how we continually create novel representations of novel messages we hear, and how we do this quickly and apparently effortlessly even though the grammar of the language is complex. Others have emphasized how comprehension is sensitive to a vast range of information, including grammatical, lexical, and contextual information, as well as knowledge of the speaker/writer and of the world in general. Theorists in the former group (e.g., Crocker, 1995; Ford, Bresnan, & Kaplan, 1982; Forster, 1979; Frazier & Rayner, 1982; Pritchett, 1992) have constructed modular, serial models that describe how people quickly construct one or more representations of a sentence based on a restricted range of primarily grammatical information that is guaranteed to be relevant to its interpretation. This representation is then quickly interpreted and evaluated, using the full range of information that might be relevant. Theorists in the latter group (e.g., MacDonald, Pearlmutter, & Seidenberg, 1994; Tanenhaus & Trueswell, 1995) have constructed parallel interactive models, sometimes implemented as connectionist models, describing how people use all relevant information to quickly evaluate the full range of possible interpretations of a sentence (see MacDonald & Seidenberg, 2006, and Pickering, 1999, for discussion).

Neither of the two approaches just described provides a full account of how the sentence processing mechanism works. Modular models, by and large, do not adequately deal with how interpretation occurs, how the full range of information relevant to interpretation is integrated, or how the initial representation is revised when necessary (but see J. D. Fodor & F. Ferreira, 1998, for some approaches to answering the last question). Parallel models, for the most part, emphasize how various sources of information compete to select one interpretation, but they do not provide convincing explanations of how the various possible interpretations are built or identified in the first place (see Frazier, 1995). However, both approaches have motivated bodies of research that have advanced our knowledge of language comprehension. New models, many of which emphasize the statistical constraints that experience with the language provides to the listener or reader, are being developed that have the promise of overcoming some of the limitations of earlier models (Gibson, 1998; Jurafsky, 1996; Levy, 2008; Vosse & Kempen, 2000).

Phenomena Common to Reading and Listening Comprehension

Comprehension of written and spoken language can be uncertain because it is not always easy to identify the *constituents* (phrases) of a sentence and how they relate to one another. The place of a particular constituent within the grammatical structure may be temporarily or permanently ambiguous. Studies of how people resolve grammatical ambiguities have provided insights into the decision processes required to comprehend language. Consider the sentence, "*The second wife will claim the inheritance belongs to her.*" When *the inheritance* is first seen or heard, it could be interpreted as either the direct object of *claim* or the subject of *belongs.* Frazier and Rayner (1982) found that readers' eyes fixated for longer than usual on the verb *belongs,* which disambiguates the sentence so that *the inheritance* is the subject of *belongs* (see Rayner, Pollatsek, & Schotter, this volume, for discussion of the eye-tracking methodology used). They interpreted this result to mean that readers first interpreted *the inheritance* as the direct object of *claim.* Readers were disrupted when they had to revise this initial interpretation to the one in which *the inheritance* is the subject of *belongs.* Frazier and Rayner described their readers as being led down a *garden path*. Readers are led down the garden path, Frazier and Rayner claimed, because the direct object analysis is structurally simpler than the other possible analysis. These researchers proposed a principle, *minimal attachment*, which claims that readers accept the structural analysis that they can build most quickly, following the constraints of grammar. This generally results in the simplest, most minimal, analysis. Many researchers have tested and confirmed the minimal attachment principle for a variety of sentence types (see Frazier & Clifton, 1996, for a review).

Other parsing principles have been proposed. These are generally similar to minimal attachment in that they result in one analysis becoming available for interpretation very quickly. One is *late closure* (Frazier, 1987a), according to which a reader or listener attempts to relate each new phrase to the phrase currently being processed, which is generally the phrase that is most available to memory. There is evidence that readers find it easier to relate words and phrases that are closer together, even in the absence of ambiguity (Gibson, 2000). Another parsing principle is some version of *prefer argument* (e.g., Abney, 1989; Konieczny, Hemforth, Scheepers, & Strube, 1997; Pritchett, 1992). Grammars often distinguish between *arguments* and *adjuncts*. An argument is a phrase whose relation to a verb or other argument assigner is specified in the mental lexicon; an adjunct is related to what it modifies in a less specific fashion (see Schütze & Gibson, 1999). For example, a verb like *kick* contains the information that there can be something that undergoes the specific action of kicking; the grammatical object of *kick* is an argument of kick. More than that, the action of kicking can take place somewhere, but the relation between where the kicking takes place and the verb *kick* doesn't have to be specified by the verb *kick.* The relation holds true generally of verbs of action; the location of the kicking is an adjunct of the verb *kick.* With the experimentally studied sentence, "*Joe expressed his interest in the car,*" the prefer argument principle predicts that a reader will attach *in the car* to the noun *interest* rather than to the verb *express,* even though the latter analysis is structurally simpler and preferred according to minimal attachment. *In the car* is an argument of *interest* (the nature of its relation to *interest* is specified by the word *interest*) but an adjunct of *express* (it states the location of the action just as it would for any action). There is substantial evidence that the argument analysis is ultimately preferred (Clifton, Speer, & Abney, 1991; Konieczny et al., 1997; Schütze & Gibson, 1999), perhaps because argument roles are specified in the lexicon and may thus be very readily available to the reader or listener.

However, phrases that are closely related syntactically can be distant from one another in a sentence. These *long-distance dependencies*, like ambiguities, can cause problems in the parsing of language. Many linguists describe constructions like, "*Whom did you see t at the zoo*" and "*The girl I saw t at the zoo was my sister*" as having an empty element, a *trace* (symbolized by *t*), in the position where the moved element (*whom* and *the girl*) must be interpreted. Psycholinguists who have adopted this analysis ask how people discover the relation between the moved element (the *filler*) and the trace (the *gap*). J. D. Fodor (1978) suggested that people might delay identifying the position of the gap as long as possible. However, there is evidence that people actually identify the gap as soon as possible, following an *active filler* strategy (Frazier, 1987b; see De Vincenzi, 1991, for a generalization of the strategy, the *minimal chain principle.*). The active filler strategy is similar to the strategies discussed so far in that it builds a syntactic analysis as soon as possible, permitting quick interpretation of a sentence.

