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Psycholinguistics: Language comprehension and production

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INTRODUCTION

Psychologists have long been interested in language, but psycholinguistics as a field of study did not emerge until the 1960s. It was motivated 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). The special feature of language on which Chomsky focused was its productivity. Possessed with a grammar, or syntax, humans can produce and understand novel sentences that carry novel messages. We do this in a way that is exquisitely sensitive to the structure of the language. For example, we interpret *The umpire helped the child to third base* and *The umpire helped the child on third base* as conveying distinct messages, although the sentences differ in just one small word. We know that *He showed her baby the pictures* and *He showed her the baby pictures* describe quite different events, even though the difference in word order is slight. We can even make some sense of *Colorless green ideas sleep furiously* (Chomsky, 1971), which is semantically anomalous but syntactically well formed. The same kinds of abilities are found at other levels of language. We combine *morphemes* (units of meaning) in systematic ways, and so understand Lewis Carroll's (1871/1977) *slithy toves* to refer to more than one tove that has the characteristics of slithiness. And we can combine *phonemes* (units of sound) according to the patterns of our language, accepting *slithy* but not *tlithy* as a potential English word.

Early psycholinguists described our comprehension and production of language in terms of the rules that were postulated by linguists (Fodor, Bever, & Garrett, 1974). The connections between psychology and linguistics were particularly close in the area of syntax, with psycholinguists testing the psychological reality of various proposed linguistic rules. As the field of psycholinguistics developed, it became clear that theories of sentence comprehension and production cannot be based in any simple way on linguistic theories; psycholinguistic theories must consider the properties of the human mind as well as the structure of the language. Psycholinguistics has thus become its own area of inquiry, informed by but not totally dependent on linguistics.

Although Chomsky and the early psycholinguists focused on the creative side of language, language also has its rote side. For example, we store a great deal of information about the properties of words in our *mental lexicon*, and we retrieve this information when we understand or produce language. On some views, different kinds of mechanisms are responsible for the creative and the habitual aspects of language. For example, we may use morpheme-based rules to decompose a complex word like *rewritable* the first few times we encounter it, but after several exposures we may begin to store and access the word as a unit (Caramazza, Laudanna, & Romani, 1988; Schreuder & Baayen, 1995). *Dual-route* views of this kind have been proposed in several areas of psycholinguistics. According to such models, frequency of exposure determines our ability to recall stored instances but not our ability to apply rules. Another idea is that a single set of mechanisms can handle both the creative side and the rote side of language. Connectionist theories (see Rumelhart & McClelland, 1986) take this view. Such theories claim, for instance, that readers use the same system of links between spelling units and sound units to generate the pronunciations of novel written words like *tove* and to access the pronunciations of familiar words, be they words that follow typical spelling-to-sound correspondences, like *stove*, or words that are exceptions to these patterns, like *love* (e.g., Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989). In this view, similarity and frequency both play important roles in processing, with novel items being processed based on their similarity to known ones. The patterns are statistical and probabilistic rather than all-or-none.

Early psycholinguists, following Chomsky, tended to see language as an autonomous system, insulated from other cognitive systems. In this *modular* view (see J.A. Fodor, 1983), the initial stages of word and sentence comprehension are not influenced by higher levels of knowledge. Information about context and about real-world constraints comes into play only after the first steps of linguistic processing have taken place, giving such models a *serial* quality. On an *interactive* view, in contrast, knowledge about linguistic context and about the world plays an immediate role in the comprehension of words and sentences. In this view, many types of information are used in *parallel*, with the different sources of information working co-operatively or competitively to yield an interpretation. Such ideas are often expressed in connectionist terms. Modular and interactive views may also be distinguished in discussions of language production, where one issue is whether there is a syntactic component that operates independently of conceptual and phonological factors.

Another tension in current-day psycholinguistics concerns the proper role of linguistics in the field. Work on syntactic processing, especially in the early days of psycholinguistics, was very much influenced by developments in linguistics. Links between linguistics and psycholinguistics have been less close in other areas, but they do exist. For instance, work on phonological processing has been influenced by linguistic accounts of *prosody* (the melody, rhythm, and stress pattern of spoken language) and of the internal structure of syllables, and some work on word recognition and language production has been influenced by linguistic analyses of *morphology* (the study of morphemes and their combination). Although most psycholinguists believe that linguistics provides an essential foundation for their field, some advocates of interactive approaches have moved away from a reliance on linguistic rules and principles and toward a view of language in terms of probabilistic patterns (e.g., Seidenberg, 1997).

In this chapter, we describe current views of the comprehension and production of spoken and written language by fluent language users. 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 likely to be strongly affected by such factors. We do not have the space to discuss the important field of *developmental psycholinguistics*, which deals with the acquisition of language by children. Nor will we cover *neurolinguistics*, how language is represented in the brain, or *applied psycholinguistics*, which encompasses such topics as language disorders and language teaching.

LANGUAGE COMPREHENSION

Spoken Word Recognition

The perception of spoken words would seem to be an extremely difficult task. Speech is distributed in time, a fleeting signal that has few reliable cues to the boundaries between segments and words. The paucity of cues leads to what is called the *segmentation problem*, or the problem of how listeners hear a sequence of discrete units even though the acoustic signal itself is continuous. Other features of speech could cause difficulty for listeners as well. Certain phonemes are omitted in conversational speech, others change their pronunciations depending on the surrounding sounds (e.g., /n/ may be pronounced as [m] in *lean bacon*), and many words have "everyday" pronunciations (e.g., *going to* frequently becomes *gonna*). Despite these potential problems, we usually seem to perceive speech automatically and with little effort. Whether we do so using procedures that are unique to speech and that form a specialized speech module (Liberman & Mattingly, 1985; see also Chapter 9), or whether we do so using more general capabilities, it is clear that humans are well adapted for the perception of speech.