Readers and listeners are not error-free in their use of grammatical constraints. Tabor, Galantucci, and Richardson (2004) measured the reading times for the words of sentences like "*The coach smiled at the player tossed the Frisbee*" using a self-paced reading task. They observed disruption after the verb *tossed,* similar to the kind of disruption seen in Bever's (1970) infamous sentence, "*The horse raced past the barn fell.*" The phrase *raced past the barn* is a reduced version of the relative clause *that was raced past the barn,* but readers generally take *raced* to be an active main verb, not the passive participle that it actually is. This may be because of the complexity of the reduced relative clause construction, or because of its low frequency, or both (but cf. McKoon & Ratcliff, 2003). The phrase *tossed the Frisbee* in the current example is also a reduced relative clause, modifying *the player,* but readers seem to take *tossed* as an active verb with *the player* as its subject. However, this *local coherence effect* violates grammatical constraints. *The player* has already received a grammatical role from *smiled at,* so it can't also be given the subject role, even though *the player tossed the Frisbee* seems to be locally coherent. Readers seem to overlook this constraint. Levy, Bicknell, Slattery, and Rayner (2009) suggest that readers may not actually overlook the constraint, but rather are uncertain about what an earlier word in a sentence is. Readers think they may have misread the little word *at* (it could have been *as*) when later material has a simple but inconsistent analysis (the analysis in which *the player* is subject of *tossed*). They consider reanalyzing earlier material, slowing reading. Levy et al. showed that the local coherence effect was reduced, or even eliminated, when the critical word earlier in the sentence (*at* in the example) was replaced by a word such as *toward* that has fewer similar words or neighbors with which it could be confused.

Most of the phenomena discussed so far show that preferences for certain structural relations play an important role in sentence comprehension. However, as syntactic theory has shifted away from describing general structural configurations and toward enriching the representation of individual words so that they specify the grammatical relations they can enter into, many psycholinguists have proposed that readers and listeners are primarily guided by information about specific words that is stored in the lexicon, interacting with the discourse context and other sources of information. The research on preference for arguments discussed earlier is one example of this move.

One important kind of information provided by a specific lexical item is the frequency with which it is used in some specific syntactic construction. Consider the reduced relative-clause construction (as in the "*The horse raced past the barn fell*" example). As mentioned, this is an unpreferred construction, for any of several reasons. Besides syntactic complexity and frequency of use, it requires the clause's verb to be identified as a past participle, but in the difficult cases the past participle can be mistaken for the more common simple past tense form of the verb (try replacing *raced* with the unambiguous *driven,* and the sentence becomes more comprehensible). However, if the verb is frequently used as a passive participle, like *accept* is, readers are less likely to get badly "garden pathed" when they encounter a reduced relative clause than if the verb is seldom used as a passive participle, as is the case for *entertain* or *help.* Trueswell (1996) showed that sentences like "*The friend accepted by the man was very impressive*" was read faster than ones like "*The manager entertained by the comedian left* *in high spirits.*" Similarly, since these reduced relative clause sentences require the initial noun phrase to be the direct object of the troublesome verb, they are read faster when the verb is frequently used as a transitive verb ("*The rancher could see that the nervous cattle pushed/moved into the crowded pen were afraid of the cowboys*") than when the verb is infrequently used as a transitive ("*The rancher could see that the nervous cattle pushed/moved into the crowded pen. . . .*") (MacDonald, 1994).

Although frequency of use may not always predict comprehension preferences and comprehension difficulty (Gibson, Schütze, & Salomon, 1996; Kennison, 2001; Pickering, Traxler, & Crocker, 2000), several recent theories have emphasized the importance of frequency of exposure to certain constructions in guiding sentence comprehension. Jurafsky (1996) proposed a model that explains a wide range of effects by appealing to the frequency of constructions, and Hale (2001) and Levy (2008) proposed computationally explicit theories that emphasize the importance of frequency-based expectancies in language comprehension. Experimental work has also shown the importance of expectancies in language processing (Lau, Straud, Plesch, & Phillips, 2006; Staub & Clifton, 2006).

Theorists who argue that lexical information guides parsing and theorists who argue for parallel processing in parsing have proposed that contextual appropriateness guides parsing. For example, Altmann and Steedman (1988) claimed that some of the effects that have previously been attributed to structural factors such as minimal attachment are really due to differences in appropriateness in the discourse context. The basic claim of the Altmann and Steedman *referential theory* is that, for a phrase to modify a definite noun phrase, there must be two or more possible referents of the noun phrase in the discourse context. For instance, in the sentence "*The burglar blew open a safe with the dynamite,*" taking *with the dynamite* to modify *a safe* is claimed to presuppose the existence of two or more safes, one of which contains dynamite. If multiple safes had not been mentioned, the sentence processor must either infer the existence of other safes or must analyze the phrase in another way, for example as specifying an instrument of *blow open.* Supporters of referential theory have argued that the out-of-context preferences that have been taken to support principles like minimal attachment disappear when sentences are presented in appropriate discourse contexts.

In one study, Altmann and Steedman (1988) examined how long readers took on sentences like "*The burglar blew open the safe with the dynamite and made off with the loot*" or "*The burglar blew open the safe with the new lock and made off with the loot*" in contexts that had introduced either one safe or two safes, one of which had a new lock. The version containing *with the dynamite* was read faster in the one-safe context, where the phrase modified the verb and thus satisfied minimal attachment. The version containing *with the new lock* was read faster in the two-safe context, fitting referential theory (see Mitchell, 1994, for a summary of similar findings). The use of a definite noun phrase when the discourse context contains two possible referents clearly disrupts reading, but disruption can be blocked in a context that provides two referents. However, context may have this effect only when the out-of-context structural preference is weak (Britt, 1994).

Additional evidence that discourse context can quickly affect sentence interpretation comes from the so-called visual world paradigm (Henderson & F. Ferreira, 2004; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995), which measures what objects people look at when they are listening to speech. Listeners quickly direct their eyes to the referent of what they hear, as shown by the Allopenna et al. (1998) study mentioned in the earlier discussion of spoken word recognition. This phenomenon allows researchers to study how comprehension is guided by situational context. Spivey, Tanenhaus, Eberhard, and Sedivy (2002) found that, when a listener heard a command like "*Put the cup on the napkin under the book,*" the eyes moved quickly to an empty napkin when the context contained just one cup, even if the cup had been on a napkin. This result suggests that *on the napkin* was taken as the goal argument of *put.* However, when the context contained two cups, only one on a napkin, the eyes did not move to an empty napkin. This result suggests that the situational context overrode the default preference to take the *on*-phrase as an argument. Related work explored how quickly comprehenders use knowledge of the roles objects typically play in events in determining the reference of phrases. In one study, people observed a scene on a video display and judged the appropriateness of an auditory sentence describing the scene (Altmann & Kamide, 1999). Their eyes moved faster to a relevant image when the verb in the sentence was commonly used with it. For instance, when people heard "*The boy will eat the cake*" their eyes moved more quickly to a picture of a cake than when they heard "*The boy will move the cake.*"

Given the wide variety of factors that affect sentence comprehension, some psycholinguists (e.g., MacDonald et al., 1994; McRae, Spivey-Knowlton, & Tanenhaus, 1998; Tanenhaus & Trueswell, 1995) have developed theories of sentence processing that posit the parallel, interactive use of all the sources of information relevant to the interpretation of a sentence. These theories generally claim that individual lexical items, together with knowledge of the context in which a sentence is used and experience-based statistical knowledge of the relevance of various information constraints, work together to guide sentence comprehension. Such *lexicalist constraint-based theories,* which are described and sometimes implemented in terms of connectionist models, assume that multiple possible interpretations of a sentence are available to the processor. Each possible interpretation receives activation (or inhibition) from various knowledge sources, as well as being inhibited by the other interpretations. Competition among the interpretations eventually results in the dominance of a single one. Increased competition is responsible for the effects that the theories discussed earlier have attributed to the need to revise an analysis.

Constraint-based theories can accommodate influences of specific lexical information, context, verb category, and many other factors, and they have encouraged the search for additional influences. However, they may not be the final word on sentence processing. These theories correctly predict that a variety of factors can reduce or eliminate garden-path effects when a temporarily ambiguous sentence is resolved in favor of an analysis that is not normally preferred (e.g., nonminimal attachment). However, the constraint-based theories also predict that these factors will create garden paths when the sentence is resolved in favor of its normally preferred (e.g., minimal attachment) analysis. This may not be the case (Binder, Duffy, & Rayner, 2001). Further, under most circumstances, constraint-based theories predict that competition among multiple possibilities slows comprehension while a syntactically ambiguous phrase is being read, but this also appears not to be the case (Clifton & Staub, 2008).

We have seen that readers and listeners quickly integrate grammatical and situational knowledge in understanding a sentence. Integration is also important across sentence boundaries. Sentences come in texts and discourses, and the entire text or discourse is relevant to the messages conveyed. Researchers have examined how readers and listeners determine whether referring expressions, especially pronouns and noun phrases, pick out a new entity or one that was introduced earlier in the discourse. They have studied how readers and listeners determine the relations between one assertion and earlier assertions, including determining what unexpressed assertions follow as implications of what was heard or read. Many studies have examined how readers and listeners create a mental model of the content, one that supports the functions of determining reference, relevance, and implications (see the several chapters on text and discourse comprehension in Gernsbacher, 1994, and in Traxler & Gernsbacher, 2006, as well as Garnham, 1999, and Sanford, 1999, for summaries of this work).

Much research on text comprehension has been guided by the work of Kintsch (1974; Kintsch & Van Dijk, 1978; see Butcher and Kintsch, this volume), who has proposed several models of the process by which the propositions that make up the semantic interpretations of individual sentences are integrated into such larger structures. His models describe ways in which readers could abstract the main threads of a discourse and infer missing connections, constrained by limitations of short-term memory and guided by how arguments overlap across propositions and by linguistic cues signaled by the text.

One line of research explores how a text or discourse contacts knowledge in long-term memory (e.g., Kintsch, 1988), including material introduced earlier in a discourse. Some research emphasizes how retrieval of information from long-term memory can be a passive process that occurs automatically throughout comprehension (e.g., McKoon & Ratcliff, 1998; Myers & O'Brien, 1998; O'Brien, Cook, & Gueraud, 2010). In the Myers and O'Brien *resonance model,* information in long-term memory is automatically activated by the presence in short-term memory of material that apparently bears a rough semantic relation to it. Semantic factors, even factors such as negation that drastically change the truth of propositions, do not seem to affect the resonance process. Other research has emphasized a more active and intelligent search for meaning as the basis by which a reader discovers the conceptual structure of a discourse. Graesser, Singer, and Trabasso (1994) argued that readers of a narrative attempt to build a representation of the causal structure of the text, analyzing events in terms of goals, actions, and reactions. Another view (Rizzella & O'Brien, 1996) is that a resonance process serves as a first stage in processing a text and that various reading objectives and details of text structure determine whether a reader goes further and searches for a coherent goal structure for the text.

Phenomena Specific to the Comprehension of Spoken Language

The theories and phenomena that we have discussed so far apply to comprehension of both spoken language and written language. One challenge that is specific to listening comes from the evanescent nature of speech. People cannot relisten to what they have just heard in the way that readers can move their eyes back in the text. However, the fact that humans are adapted through evolution to process auditory, not written, language suggests that this may not be such a problem. Auditory sensory memory can hold information for up to several seconds (Cowan, 1984; see Nairne & Neath, this volume), and so language that is heard may persist, permitting effective revision. In addition, auditory structure may facilitate short-term memory for spoken language. Imposing a rhythm on the items in a to-be-remembered list can help people remember them (Ryan, 1969), and prosody may aid memory for sentences as well (Speer, Crowder, & Thomas, 1993). Prosody may also guide the parsing and interpretation of utterances (see Carlson, 2009; Frazier, Carlson, & Clifton, 2006). For example, prosody can help resolve lexical and syntactic ambiguities, it can signal the importance, novelty, and contrastive value of phrases, and it can relate newly heard information to the prior discourse. Readers who translate visually presented sentences into a phonological form include prosody, and this implicit prosody affects how written sentences are interpreted (Bader, 1998; J. D. Fodor, 1998).

Consider how prosody can permit listeners to avoid the kinds of garden paths that have been observed in reading (Frazier & Rayner, 1982). Several researchers (see Warren, 1999) have demonstrated that prosody can disambiguate utterances. In particular, an intonational phrase boundary (marked by pausing, lengthening, and tonal movement) can signal the listener that a syntactic phrase is ending (see Selkirk, 1984, for discussion of the relation between prosodic and syntactic boundaries). Convincing evidence for this conclusion comes from a study by Kjelgaard and Speer (1999) that examined temporary ambiguities like "*When Madonna sings the song it's a hit*" versus "*When Madonna sings the song is a hit.*" Readers, following the late-closure principle, initially take the phrase *the song* as the direct object of *sings.* This results in a garden path when the sentence continues with *is a hit,* forcing readers to reanalyze *the song* as the subject of *is a hit.* Kjelgaard and Speer found that such difficulties were eliminated when the sentences were pronounced with an appropriate prosody (an intonational phrase boundary after *sings*). The relevant prosodic property does not seem to be just the occurrence of a local cue, such as an intonational phrase break (Schafer, 1997). Rather, the effectiveness of a prosodic boundary seems to depend on its place in the global prosodic representation of a sentence (Carlson, Clifton, & Frazier, 2001; Frazier et al., 2006).