Listeners attempt to map the acoustic signal onto a representation in the mental lexicon beginning almost as the signal starts to arrive. The *cohort model*, first proposed by Marslen-Wilson and Welsh (1978), illustrates how this may occur. According to this theory, 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 for activation. As more acoustic input is analyzed, candidates that are no longer consistent with the input drop out of the set. This process continues until only one word candidate matches the input; the best fitting word may be chosen if no single candidate is a clear winner. Supporting this view, listeners sometimes glance first at a picture of a candy when instructed to “pick up the candle” (Allopenna, Magnuson, & Tanenhaus, 1998). This result suggests that a set of words beginning with /k{n/ is briefly activated. Listeners may glance at a picture of a handle, too, suggesting that the cohort of word candidates also includes words that rhyme with the target. Indeed, later versions of the cohort theory (Marslen-Wilson, 1987; 1990) have 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 between spoken input and lexical representations, with the initial portion of the spoken word exerting a strong but not exclusive influence on the set of candidates.

The cohort model and the model of McClelland and Elman (1986) are examples of interactive models, those in which higher processing levels have a direct, “top-down” influence on lower levels. In particular, lexical knowledge can affect the perception of phonemes. A number of researchers have found evidence for interactivity in the form of lexical effects on the perception of sublexical units. Wurm and Samuel (1997), for example, reported that listeners’ knowledge of words can lead to the inhibition of certain phonemes. Samuel (1997) found additional evidence of interactivity by studying the phenomenon of *phonemic restoration*. This refers to the fact that listeners continue to “hear” phonemes that have been removed from the speech signal and replaced by noise. Samuel discovered that the restored phonemes produced by lexical activation lead to reliable shifts in how listeners labeled ambiguous phonemes. This finding is noteworthy because such shifts are thought to be a very low-level processing phenomenon.

Modular models, which do not allow top-down perceptual effects, have had varying success in accounting for some of the findings just described. The race model of Cutler and Norris (1979; see also Norris, McQueen, & Cutler, 2000) is one example of such a model. The model has two routes that race each other -- a pre-lexical route, which computes phonological information from the acoustic signal, and a lexical route, in which the phonological information associated with a word becomes available when the word itself is accessed. When word-level information appears to affect a lower-level process, it is assumed that the lexical route won the race. Importantly, though, knowledge about words never influences perception at the lower (phonemic) level. There is currently much discussion about whether all of the experimental findings suggesting top-down effects can be explained in these terms or whether interactivity is necessary (see Norris et al., 2000, and the associated commentary).

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 patterns facilitates perception in some ways. For example, listeners use *phonotactic* information such as the fact that initial /tl/ is illegal in English to help identify phonemes and word boundaries (Halle, Segui, Frauenfelder, & Meunier, 1998). As another example, listeners use their knowledge that English words are often stressed on the first syllable to help parse the speech signal into words (Norris, McQueen, & Cutler, 1995). These types of knowledge help us solve the segmentation problem in a language that we know, even though we perceive an unknown language as an undifferentiated string.

Printed Word Recognition

Speech is as old as our species and is found in all human civilizations; reading and writing are newer and less widespread. These facts lead us to expect that readers would use the visual representations that are provided by print to recover the phonological and linguistic structure of the message. Supporting this view, readers often access phonology even when they are reading silently and even when reliance on phonology would tend to hurt their performance. In one study, people were asked to quickly decide whether a word belonged to a specified category (Van Orden, 1987). They were more likely to misclassify a homophone like *meet* as a food than to misclassify a control item like *melt* as a food. In other studies, readers were asked to quickly decide whether a printed sentence makes sense. Readers with normal hearing were found to have more trouble with sentences such as *He doesn't like to eat meet* than with sentences such as *He doesn't like to eat melt*. Those who were born deaf, in contrast, did not show a difference between the two sentence types (Treiman & Hirsh-Pasek, 1983).

The English writing system, in addition to representing the sound segments of a word, contains clues to the word's stress pattern and morphological structure. Consistent with the view that print serves as a map of linguistic structure, readers take advantage of these clues as well. For example, skilled readers appear to have learned that a word that has more letters than strictly necessary in its second syllable (e.g., -*ette* rather than -*et*) is likely to be an exception to the generalization that English words are typically stressed on the first syllable. In a *lexical decision task*, where participants must quickly decide whether a letter string is a real word, they perform better with words such as *cassette*, whose stressed second syllable is spelled with -*ette*, than with words such as *palette*, which has final -*ette* but first-syllable stress (Kelly, Morris, &

Verrekia, 1998). Skilled readers also use the clues to morphological structure that are embedded in English orthography. For example, they know that the prefix *re-* can stand before free morphemes such as *print* and *do*, yielding the two-morpheme words *reprint* and *redo*. Encountering *vive* in a lexical decision task, participants may wrongly judge it to be a word because of their familiarity with *revive* (Taft & Forster, 1975).

Although there is good evidence that phonology and other aspects of linguistic structure are retrieved in reading (see Frost, 1998 for a review), there are a number of questions about how linguistic structure is derived from print. One idea, which is embodied in dual-route theories such as that of Coltheart, Rastle, Perry, Langdon, and Ziegler (2001), is that two different processes are available for converting orthographic representations to phonological representations. A lexical route is used to look up the phonological forms of known words in the mental lexicon; this procedure yields correct pronunciations for exception words such as *love*. 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. This latter route gives incorrect pronunciations for exception words, so that these words may be pronounced slowly or erroneously (e.g., *love* said as /lov/) in speeded word naming tasks (e.g., Glushko, 1979). In contrast, connectionist theories claim that a single set of connections from orthography to phonology can account for performance on both regular words and exception words (e.g., Plaut et al., 1996; Seidenberg & McClelland, 1989).

Another question about orthography-to-phonology translation concerns its grain size. English, which has been the subject of much of the research on word recognition, has a rather irregular writing system. For example, *ea* corresponds to /i/ in *bead* but /E/ in *dead*; *c* is /k/ in *cat* but /s/ in *city*. Such irregularities are particularly common for vowels. Quantitative analyses have shown, however, that consideration of the consonant that follows a vowel can often help to specify the vowel's pronunciation (Kessler & Treiman, 2001; Treiman, Mullennix, Bijeljac-Babic, & Richmond-Welty, 1995). The /E/ 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 letter groups that correspond to the syllable *rime* (the vowel nucleus plus an optional consonantal coda) in spelling-to-sound translation (see Bowey, 1990; Treiman et al., 1995, for supporting evidence). In more regular alphabets, such as Dutch, spelling-to-sound translation can be successfully performed at a small grain size and rime-based processing may not be needed (Martensen, Maris, & Dijkstra, 2000).

Researchers have also asked whether a phonological form, once activated, feeds activation back to the orthographic level. If so, a word such as *heap* may be harder to process than otherwise expected because its phonological form, /hip/, would be consistent with the spelling *heep* as well as with the actual *heap*. Some studies have found evidence for feedback of this kind (e.g., Stone, Vanhoy, & Van Orden, 1997), but others have not (e.g., Peereman, Content, & Bonin, 1998).

Because spoken words are spread out in time, as discussed earlier, spoken word recognition is generally considered a sequential process. With many printed words, though, the eye takes in all of the letters during a single fixation (Rayner & Pollatsek, 1989). The connectionist models of reading cited earlier maintain that all phonemes of a word are activated in parallel. Current dual-route theories, in contrast, claim that the assembly process operates in a serial fashion such that the phonological forms of the leftmost elements are delivered before those for the succeeding elements (Coltheart et al., 2001). Still another view (Berent & Perfetti, 1995) is that consonants, whatever their position, are translated into phonological form before vowels. These issues are the subject of current research and debate (see Lee, Rayner, & Pollatsek, 2001; Lukatela & Turvey, 2000; Rastle & Coltheart, 1999; Zorzi, 2000).

Progress in determining how linguistic representations are derived from print will be made as researchers move beyond the short, monosyllabic words that have been the focus of much current research and modeling. In addition, experimental techniques that involve the brief presentation of stimuli and the tracking of eye movements are contributing useful information. These methods supplement the naming tasks and lexical decision tasks that are used in much of the research on single word reading (see Chapter 20 for further discussion of eye movements and reading). Although many questions remain to be answered, it is clear that the visual representations provided by print rapidly make contact with the representations stored in the mental lexicon. Once this contact has been made, it matters little whether the initial input was by eye or by ear. The principles and processing procedures are much the same.

The mental lexicon

So far, in discussing how listeners and readers access information in the mental lexicon, we have not said much about the nature of the information that they access. It is to this topic that we now turn. One question, which relates to the trade-off between computation and storage in language processing, is whether the mental lexicon is organized by morphemes or by words. Under a word-based view, the lexicon contains representations of all words that the language user knows, whether they are single-morpheme words such as *cat* or polymorphemic words such as *beautifully*. Supporting this view, Tyler, Marslen-Wilson, Rentoul, and Hanney (1988) found that spoken word recognition performance was related to when the word began to diverge from other words in the mental lexicon, as predicted by the cohort model, but was not related to morphemic predictors of where recognition should take place. Under a morpheme-based view, in contrast, the lexicon is organized in terms of morphemes such as *beauty*, *ful*, and *ly*. In this view, complex words are processed and represented in terms of such units.

The study by Taft and Forster (1975) brought morphological issues to the attention of many psychologists and pointed to some form of morpheme-based storage. As mentioned earlier, these researchers found that nonwords such as *vive* (which is the stem of *revive*) were difficult to reject in a lexical decision task. Participants also had trouble with items such as *dejuvenate* which, although not a real word, consists of genuine prefix together with a genuine root. Taft and Forster interpreted their results to suggest that access to the mental lexical is based on root morphemes and that obligatory decomposition must precede word recognition for polymorphemic words.

More recent studies suggest that there are in fact two routes to recognition for polymorphemic words, one based on morphological analysis and the other based on whole-word storage. In one instantiation of this dual-route view, morphologically complex words are simultaneously analyzed as whole words and in terms of morphemes. In the model of Wurm (1997, Wurm & Ross, 2001), for instance, the system maintains a representation of which morphemes can combine, and in what ways. A potential word root is checked against a list of free roots that have combined in the past with the prefix in question. In another instantiation of the dual-route view, some morphologically complex words are decomposed and others are not. For example, Marslen-Wilson, Tyler, Waksler, and Older (1994) argued that semantically opaque words such as *organize* and *casualty* are treated by listeners and readers as monomorphemic and are not decomposed no matter how many morphemes they technically contain. Commonly encountered words may also be treated as wholes rather than in terms of morphemes (Caramazza et al., 1988; Schreuder & Baayen, 1995). Although morphological decomposition may not always take place, the evidence we have reviewed suggests that the lexicon is organized, in part, in terms of morphemes. This organization helps explain our ability to make some sense of *slithy* and *toves*.

Ambiguous words, or those with more than one meaning, might be expected to cause difficulties in lexical processing. Researchers have been interested in ambiguity because studies of this issue may provide insight into whether processing at the lexical level is influenced by information at higher levels or whether it is modular. In the former case, comprehenders would be expected to access only the contextually appropriate meaning of a word. In the latter case, all meanings should be retrieved and context should have its effects only after the initial processing has taken place. The original version of the cohort model (Marslen-Wilson & Welsh, 1978) adopts an interactive view when it states that context acts directly on cohort membership. However, later versions of cohort theory (Marslen-Wilson, 1987; 1990; Moss & Marslen-Wilson, 1993) hold that context has its effects at a later, integrative stage.

Initially, it appears, both meanings of an ambiguous morpheme are looked up in many cases. This may even occur when the preceding context would seem to favor one meaning over the other. In one representative study (Gernsbacher & Faust, 1991), participants read sentences such as *Jack tried the punch but he didn't think it tasted very good*. After the word *punch* had been presented, an upper-case letter string was presented and participants were asked to decide whether or not it was a real word. Of interest were lexical decision targets such as *HIT*, which are related to an unintended meaning of the ambiguous word, and *DRINK*, which are related to the intended meaning. When the target was presented immediately after the participant had read *punch*, performance was speeded on both *HIT* and *DRINK*. This result suggests that even the contextually inappropriate meaning of the ambiguous morpheme was activated. The initial lack of contextual effects in this and other studies (e.g., Swinney, 1979) supports the idea that lexical access is a modular process, uninfluenced by higher-level syntactic and semantic constraints.