Phenomena specific to the comprehension of written language. Written language carries some information that is not available in the auditory signal. For example, word boundaries are explicitly indicated in some but not all writing systems, and the spaces between words can facilitate reading. Removing them when they are normally present slows reading (Rayner & Pollatsek, 1996), and providing them in a writing system that does not have them can speed reading (Winskel, Radach, & Luksaneeyanawin, 2009). Further, readers seldom have to suffer the kinds of degradation in signal quality that listeners commonly experience in noisy environments. However, writing lacks the full range of grammatically relevant prosodic information that is available in speech. Punctuation restores some of this information (see Hill & Murray, 1998). For instance, readers can use the comma in "*Since Jay always jogs, a mile seems like a very short distance to him*" to avoid misinterpretation. Readers also seem to be sensitive to line breaks, paragraph marking, and the like. Their comprehension improves, for example, when line breaks in a text correspond to major constituent boundaries (Graf & Torrey, 1966, cited in Clark & Clark, 1977; Jandreau & Bever, 1992).

LANGUAGE PRODUCTION

As we have discussed, listeners and readers must map the spoken or written input onto entries in the mental lexicon, and they must generate various levels of syntactic, semantic, and conceptual structure. Speakers are faced with the converse problem, mapping from a conceptual structure to words and their elements. In this section, we first discuss how people produce single words and then turn to the production of sentences. Because of space limitations, we do not discuss writing (for some key references see Bonin, Malardier, Meot, & Fayol, 2006; Damian & Stadthagen-Gonzales, 2009; Kessler & Treiman, 2001; Olive, Kellogg, & Piolat, 2008; Zhang & Damian, 2010).

Producing Single Words

Contemporary models of word production share the assumption that words are planned in several steps. Each step generates a specific type of representation, and information is transmitted between representations via the spreading of activation. To facilitate the exposition, we first outline the model proposed by Levelt, Roelofs, and Meyer (1999). We then discuss which aspects of this model are controversial and which are assumed in other models as well, describing some of the empirical work done to address the points of controversy.

The first step in planning a word is determining which notion to express. This involves not only deciding which object, person, or event to refer to, but also how. For instance, a speaker can say "*the baby,*" "*my brother,*" "*Tommy,*" or simply "*he*" to refer to a small person in a highchair. In making such a choice, the speaker may consider a variety of things, including, for instance, whether and how the person has been referred to before and whether the listener is likely to know his proper name.

The next step in single word production is to select a lexical unit that corresponds to the chosen concept. In the model we are discussing, the speaker first selects a *lemma* and then generates the corresponding phonological form. Lemmas are grammatical units that specify the syntactic class of the words and, where necessary, additional syntactic information, such as whether a verb is intransitive (e.g., *sleep*) or transitive (e.g., *eat*). Lemma selection is a competitive process. Several lemmas may be activated at the same time, for instance when a speaker has not yet decided which concept (e.g., *lamb* or *sheep*) to express. A lemma is selected as soon as its activation level exceeds the summed activation of all competitors. A checking mechanism ascertains that the selected lemma indeed maps onto the intended concept.[1]

The following step is the generation of the form of the word. Intuitive evidence for the lemma/word-form distinction comes from the existence of tip-of-the-tongue states in which speakers have a strong feeling of knowing a word and can retrieve part of the information pertaining to it, for example its grammatical gender, but cannot retrieve its complete phonological form (e.g., Brown & McNeill, 1966; Vigliocco, Antonini, & Garrett, 1997). Such partial retrieval of lexical information demonstrates that the lemma and form of a word are retrieved in separate steps.

Word form encoding encompasses several processes. The first is the retrieval of one or more morphemes. As discussed earlier, many words (e.g., *baby, tree*) only include a single morpheme, whereas others (e.g., *grandson* or *walked*) include two or more morphemes. In the model proposed by Levelt and colleagues (1999), speakers build the morphological representations by retrieving and combining the constituent morphemes. Evidence for this view comes, for instance, from speech errors such as "*imagine getting your model renosed,*" where word stems exchange while affixes remain in place (Fromkin, 1971).

The next processing step is the generation of the phonological form of the word. Word forms are not retrieved as units, but are built up out of phonological segments (and perhaps groups of segments, such as /st/). This is shown by the occurrence of sound errors, where segments are transposed (e.g., *plack ben* instead of *black pen*), added (my *blue blag* instead of my *blue bag*) or deleted (*nice tie* instead of *nice try*; see Fromkin, 1971; see also Garrett, 1975). In the model under discussion here, the segments of a word are retrieved in parallel. The string of segments is subsequently divided into syllables and is assigned stress. This is a sequential process, proceeding from the beginning to the end of the word (e.g., Meyer, 1990, 1991; Roelofs, 1993). For words that deviate from the stress rules of the language, the stress pattern is stored in the lexicon.

The phonological representation of a word consists of discrete, nonoverlapping segments, which define static positions of the vocal tract or states of the acoustic signal to be attained. The definitions of the segments are independent of the contexts in which they appear. However, speech movements overlap in time, and they are continuous and context-dependent. Hence, a final planning step, phonetic encoding, is needed, during which the articulatory gestures are specified. This may involve the retrieval of syllable-sized routines for frequent syllables (e.g., Cholin, Dell, & Levelt, 2011; Levelt & Wheeldon, 1994).

The global architecture of the model, in particular the distinction between conceptual/semantic, syntactic, decomposed morphological, phonological, and articulatory representations is widely accepted in the field (e.g., Caramazza, 1997; Dell, Burger, & Svec, 1997; Miozzo & Caramazza, 1997; for reviews see Goldrick & Rapp, 2007; Levelt, 1999; Rapp & Goldrick, 2006). The same is true for the assumption that conceptual, syntactic, morphophonological and articulatory encoding processes are initiated in that order. Both the structural assumptions and the assumptions about the rough time course of processing are supported by converging evidence using a variety of paradigms, including reaction time studies (e.g., Roelofs, 1992, 1993, 1997; van Turennout, Hagoort, & Brown, 1998), analyses of errors in healthy persons and neuropsychological patients (e.g., Dell, Schwartz,

[1]The notion of lemmas appears to be more popular in theories of speech production than in theories of speech comprehension. Of course, the information taken to be encoded in lemmas in theories of production must be accessed in comprehension as well. Thus, the process of lemma selection in production corresponds roughly to the processes of lexical access discussed in the sections on word recognition.

Martin, Saffran, & Gagnon, 1997; Rapp & Goldrick, 2000, 2006), and brain imaging studies (e.g., Indefrey & Levelt, 2004).

A more controversial issue is how information is transmitted from one level to the next, specifically whether this is a strictly serial process or a cascaded process (e.g., Humphreys, Price, & Riddoch, 2000; MacKay, 1987) and, in the latter case, whether the flow of information is unidirectional or whether there is feedback from lower to higher levels of processing (Dell, 1986, 1988; Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Goldrick, Folk, & Rapp, 2010). In the model proposed by Levelt et al. (1999), there is bidirectional information flow between the message and the concepts, but from the lemma level onward, processing is strictly serial. This architecture was implemented in a computational model by Roelofs (1997), and numerous experiments and simulations have demonstrated the strength of this approach (Roelofs, 1998). However, recent evidence points toward continuous flow of information in the speech planning system. For instance, several studies have shown that an object that a speaker does not intend to name can nevertheless activate its name (e.g., Morsella & Miozzo, 2002; Roelofs, 2008). According to a strictly serial view, such incidental activation should not happen.