Importantly, Gernsbacher and Faust (1991) found a different pattern of results when the lexical decision task was delayed by a half second or so but still preceded the following word of the sentence. In this case, *DRINK* remained active but *HIT* did not. Gernsbacher and Faust interpreted these results to mean that comprehenders initially access all meanings of an ambiguous word but then actively suppress the meaning (or meanings) that does not fit the context. This suppression process, they contend, is more efficient in better comprehenders than in poorer comprehenders. Because the inappropriate meaning is quickly suppressed, the reader or listener is typically not aware of the ambiguity.

Although all meanings of an ambiguous word may be accessed initially in many cases, this may not always be so (see Simpson, 1994). For example, when one meaning of an ambiguous word is much more frequent than the other or when the context very strongly favors one meaning, the other meaning may show little or no activation. It has thus been difficult to provide a clear answer to the question of whether lexical access is modular.

The preceding discussion considered words that have two or more unrelated meanings. More common are *polysemous* words, which have several senses that are related to one another.

For example, *paper* can refer to a substance made of wood pulp or to an article that is typically written on that substance but that, nowadays, may be written and published electronically. Processing a polysemous word in one of its senses can make it harder to subsequently comprehend the word in another of its senses (Klein & Murphy, 2001). That one sense can be activated and the other suppressed suggests to these researchers that at least some senses have separate representations, just as the different meanings of a morpheme like *punch* have separate representations.

Problems with ambiguity are potentially greater in bilinguals than in monolinguals. For example, *leek* has a single sense for a monolingual speaker of English, but it has another meaning, *layperson*, for one who also knows Dutch. When asked to decide whether printed words are English or not, and when the experimental items included some exclusively Dutch words, Dutch-English bilinguals were found to have more difficulty with words such as *leek* than with appropriate control words such as *zuivel* (*dairy*) (Dijkstra, Timmermans, & Schriefers, 2000). Such results suggest that the Dutch lexicon is activated along with the English one in this situation. Although optimal performance could be achieved by deactivating the irrelevant language, bilinguals are sometimes unable to do this. Further evidence for this view comes from a study in which Russian-English bilinguals were asked, in Russian, to pick up objects such as a *marku* (a stamp) (Spivey & Marian, 1999). When a marker was also present -- an object whose English name is similar to *marku* -- people sometimes looked at it before looking at the stamp and carrying out the instruction. Although English was not used during the experimental session, the bilinguals appeared unable to ignore the irrelevant lexicon.

Information about the meanings of words and about the concepts that they represent is also linked to lexical representations. Chapter 22 includes a discussion of conceptual representation.

Comprehension of sentences and discourse

Important as word recognition is, understanding language requires far more than adding the meanings of the individual words together. We must combine the meanings in ways that honor the grammar of the language and that are sensitive to the possibility that language is being used in a metaphoric or nonliteral manner (see Cacciari & Glucksberg, 1994). Psycholinguists have addressed the phenomena of sentence comprehension in different ways. Some theorists have focused on the fact that the sentence comprehension system continually creates novel representations of novel messages, following the constraints of a language's grammar, and does so with remarkable speed. Others have emphasized that the comprehension system is sensitive to a vast range of information, including grammatical, lexical, and contextual, as well as knowledge of the speaker/writer and of the world in general. Theorists in the former group (e.g., Ford, Bresnan, & Kaplan, 1982; Frazier & Rayner, 1982; Pritchett, 1992) have constructed modular, serial models that describe how the processor quickly constructs one or more representations of a sentence based on a restricted range of information that is guaranteed to be relevant to its interpretation, primarily grammatical information. Any such 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 models, often of a connectionist nature, describing how the processor uses all relevant information to quickly evaluate the full range of possible interpretations of a sentence (see 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 & Ferreira, 1998, for a beginning on the latter question). Parallel models, for the most part, do not adequately deal with how the processor constructs or activates the various interpretations whose competitive evaluation they describe (see Frazier, 1995). However, both approaches have motivated bodies of research that have advanced our knowledge of language comprehension, and new models are being developed that have the promise of overcoming the limitations of the models that have guided research in the past (Gibson, 1998; Jurafsky, 1996; Vosse & Kempen, 2000).

Phenomena common to reading and listening comprehension. Comprehension of written and spoken language can be difficult, in part, because it is not always easy to identify the *constituents* (phrases) of a sentence and the ways in which 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, like studies of how they resolve lexical ambiguities, have provided insights into the processes of language comprehension. Consider the sentence *The second wife will claim the inheritance belongs to her*. When *the inheritance* first appears, 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. They interpreted this result to mean that readers first interpreted *the inheritance* as a direct object. Readers were disrupted when they had to revise this initial interpretation to the one in which *the inheritance* is subject of *belongs*. Following Bever (1970), 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 defined “structurally simpler,” and they claimed that structural simplicity guides all initial analyses. In this view, the sentence processor constructs a single analysis of a sentence and attempts to interpret it. The first analysis is the one that requires the fewest applications of grammatical rules to attach each incoming word into the structure being built; it is the automatic consequence of an effort to get some analysis constructed as soon as possible. Many researchers have tested and confirmed the minimal attachment principle for a variety of sentence types (see Frazier & Clifton, 1996, for a review).

Minimal attachment is not the only principle that has been proposed as governing how readers and listeners use grammatical knowledge in parsing. Another principle that has received substantial support is *late closure* (Frazier, 1987a). Frazier and Rayner (1982) provided some early support for this principle by showing disruption on the phrase *seems like* in *Since Jay always jogs a mile seems like a very short distance to him*. Here, *a mile* is first taken to be the direct object of *jogs* because the processor tries to relate it to the phrase currently being processed. Reading is disrupted when *a mile* must be reanalyzed as the subject of *seems*.

Another 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 lexically specified; an adjunct is related to what it modifies in a less specific fashion (see Schütze & Gibson, 1999). With the 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 preferred in the end (Clifton, Speer, & Abney, 1991; Konieczny et al., 1997; Schütze & Gibson, 1999). However, some evidence suggests a brief initial preference for the minimal attachment analysis (Clifton et al., 1991).

Long-distance dependencies, like ambiguities, can cause problems in the parsing of language. Language gains much of its expressive power from its recursive properties: Sentences can be placed inside sentences, without limit. This means that related phrases can be distant from one another. 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 the sentence processor discovers the relation between the moved element (or *filler*) and the trace (or *gap*). One possibility, J.D. Fodor (1978) suggested, is that the processor might delay filler-gap assignment as long as possible. However, there is evidence that the processor actually identifies the gap as soon as possible, an *active filler* strategy (Frazier, 1987b).

The active filler strategy is closely related to minimal attachment, for both strategies attempt to find some grammatical analysis of a sentence as soon as possible (see De Vincenzi, 1991). But the active filler strategy may not be the whole story. Pickering and Barry (1991) and Boland, Tanenhaus, Garnsey, and Carlson (1995) proposed what the latter called a *direct assignment strategy*, according to which a filler is semantically interpreted as soon as a reader or listener encounters the verb to which it is related, without waiting for the gap position. Evidence for this strategy comes from a study in which Boland et al. presented sentences word by word, asking readers to indicate when and if a sentence became unacceptable. An implausible sentence like *Which public library did John contribute some cheap liquor to t last week* tended to be rejected right on the word *liquor*, before the position of the gap.

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 particular structural configurations and toward specifying lexical information that constrains possible grammatical relations, many psycholinguists have proposed that the human sentence processor is primarily guided by information about specific words that is stored in the lexicon. The research on comprehenders' preference for arguments discussed earlier is one example of this move[i].

Spivey-Knowlton and Sedivy (1995) demonstrated effects of particular categories of lexical items, as well as effects of discourse structure, in the comprehension of sentences like *The salesman glanced at a/the customer with suspicion/ripped jeans*. The prepositional phrases *with suspicion* or *with ripped jeans* could modify either the verb *glance* or the noun *customer*. Minimal attachment favors the former analysis, but Spivey-Knowlton and Sedivy showed that this held true only for action verbs like *smash down*, not for perception verbs like *glance at*. The researchers further noted that an actual preference for noun phrase modification only appeared when the noun had the indefinite article *a.* This outcome, they suggested, points to the importance of discourse factors (such as whether an entity is newly referred to or not) in sentence comprehension.

Some theorists (e.g., Altmann & Steedman, 1988) have proposed that contextual appropriateness guides parsing and indeed is responsible for the effects that have previously been attributed to structural factors such as minimal attachment. The basic claim of their *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,* treatment of *with the dynamite* as modifying *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 examined how long readers took on sentences like *The burglar blew open the safe with the dynamite/new lock and made off with the loot* in contexts that had introduced either one safe or two safes, one with 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.

Many studies have examined effects like the one just described (see Mitchell, 1994, for a summary). It is clear that the use of a definite noun phrase when the discourse context contains two possible referents disrupts reading. This result shows once again that interpretation is nearly immediate and that reading is disrupted when unambiguous interpretation is blocked. A context that provides two referents can eliminate the disruption observed out of context when a phrase must modify a noun, at least when the out-of-context structural preference is weak (Britt, 1994). When the out-of-context bias is strong (as in the case of reduced relative clauses, like Bever's [1970] *The horse raced past the barn fell),* a context that satisfies the presumed referential presuppositions of a modifier reduces the amount of disruption rather than eliminating it.

Given the wide variety of factors that seem to affect sentence comprehension, some psycholinguists have developed lexicalist, constraint-based theories of sentence processing (e.g., MacDonald et al., 1994; Tanenhaus & Trueswell, 1995). These theories, which are described and sometimes implemented in connectionist terms, assume that multiple possible interpretations of a sentence are available to the processor. Each possible interpretation receives activation (or inhibition) from some knowledge sources, as well as (generally) 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).

But the constraint-based theories also predict that these factors will create garden paths when the sentence is resolved in favor of its normally-preferred analysis. This may not always be the case (Binder, Duffy, & Rayner, 2001).

Competitive constraint-based theories, like other connectionist theories, grant a major role to frequency. Frequent constructions should be more readily activated by appropriate sources of information than less common constructions are. Supporting this view, readers understand sentences like *The award accepted by the man was very impressive* more readily when the first verb is frequently used as a passive participle, as *accept* is, than when the verb is not frequently used as a passive particle, as with *entertain* (Trueswell, 1996). Also, reduced relative clause sentences, such as *The rancher could see that the nervous cattle pushed/moved into the crowded pen were afraid of the cowboys*, are read more rapidly when the verb of the complement sentence is more often used as a transitive verb (*push*) than when it is more often used as an intransitive verb (*move*) (MacDonald, 1994). The frequency of particular constructions may not always predict comprehension preferences and comprehension difficulty (Gibson, Schütze, & Salomon, 1996; Kennison, 2001; Pickering, Traxler, & Crocker, 2000). However, theorists such as Jurafsky (1996) have made a strong case that the frequency of exposure to certain constructions is a major factor guiding sentence comprehension.

Competitive constraint-based theories have also emphasized discourse and situational context as constraints on sentence comprehension. Researchers have taken advantage of the fact that listeners quickly direct their eyes to the referents of what they hear, as shown by the Allopenna et al. (1998) study mentioned in the earlier discussion of spoken word recognition, to study how comprehension is guided by situational context. Spivey, Tanenhaus, Eberhard and

Sedivy (2001) found that, when a listener hears a command like *Put the cup on the napkin under the book*, the eyes move quickly to an empty napkin when the context contains 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 contains two cups, only one on a napkin, the eyes do 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 explores how quickly knowledge of the roles objects typically play in events is used 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 target when the verb in the sentence was commonly used with the target item. 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*.