Much of the evidence in support of feedback between processing levels comes from the results of analyses of speech errors made by neuropsychological patients and healthy speakers (Dell, 1986; 1988; Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Foygel & Dell, 2000; Rapp & Goldrick, 2000, 2004). The relevant observations include the fact that sound errors tend to form existing words more often than would be expected on the basis of chance estimates (e.g., Baars, Motley, & MacKay, 1975; Dell & Reich, 1981). However, this and related observations can also be seen as demonstrating the operation of a speech monitor that has access to the phonological form of the planned words and is sensitive to syntactic and semantic constraints (e.g., Roelofs, 2004a, b). In addition, several studies have reported effects of the phonological neighborhood on the speed and accuracy of word retrieval in production tasks. Words from dense neighborhoods (i.e., words that are phonologically similar to many words other words) tend to be produced faster or more accurately than words from sparser neighborhoods (e.g., Dell & Gordon, 2003; Goldrick et al., 2010; Vitevitch, 2002). In models without feedback, neighbors of a target word may become activated during retrieval, but it is not clear how this would facilitate lexical access. Overall, the evidence supports the assumption of models with restricted feedback between processing levels (see also Goldrick & Rapp, 2007).

Another controversial issue is whether the time required to select a lemma depends on the activation levels of competing lemmas, as proposed by Levelt and colleagues (1999), or whether the selection of a target lemma occurs independently of the activation of competitors. Strong evidence for the lexical-selection-by-competition view comes from experiments demonstrating that speakers are slower to name pictures (e.g., a picture of a dog) accompanied by distractor words from the same semantic category (e.g., *cat*) than by distractors from a different category (e.g., *fork*). A standard account of this semantic interference effect is that it arises during lemma selection and that related lemmas compete more strongly with each other for selection than unrelated ones (e.g., Hantsch, Jescheniak, & Schriefers, 2009; Rahman & Melinger, 2009; Roelofs, 1993; Schriefers, Meyer, & Levelt, 1990; see also Oppenheim, Dell, & Schwartz, 2010; Rapp & Goldrick, 2000). However, it has been argued the interference effect could arise later, during the selection of a response, and that lemma selection is not a competitive process (e.g., Finkbeiner & Caramazza, 2006; Mahon & Caramazza, 2009; Mahon, Costa, Peterson, Vargas, & Caramazza, 2007).

A closely related issue is how determiners and pronouns, whose forms depend on the grammatical features of the corresponding nouns and sometimes on the phonological context, are selected (e.g., Foucart, Branigan, & Bard, 2010; Miozzo & Caramazza, 1999; Schiller & Caramazza, 2003; see also Mirkovic, MacDonald, & Seidenberg, 2005; Paolieri et al., 2010). A key issue is, again, whether this is a competitive process and, if so, at which level of processing—the grammatical feature level or level of the phonological forms of the pronouns—competition arises (e.g., Cubelli, Lotto, Paolieri, Girelli, & Job, 2005; Schiller & Caramazza, 2003; Schriefers, Jescheniak, & Hantsch, 2002).

Much of the research on morphological processing in production has concentrated on demonstrating that there are morphological representations for complex words that are independent of the semantic and phonological representations of the words. We described some evidence for this claim in the earlier section on written word recognition. Studies of word production have shown that morphologically related primes are more effective than morphologically unrelated primes that share the same number of phonemes with the targets (e.g., target: *Rock*/German *skirt,* morphologically related prime: *Faltenrock/pleated skirt,* phonologically related distractor:

Barock/baroque; Gumnior, Bölte, & Zwitserlood, 2006; see also Koester & Schiller, 2008; Zwitserlood, Bölte, & Dohmes, 2000). Such a morphological relatedness effect demonstrates that priming does not have a purely phonological basis. Strong evidence for decomposed representations of compounds also comes from a study by Bien, Levelt, and Baayen (2005) demonstrating that the time speakers needed to retrieve compound nouns depended on the frequency of the components more than on the frequency of the entire compound. This finding is similar to the results described earlier in the case of reading (Pollatsek et al., 2000).

Most research in the area of phonological encoding has focused on the retrieval of segmental information. As mentioned, there is good consensus in the field that speakers of English and other Indo-European languages build up phonological forms by retrieving and combining phonological segments. Construction of phonological form has been shown to be a sequential process proceeding from the beginning to the end of the word (e.g., Meyer, 1990, 1991; Roelofs, 2004c). Other, important issues have remained largely unexplored. For instance, there has been little research on how speakers generate the stress patterns of words (but see Roelofs & Meyer, 1998; Schiller, Bles, & Jansma, 2003). Another important issue concerns how phonological and phonetic plans are translated into articulatory commands. One aspect of this issue is how detailed speakers' phonological and phonetic plans are and when and how information about the precise way the articulatory commands are to be executed is provided (Goldrick & Rapp, 2007; Pouplier & Goldstein, 2010). Most importantly perhaps, there is little evidence about how word forms are generated in non–Indo-European languages. The research that has been done suggests that phonological segments may not play same critical role as the primary units of phonological encoding that they do in English. On the basis of results of speech error analyses and experimental evidence, O'Seaghdha, Chen, and Chen (2010) argued that in Mandarin Chinese the primary units of phonological encoding are syllables, rather than segments (see also Chen, Chen, & Dell, 2002; Wong & Chen, 2008; for related evidence from Japanese see Kureta, Fushimi, & Tasumi, 2006).

The Production of Sentences

To produce phrases and sentences, speakers must select several words in quick succession. The lexical retrieval processes probably occur in much the same way as described above for single word production. However, the selection of lexical items is not governed exclusively by individual lexical concepts, but depends on the meaning of the entire utterance, which is encoded in the preverbal message (e.g., Bock & Levelt, 1994; Levelt, 1989). In this section, we first discuss the generation of messages and then turn to the linguistic formulation processes occurring during phrase and sentence production.

Messages are generally considered to be the interface between the speaker's thoughts and their linguistic formulation; they represent those concepts and relationships that a speaker has singled out for verbal expression. They are conceptual rather than linguistic representations (for different ways of describing their properties see Bierwisch & Schreuder, 1992; Chang, Dell, & Bock, 2006; Levelt, 1989). However, they provide all the conceptual information that speakers need to create well-formed utterances of their language. Languages differ dramatically in the properties of events and objects that need to be linguistically encoded (e.g., Evans & Levinson, 2009; Talmy, 1985). For instance, they differ in whether they routinely encode the manner of movement (as in English *jump*) or the endpoint of movements (as in English *enter*; Papafragou, Hulbert, & Trueswell, 2008), and in whether they express how the speaker learned about an event (hearsay versus direct observation, Slobin & Aksu-Koç, 1982). The content of a message, though prelinguistic, must nevertheless be language-specific, and this is why message generation has been referred to as thinking for speaking (Slobin, 1996).

In much of the research in this area, speakers' message generation has been constrained by asking them to describe pictures of scenes or events. To produce a description such as "*The mailman is chased by the dog,*" the speaker must create a message that specifies the event participants (mailman, dog) and the event, which could, for instance, be conceptualized as either chasing or fleeing. One important issue in research on message generation has been how speakers choose the starting point for their description, that is, the first object or event participant to be mentioned (for a review see Bock, Irwin, & Davidson, 2004). A much debated question is how much this decision is affected by the speaker's understanding of the entire scene and by properties of the individual objects or event participants that attract attention, such as their animacy or size (e.g., Bock 1982; Bock & Warren, 1985; Gleitman, January, Nappa, & Trueswell, 2007; McDonald, Bock, & Kelly, 1993). Griffin and Bock (2000) proposed that speakers initially spend a few hundred milliseconds gaining an understanding of what the scene is about and then select the starting point for the utterance (see also Bock, Irwin, Davidson, & Levelt, 2003). This proposal entails that speakers generate a rough plan for the entire utterance before choosing a starting point (see also Allum & Wheeldon, 2009; Smith & Wheeldon, 1999).

Another issue that has received much attention is how speakers choose between alternative ways of referring to an object, for instance between a noun (*a boy*), an adjective-noun phrase (*a little boy*), and a pronoun (*he*). These decisions are also taken at the message level. Obviously, speakers should aim to express themselves in such a way that the listener can easily understand what they mean. How this goal is best achieved depends on many variables, including characteristics of the listener (e.g., his or her familiarity with the topic; Brennan & Clark, 1996), the situation (e.g., whether the referent object can easily be confused with similar objects in the environment; Brown-Schmidt & Tanenhaus, 2006; Engelhardt, Bailey, & F. Ferreira, 2006) and the linguistic context (e.g., whether, when, and how the object has been referred to before; Grosz, Joshi, & Weinstein, 1995). A large body of linguistic and psycholinguistic research illustrates that speakers are indeed sensitive to such variables (for reviews see Arnold, 2008; Horton & Gerrig, 2005). However, context effects are not necessarily due to speakers' efforts to tailor their utterances to listeners' communicative needs, but can also arise because of speaker-internal processes. For instance, Engelhardt et al. (2006) showed that speakers produced complex noun phrases (e.g., *the apple on the napkin*) when listeners needed to know the location of the target object in order to identify it. This indicates that the speakers were aware of the listeners' information needs (see also V. Ferreira, Slevc, & Rogers, 2005). However, speakers often also mentioned the location when the listener did not need it to find the target. Engelhardt et al. proposed that speakers did this because the positions of the objects were salient to them and that effort would be required to restrict utterances to the necessary information. Similarly, Arnold, Eisenband, Brown-Schmidt, and Trueswell (2000) showed that speakers avoided personal pronouns (*he, she*) to refer to an agent when another person with the same gender was present, presumably to avoid confusion among them. However, Arnold and Griffin (2007) showed that speakers had some tendency to avoid pronouns when a different-gender competitor was present. Speakers did this, the researchers proposed, because they divided their attention across the target and the competitor, making the target less accessible. Because pronouns are typically used to refer to highly accessible concepts, speakers were less likely to refer to the target with a pronoun (see also Fukumura, van Gompel, & Pickering, 2010). Of course, it is possible that the presence of the competitor also made the target less accessible for the listener and that the speaker avoided the pronoun to help the listener, but Arnold and Griffin (2007) argued that their findings reflected limitations of speaker capacity.

Based on the message, speakers select appropriate words and order them in a way that expresses the intended meaning and honors the grammatical rules of the language. Most models of utterance planning assume that speakers generate syntactic frames to which words are linked (e.g., Dell, 1986; Dell, Burger, & Svec, 1997). Based on analyses of speech errors, Garrett (1975) proposed that two distinct sets of processes are involved in generating syntactic structure (see also Bock & Levelt, 1994; Levelt, 1989; see Chang et al., 2006 for a related approach). During the first set, a functional structure is created, which involves selecting lemmas (as described in the preceding section) and assigning them grammatical functions, such as subject, verb, direct object, and indirect object. Word order is not yet represented but is determined during the following step, called positional processing by Bock and Levelt (1994). Now the morphological forms associated with the selected lemmas are retrieved and assigned to positions in independently created structural frames, which encode the syntactic surface structure of the utterance. Thus, in English, the sentence subject assumes a position preceding the verb, the direct and indirect object are assigned to positions following the verb, and so on.

The distinction between functional and positional encoding is supported by a number of findings, including the results of priming studies. In such studies, participants first hear or produce a sentence such as "*The woman shows the man the dress.*" Then they see a picture that can be described using the same type of structure (e.g., "*The boy gives the teacher the flowers*") or a different structure ("*The boy gives the flowers to the teacher*"). Speakers tend to repeat the structure used on the priming trial, even when the words in the prime and target sentences are different and when the events are conceptually unrelated. This finding suggests that there are structural encoding processes that can be primed and that are distinct from the generation of the functional representation, where the event semantics are represented (Bock, 1986; Bock & Loebell, 1990; Chang, Dell, Bock, & Griffin, 2000; Pickering & F. Ferreira, 2008).

This view of grammatical encoding entails that the generation of grammatical frames and the selection of lexical items are independent. However, these processes must be coordinated in some way, as the grammatical frame must have the correct number and types of slots to accommodate the retrieved words. For instance, *give* can appear in two frames, as in *give the child a sweet* and *give a sweet to the child,* whereas *donate* can only appear in one frame, as in *donate the inheritance to the church* (V. Ferreira, 1996). Several studies have found that the effect of structural priming interacted with the effect of repeating words of the prime sentence in the target sentence and with semantic priming effects. These studies suggest that lexical-retrieval and structure-building processes are not, in fact, independent (e.g., Cleland & Pickering 2003, 2006; Santesteban, Pickering, & McLean, 2010; Wheeldon, Smith, & Apperly, in press). Key issues in current research on grammatical encoding are how much syntactic information is represented at the lexical level, as part of individual lemmas or in links between lemmas and abstract grammatical nodes, and to what extent grammatical encoding is affected by lexical retrieval (e.g., Bock et al., 2004; Chang et al., 2006; V. Ferreira & Dell, 2000; F. Ferreira & Swets, 2002; Konopka & Bock, 2009; Pickering & Branigan, 1998).