The research just described shows how quickly listeners 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 nonlinguistic representation 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 also 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 Chapter 21), who has proposed a series of 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 makes contact with 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). 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 details, including 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 a reader of a narrative text attempts 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 re-listen 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 Chapter 15), and so language that is heard may in fact persist for longer than language that is read, 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 Warren, 1999). 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. If readers translate visually presented sentences into a phonological form, complete with prosody, these benefits may extend to reading (Bader, 1998; Slowiaczek & Clifton, 1980).

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). Recent evidence for this conclusion comes from a study by Kjelgaard and Speer (1999) that examined ambiguities like *When Madonna sings the song it's/is a hit*. Readers, as mentioned earlier, initially take the phrase *the song* as the direct object of *sings*. This results in a garden path when the sentence continues with *is*, forcing readers to reinterpret the role of *the song*. Kjelgaard and Speer found that such difficulties were eliminated when these kinds of sentences were supplied with appropriate prosodies. The relevant prosodic property does not seem to be simply 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 relation to certain other boundaries (Carlson, Clifton & Frazier, 2001), even the global prosodic representation of a sentence.

<u>Phenomena specific to the comprehension of written language</u>. Written language carries some information that is not available in the auditory signal. For example, word boundaries are explicitly indicated in many languages, and readers seldom have to suffer the kinds of degradation in signal quality that are commonly experienced by listeners in noisy environments. However, writing lacks the full range of grammatically-relevant prosodic information that is available in speech. Punctuation has value in that it 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).

LANGUAGE PRODUCTION

As we have discussed, comprehenders must map the spoken or written input onto entries in the mental lexicon and must generate various levels of syntactic, semantic, and conceptual structure. In language production, people are faced with the converse problem. They must map 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 longer utterances. Our discussion will concentrate on spoken language production, which has been the focus of most of the research on language production. We will then consider how the representations and processes involved in writing differ from those involved in speaking.

Access to single words in spoken language production

To give an overview of how speakers generate single words, we first summarize the model of lexical access proposed by Levelt, Roelofs, and Meyer (1999; see Roelofs, 1997, for a computational model implementing key parts of the theory). Like most other models of word production, this model claims that words are planned in several processing steps. Each step generates a specific type of representation, and information is transmitted between representations via the spreading of activation. The first processing step, called conceptualization, is deciding what notion to express. For instance, a speaker can say "the baby," "Emilio," "Her Majesty's grandson," or simply "he" to refer to a small person in a highchair. In making such a choice, the speaker considers a variety of things, including whether the person has been mentioned before and whether the listener is likely know his proper name (see Clark, 1996; Levelt, 1989, for discussions of conceptualization and the role of social factors therein).

The next step is to select a word that corresponds to the chosen concept. In the view of Levelt et al. (1999), the speaker first selects a *lemma*, or syntactic word unit. Lemmas specify the syntactic class of the word and often additional syntactic information, such as whether a verb is intransitive (e.g., *sleep*) or transitive (e.g., *eat*) and, if transitive, what arguments it takes.

Deleted: Verb

Lemma selection is a competitive process. Several lemmas may be activated at once because several concepts are more or less suitable to express the message, and because lemmas that correspond to semantically similar concepts activate each other via links to shared superordinate concepts or conceptual features. 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.

The following processing step, morpho-phonological encoding, begins with the retrieval of the morphemes corresponding to the selected lemma. For the lemma *baby* there is only one morpheme to retrieve, but for *grandson* or *walked* two morphemes must be retrieved. Evidence that speakers access morphological information comes from a variety of sources. For instance, people sometimes make speech errors such as "imagine getting your model renosed", where stems exchange while affixes remain in place (Fromkin, 1971). Other evidence shows that morphologically related primes have different effects on the production of target words than do semantically or phonologically related primes (e.g., Roelofs, 1996; Zwitserlood, Boelte, & Dohmes, 2000). Priming experiments have also shown that morphemes are accessed in sequence, according to their order in the utterance (e.g., Roelofs, 1996).

In the model by Levelt et al. (1999), the next processing step is the generation of the phonological form of the word. Word forms are not simply retrieved as units, but are first decomposed into individual segments (or perhaps segments and certain groups of segments, such as /st/), which are subsequently mapped onto prosodic patterns. The most convincing evidence for phonological decomposition stems from studies of speech errors (e.g., Fromkin, 1971). Speakers sometimes make errors in which they replace or misorder single phonemes, as in “perry pie” instead of “cherry pie.” These errors show that the words’ segments constitute processing units; if word forms were retrieved as units, such errors could not occur. Thus, for the word “baby,” the segments /b/, /e/, /b/, /i/ are retrieved. In the model of Levelt et al., the string of segments is subsequently syllabified following the syllabification rules of the language and is assigned stress. Many words are stressed according to simple default rules: For example, bisyllabic English words are usually stressed on the first syllable. For words that deviate from these rules, stress information is stored in the lexicon. During phonological encoding, the segmental and stress information are combined. Results from a large number of experiments using various types of priming and interference paradigms suggest that all phonemes of a word may be activated at the same time, but that the formation of syllables is a sequential process, proceeding from the beginning of the word to the end (e.g., Meyer, 1991; Meyer & Schriefers, 1991; O’Seaghdha & Marin, 2000).

The phonological representation of a word is abstract in that it consists of discrete, non-overlapping segments, which define static positions of the vocal tract or states of the acoustic signal to be attained, and in that the definitions of the segments are independent of the contexts in which they appear. However, actual speech movements overlap in time, and they are continuous and context-dependent. The final planning step for a word is the generation of a phonetic representation, which specifies the articulatory gestures to be carried out and their timing. There may be syllable-sized routines for frequent syllables that can be retrieved as units and unpacked during articulation (e.g., Levelt & Wheeldon, 1994). Chapter 9 discusses the generation and execution of articulatory commands.

All current models of word production distinguish among conceptual processes, word retrieval processes, and articulatory processes. The models differ in the types of representations they postulate at each level and in their assumptions about processing. One important representational issue is whether it is useful to assume lemmas as purely syntactic units and to postulate separate units representing word forms, or whether there are lexical units that encompass both syntactic and word-form information. Relevant evidence comes from experiments that use reaction times and measures of brain activity to trace how syntactic and form information is retrieved across time (e.g., van Turennout, Hagoort, & Brown, 1998). Also relevant are analyses of *tip-of-the-tongue states*, in which speakers can only retrieve part of the information pertaining to a word, for instance its grammatical gender but not its form (e.g., Vigliocco, Antonini, & Garrett, 1997). How these findings should be interpreted is still a matter of debate (see Caramazza & Miozzo, 1997; Roelofs, Meyer, & Levelt, 1998). Representational issues also arise at the phonological level. In the model of Levelt et al. (1999), segments are associated to unitary syllable nodes without internal structure. In other models, syllables are frames with slots corresponding to subsyllabic units (onset and rime, or onset, nucleus, and coda; see Dell, 1986) or consonantal and vocalic positions (Dell, 1988; O'Seaghdha & Marin, 2000).

Comment:

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Models of language production also differ in the emphasis that they place on storage versus computation. Levelt et al. (1999) emphasize computation. In their view, stress is computed rather than stored when possible. Also, even common forms like *walked* are derived by the combination of stems and affixes. Other models assume that some information that could in principle be computed is stored in the lexicon. For example, stress may be stored for all entries, and forms such as *walked* may be retrieved as wholes (e.g., Stemberger & MacWhinney, 1986).

In all models of language production, the main direction of processing is from the conceptual level to articulation. Some production models, like some comprehension models, assume serial processing stages such that processing at one level must finish before processing at the next level can begin. Other models assume *cascaded* processing, which implies that each activated unit immediately spreads activation to its subordinate units (e.g., Humphreys, Price, & Riddoch, 2000; MacKay, 1987). Some cascading models permit feedback from lower to higher levels of processing (e.g., Dell, 1986, 1988; Dell, Schwartz, Martin, Saffran, & Gagnon, 1997). In serial stage models, in which higher-level processing is completed before lower-level processing begins, lower-level information cannot affect higher-level processing.

In the model of Levelt et al. (1999), there is feedback between the conceptual and lemma levels. Because these levels are shared between production and comprehension, information would be expected to flow in both directions. Processing at the lemma and word-form levels is strictly sequential. Thus, in this model, word-form retrieval only begins after a lemma has been selected. In cascaded models, by contrast, each lemma that receives some activation from the conceptual level spreads some of its activation to the corresponding word form, so that several word forms may be active at once. In priming experiments, Levelt, Schriefers, Vorberg, Meyer, Pechman, and Havinga (1991) found no evidence for simultaneous activation of the forms of competing lemmas. However, Peterson and Savoy (1998) showed that near homophones such as “couch” and “sofa” may simultaneously activate their forms. Levelt et al. proposed that in such cases, speakers may have failed to unambiguously select one lemma. An important argument for feedback from lower to higher levels of processing is that speech errors in which the target and outcome are related in both form and meaning (as in “cat” for “rat”) occur far more often than would be expected if lemma and word form were selected independently (e.g., Dell, 1986, 1988). To account for this finding within a serial stage model, Levelt et al. proposed that people are particularly likely to overlook such errors when they monitor their speech.

Generation of sentences in spoken language production

We will now consider how speakers generate longer utterances, such as descriptions of scenes or events. The first step is again conceptual preparation – deciding what to say. Evidently, conceptual preparation is more complex for longer than for shorter utterances. To make a complicated theoretical argument or to describe a series of events, the speaker needs a global plan (see Levelt, 1989). Each part of the global plan must be further elaborated, perhaps via intermediate stages, until a representational level is reached that consists of lexical concepts. This representation, the message, forms the input to linguistic planning. Utterances comprising several sentences are rarely laid out entirely before linguistic planning begins. Instead, all current theories of sentence generation assume that speakers prepare utterances incrementally. That is, they initiate linguistic planning as soon as they have selected the first few lexical concepts and prepare the rest later, either while they are speaking or between parts of the utterance. Speakers can probably choose conceptual planning units of various sizes, but the typical unit for many situations appears to correspond roughly to a clause (Bock & Cutting, 1992).

When speakers plan sentences, they retrieve words as described earlier. However, because sentences are not simply sets of words but have syntactic structure, speakers must apply syntactic knowledge to generate sentences. Following Garrett (1975), models of sentence production generally assume that two distinct sets of processes are involved in generating syntactic structure (Bock & Levelt, 1994; Levelt, 1989). The first set, often called functional planning processes, assigns grammatical functions, such as subject, verb, or direct object, to lemmas. These processes rely primarily on information from the message level and the syntactic properties of the retrieved lemmas. The second set of processes, often called positional encoding, uses the retrieved lemmas and the functions they have been assigned to generate syntactic structures that capture the dependencies among constituents and their order. In English, the mapping from the functional to the positional level is usually quite straightforward: The subject usually precedes the verb, and the direct object and indirect object follow it. However, inversions can occur, as in “I don’t mind bikes; cars I hate.”

Evidence for the distinction between functional and positional processes comes from the finding that some speech errors (e.g., exchanges of words from different phrases, as in “put the tables on the plate”) can best be explained as errors of functional encoding. Other errors with different properties (e.g., shifts of morphemes within phrases, as in “the come homing of the queen”) can best be explained as errors of positional encoding. The distinction is further supported by the results of structural priming studies. In such studies, people first hear or say a sentence such as “The woman shows the man the dress.” They later see a picture that can be described using the same kind of structure (e.g., “The boy gives the teacher the flowers”) or a different one (“The boy gives the flowers to the teacher”). Speakers tend to repeat the structure used on previous trials, even when the words featured in prime and target sentences are different and even when the events are unrelated. The results of many such studies strongly suggest that the priming effect arises during the positional encoding processes (Bock, 1986; Bock & Loebell, 1990; Chang, Dell, Bock, & Griffin, 2000).