In most languages, certain elements in well-formed sentences must agree with one another (e.g., Corbett, 1979). For instance, English subject and verb must agree in number, and pronouns (*he, she, it*) must agree with their noun antecedents in gender and number. The relevant information, the natural gender and the number of event participants, is specified at the conceptual level (though there are exceptions—we say, "*The rice IS overcooked* but *The lentils ARE overcooked*"). Many languages have not only subject-verb agreement in number but also agreement between nouns and adjectives and pronouns in grammatical gender (e.g., Dutch, French) or case (e.g. German, Russian).

Research on agreement has centered mainly on subject-verb agreement (but see Badecker & Kuminiak, 2007). One question that has received much attention is which kinds of information speakers take into account when they create agreement. To examine this issue, researchers have studied agreement for English collective nouns such as *fleet* and *gang, where conceptual and grammatical number mismatch. These studies have o*ften used sentence completion tasks, in which speakers hear the beginning of a sentence (e.g., *The condition of the ship/ships/fleet/fleets* . . .), repeat the fragment, and then complete it to form a full sentence (e.g., Bock & Eberhard, 1993; Thornton & MacDonald, 2003). When a singular head noun (*condition* in the example) is followed by a plural noun, speakers sometimes make agreement errors (e.g., *The condition of the ships WERE poor*). Early studies suggested that the speakers' choice of verb form was based exclusively on grammatical information. For instance, agreement errors were no more likely for *the condition of the fleet, where the local noun (fleet) refers to several objects* than for *the condition of the ship, where the local noun (ship refers to a single object* (Bock & Eberhard, 1993; Bock & Miller, 1991). However, more recent studies have shown that agreement can be influenced by semantic variables, such as the conceptual number of the nouns (*ship* versus *fleet,* e.g., Eberhard, 1999; Haskell & MacDonald, 2003; Thornton & MacDonald, 2003; Vigliocco, Butterworth, & Garrett, 1996; Vigliocco, Hartsuiker, Jarema, & Kolk, 1996) as well as by morphological and phonological variables, such as the overt marking of grammatical gender of a noun in the phonological form (e.g., Antón-Méndez & Hartsuiker, 2010; Franck, Vigliocco, Antón-Méndez, Collina, & Frauenfelder, 2008; Hartsuiker, Schriefers, Bock, & Kikstra 2003). Bock, Eberhard, Cutting, Meyer, and Schriefers (2001) proposed a serial two-step model account of these influences. In the first step, speakers use the conceptual information encoded in the message to assign number to the subject noun phrase, and in a second step they determine the morphological forms of the individual words. Semantic variables affect only the first processing step, whereas morphological and phonological variables affect only the second step (for an extension of the model to capture agreement between nouns and pronouns see Eberhard, Cutting, & Bock, 2005; for a critical discussion and a slightly different model see Frank et al., 2008). Deutsch and Dank (2009) demonstrated that the model, originally developed to account for number agreement in English, accounts well for error patterns seen when speakers of Hebrew create subject-verb agreement, which is governed both by conceptual variables (conceptual number and natural gender) and arbitrary grammatical variables (grammatical number and gender). An interesting recent development is to consider agreement not as resulting from the application of strict grammatical rules but from the interaction of multiple graded probabilistic constraints (e.g., Haskell & MacDonald, 2003, 2005; Haskell, Thornton & MacDonald, 2010; Thornton & MacDonald, 2003).

The positional encoding and agreement processes result in a morphological representation of the utterance. Next, speakers generate a phonological representation. The phonological form of each word is retrieved from the mental lexicon as described earlier. However, the phonological form of a sentence or phrase is not a mere concatenation of the citation forms of words. Instead, the word forms are combined into new prosodic units (e.g., Nespor & Vogel, 1986). Phonological words often correspond to lexical words, but a morphologically complex word may comprise several phonological words, and unstressed words such as conjunctions and pronouns can combine with preceding or following words into single phonological words. For instance, the words *find it* may be produced as one phonological word, [fain][dIt], with an altered syllable boundary (e.g., Wheeldon & Lahiri, 1997, 2002). Phonological words are grouped into larger prosodic units, the boundaries of which are marked by pauses, changes in pitch, and/or lengthening of the word preceding the boundary (e.g., Cutler, Dahan, & van Donselaar, 1997; Shattuck-Hufnagel & Turk, 1996; Wagner & Watson, 2010).

The prosodic structure of utterances depends on the meaning and the syntactic structure of the utterance and on properties of the individual words. For instance, speakers can use prosody to express emotions and opinions (e.g., Pell, 2001) and the type of speech act (for instance, whether an utterance is a declarative or a question; e.g., Fletcher, Stirling, Mushin, & Wales, 2002) and to highlight the information structure of the utterance (i.e., which parts of the utterance refer to concepts mentioned before and which parts are new; see Cutler et al., 1997; Levelt, 1989; Shattuck-Hufnagel & Turk, 1996; Wagner & Watson, 2010). Some syntactic boundaries, including that between a subordinate clause and a following main clause, are regularly marked prosodically, but the marking of most boundaries is optional. Snedeker and Trueswell (2003) found that speakers used prosody to disambiguate utterances such as "*Tap the frog with the flower*" when the visual context supported both interpretations (i.e., the display included a frog holding a flower, a frog without a flower, and a flower, which might be used as an instrument), but not when the context supported only one of the two interpretations. By contrast, Kralijc and Brennan (2005) found that speakers prosodically marked syntactic boundaries even when the nonlinguistic context sufficed to disambiguate the utterances (see Schafer, Speer, & Warren, 2005, for similar evidence).

How speakers create prosodic structures has not been widely studied. Levelt (1989) postulated a prosody generator (see also Calhoun, 2010), which uses message level and linguistic information to plan the prosodic structure of utterances, but how the prosody generator works remains to be explored. There has been some work on the placement of prosodic boundaries and the way they are indicated (e.g., through pauses of varying duration, through lengthening of phrase final words; F. Ferreira, 1993) As mentioned, prosodic phrasing depends on the meaning and structure of the utterance, but it also depends on the speaker's planning processes: Speakers can pause when they need time to plan the next utterance fragment and/or recover after completion of the preceding utterance one (e.g., F. Ferreira, 1993; Wagner & Watson, 2010; Watson & Gibson, 2004). This is one reason why long syntactic constituents are more likely to be preceded by intonational phrase boundaries than shorter constituents. An important task for future research in this area (and, in fact, for the listener, see Frazier et al. 2006) is to identify those properties of prosodic structures that are planned to express the intended meaning and those that result from the speaker's planning processes (F. Ferreira, 2007).

In sum, speakers need to plan their utterances at a number of different levels. According to all current theories of speech planning, they do this incrementally, which means that they generate a plan for part of their utterance, begin to speak, and plan the following part of the utterance while they are talking (e.g., Levelt, 1989; Pickering & Garrod, 2004). At the message level, the planning increments can correspond to entire sentences (e.g., Allum & Wheeldon, 2007, 2009; Griffin & Bock, 2000; Wheeldon et al., in press), but more often they correspond to smaller parts of an utterance, for instance a subject noun phrase or a verb phrase (e.g., Branigan, Pickering, McLean, & Stewart, 2006; F. Ferreira & Swets, 2002; Martin, Crowther, Knight, Tamborello, & Yang, 2010). The parallel activation of several concepts at the message level may lead to parallel activation of the associated lemmas and word forms (Jescheniak, Schriefers, & Hantsch, 2003; Malpass & Meyer, 2010; Oppermann, Jescheniak, & Schriefers, 2008; Schnur, Costa, & Caramazza, 2006). However, since words must be eventually produced in sequence, a procedure is needed that selects activated lexical units in the appropriate order. A common assumption is that this linearization occurs when words are associated, sequentially, to the slots in the positional representation (e.g., Dell, Burger, & Svec, 1997). Thus, although several concepts and words may be activated at the same time during the planning process, the actual selection of the words as part of the utterance is a sequential process.

Speakers monitor their output as they talk, allowing them to detect and correct at least some of their speech errors. Theories of speech monitoring (for reviews see Hartsuiker & Kolk, 2001; Nooteboom & Quené, 2008; Postma, 2000) assume that speakers monitor not only their overt speech but also their speech plan. Strong evidence for this assumption comes from analyses of the time course of self-repairs, such as "*I am so- eh happy to see you.*" Often, the interval between the end of the incorrect utterance and the repair is so short that the speaker cannot have detected the error in the overt utterance but must have spotted an error in the speech plan. The Levelt et al. (1999) model assumes that speakers monitor their speech plans at two levels, the message level and the level of phonological or phonetic representations, but not at intermediate levels (see also Slevc & V. Ferreira, 2006; but see Hartsuiker, Pickering, & de Jong, 2005). Monitoring at the phonological level is taken to involve the speech input system, which processes self-generated phonological representations in the same way as input from other speakers. These monitoring processing are effortful and relatively deliberate. In addition, there may be faster and more automatic checking processes that are intrinsic to the speech planning system. These processes might, for instance, be sensitive to novel or unexpected patterns of activation of lexical or sublexical units (e.g., MacKay, 1987; for further discussion see Nozari & Dell, 2009; Postma, 2000).

CONCLUSIONS

We have talked about language comprehension and language production in separate sections of this chapter. This is because reading, listening to spoken language, and speaking are experienced as different activities and because most psycholinguistic studies have concerned only one of these linguistic activities.

Nonetheless, speaking, listening and reading must be intimately related. It is highly likely that shared or overlapping knowledge is used in the production and comprehension of language. Thus, people probably access the same concepts when they hear and read words and when they produce words; they probably have only one store of syntactic knowledge; and large parts of the mental lexicon are likely to be shared as well. If shared knowledge structures are involved in different linguistic activities, the processes involved in accessing these structures are probably similar too. For instance, it would be very surprising if morphologically complex words were always decomposed into their components during comprehension but retrieved as units in production, or that familiarity or simplicity of specific syntactic structures affected their ease of comprehension but not their ease of production.

Production and comprehension of spoken language are also related by virtue of the fact that people rarely engage in only one of these activities at time. As we have discussed, speakers hear themselves when they talk and probably engage the speech comprehension system when they monitor their own speech. Similarly, it has been proposed that comprehending language engages the production system (Pickering & Garrod, 2007). Further, as Garrod and Pickering (2004) emphasized, people engaged in discourse influence each other, so that words or structures that one person says affect how the other person expresses his or her thoughts.

Future work, in addition to exploring the ties between comprehension and production, will need to build better bridges between studies of the processing of isolated words and studies of sentence and text processing. For example, theories of word recognition have focused on how readers and listeners access phonological and morphological information. They have paid little attention to how people access the syntactic information that is necessary for sentence processing and comprehension. Further work is needed, too, on the similarities and differences between the processing of written language and the processing of spoken language. Given the importance of prosody in spoken language comprehension, for example, we need to know more about its possible role in reading.

We have identified some key themes in all the areas we have discussed. One theme is the balance between computation and storage. Clearly, a good deal of information must be stored as such, including the forms of irregular verbs such as *went.* But are forms that could, in principle, be derived by rule (e.g., the regular past tense form *walked*) computed each time they are heard or said, or are they stored as ready-made units, or are both procedures available?

A second theme, supposing that some rule-based computation takes place, involves the nature of the rules that guide computation. Are they hard-and-fast rules, like traditional linguistic rules, or are they more like probabilistic constraints? People seem to be very good at picking up statistical regularities in the language they are exposed to (Saffran, 2003). However, many linguistic patterns seem to be all-or-none (for example, nouns and adjectives in French always agree in gender). Our ability to follow such patterns, as well as our ability to make some sense of sentences like *Colorless green ideas sleep furiously,* suggests that Chomsky's notion of language as an internalized system of rules still has an important place to play in views of language processing.

A third theme is the debate between interactive and modular views. Various sources of evidence speak against a strictly serial, unidirectional flow of information in language processing, including observations suggesting that knowledge of a word may influence perception of its component phonemes. However, there is no way of disconfirming a theory that claims that a language user can potentially use all available information in any logically possible way. The debate has proven valuable because it has led researchers to seek out and understand new and interesting phenomena, but it will not be resolved until theorists provide and test more constrained and explicit models, both interactive and modular.

A fourth theme, which we have only briefly mentioned but which we find in all the areas covered, is how general cognitive processes such as memory and attention are involved in language comprehension and production. Attention clearly plays a role in the recognition of written and spoken words (e.g., Sanders & Neville, 2003), and memory has to play a role in putting together the words in a sentence (e.g., Lewis & Vasishth, 2005). Understanding the involvement of these processes in linguistic tasks is crucial for understanding how differences in language use between persons and situations arise, and in what ways language is similar to and different from other cognitive activities.

A fifth, and recently emerging, theme is the increasing interest in studying languages other than English, including non-Indo-European languages (e.g., Bornkessel-Schlesewsky & Schlesewsky, 2009). We hope that this trend will continue. This is important because, so far, psycholinguists have rarely appreciated the full diversity of languages and the differences in processing requirements for speakers of different languages. A great deal has been learned, but even more remains to be learned.

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