As we have noted, grammatical encoding begins with the assignment of lemmas to grammatical functions. This mapping process is largely determined by conceptual information. In studies of functional encoding, speakers are often asked to describe pictures of scenes or events or to recall sentences from memory; the recall task involves the reconstruction of the surface structure of the utterance on the basis of stored conceptual information. Many such studies have focused on the question of which part of the conceptual structure will be assigned the role of grammatical subject (e.g., McDonald, Bock, & Kelly, 1993). The results show that function assignment is strongly affected by the relative availability or salience of concepts. If a concept is very salient, for instance because it has recently been referred to or because it is the only concrete or animate entity to be mentioned, it is likely to become the sentence subject. As soon as the subject role has been filled, the positional processes can generate the corresponding fragment of the phrase structure and the retrieval of the phonological form of the subject noun phrase can begin.

Events or actions are often encoded in a verb. As noted earlier, verb lemmas specify the arguments that the verbs require. Pickering and Branigan (1998) proposed to represent this information in nodes, which receive activation from verb lemmas. For instance, the lemma for *give* is connected to two syntactic nodes, one representing the NP,NP node and the other the NP,PP node. Selection of the NP,NP node results in a double object construction such as "the baby gives the dog a cookie." Selection of the NP,PP node yields a prepositional phrase structure, as in "the baby gives a cookie to the dog."

Many verbs, such as *give*, license more than one syntactic structure. Speeded sentence production experiments carried out by Ferreira (1996) show that the alternative syntactic structures associated with verb lemmas do not compete with each other but instead represent different options for generating sentences. This explains why, under certain conditions, speakers are faster to complete sentences with alternator verbs (e.g., *to give*) than sentences with non-alternator verbs (e.g., *to donate*). Ferreira proposed that a speaker's choice among the structures permitted by an alternator verb depends, in part, on the salience of the lemmas assigned to the patient and recipient roles. If the patient is very salient, the corresponding fragment of the sentence will be built early. This encourages the generation of an NP-NP construction in which the patient is expressed early ("give the dog a cookie"). If the direct object is highly activated, an NP-PP construction will be more likely ("give the cookie to the dog"). Ferreira and Dell (2000) proposed that, in general, the choice of syntactic structure may depend largely on the availability of lemmas filling different thematic roles. If a lemma is highly available, it will be processed early at the functional and positional levels and will thus appear early in the sentence. Whether lemma availability by itself is sufficient to explain how speakers choose between alternative word orders remains to be determined.

Certain elements within well-formed sentences must agree with one another. In English, subject and verb must agree in number, as must pronouns and their noun antecedents. In languages such as German, Dutch, Italian, and French, nouns have grammatical gender, and there is gender agreement between nouns and determiners, adjectives, and pronouns. Number and grammatical gender agreement differ in that number information usually stems from the conceptual level, whereas grammatical gender is specified as part of the noun lemma. Consequently, different mechanisms are likely to be involved in generating the two types of agreement. We briefly consider each type of agreement, beginning with English number agreement.

In most cases, the mapping from conceptual number onto the lemma level is straightforward: The singular form of a noun is chosen to refer to one entity, and the plural form to refer to two or more entities. Because number is coded at both the conceptual and grammatical levels, speakers could use either or both types of information to generate agreement. What information do speakers actually use? According to a strictly modular theory of language production, the grammatical coding process should be sensitive only to grammatical information. A more interactive theory would permit grammatical encoding processes to be affected by both grammatical and conceptual information. To examine this issue, researchers have studied agreement for *collective* nouns such as *fleet* and *gang*, which are exceptions to the straightforward mapping between conceptual and grammatical number. For example, *fleet* is grammatically singular but refers to a group of ships. The studies have often used sentence completion tasks, in which speakers hear the beginnings of sentences (e.g., “The condition of the ship/ships/fleet/fleets…”; Bock & Eberhard, 1993), repeat the fragments, and then complete them to form full sentences. When the two nouns in the fragment differ in number, speakers sometimes make agreement errors (“The condition of the ships WERE poor”).

Most studies using sentence completion tasks like those described above have found that speakers rely primarily on grammatical information to generate subject-verb agreement. For instance, agreement errors appear to be no more likely for “the condition of the fleet” than for “the condition of the ship,” but such errors are more common for “the condition of the ships” (Bock & Eberhard, 1993; Bock & Miller, 1991; but see Vigliocco, Butterworth, & Garrett, 1996). In contrast, studies of noun-pronoun agreement in American English have shown that this type of agreement is primarily based on conceptual number information (Bock, 1995; Bock, Nicol, & Cutting, 1999). Thus, speakers are likely to say, “The gang with the dangerous rival armed themselves,” using the plural pronoun “themselves” to refer to a collective (Bock et al., 1999).

Whereas number information usually originates at the conceptual level, grammatical gender is lexical information and gender agreement can therefore be achieved only by consulting grammatical information. For determiner-noun agreement (as in Dutch “het huis” (the house, neuter gender) and “de kerk” (the church, non-neuter gender)), most theories invoke a mechanism of indirect selection. In the model proposed by Jescheniak and Levelt (1994) for Dutch, each noun lemma is connected to one of two gender nodes (neuter or non-neuter). Each gender node is connected to the lemma for the determiner that is appropriate for that gender. Activation flows from a selected noun lemma to the gender node and from there to the determiner lemma, which can then be selected as well (see Miozzo & Caramazza, 1999, for a model for Italian, where determiner-noun agreement is more complex).

Determiners are special in that their choice is governed exclusively by the grammatical gender of the noun. Other forms of agreement involve independently selected words. For instance, the lemmas of adjectives are selected on the basis of conceptual information and are then, in some languages, marked depending on the grammatical gender of the noun to which they refer. In French and Italian, agreement errors between adjectives and nouns (such as the French “la sortie (f) du tunnel (m) glissant (m)” instead of “la sortie (f) du tunnel (m) glissante (f); the way out of the slippery tunnel) are less likely for animate subjects, which have natural gender in addition to grammatical gender, than for inanimate subjects, which have grammatical gender alone (Vigliocco & Franck, 1999). Such results suggest that agreement processes, although primarily guided by syntactic information, can get support from the conceptual level if gender is marked there as well.

When the positional representation for an utterance fragment has been generated, the corresponding phonological form can be built. For each word, phonological segments and, where necessary, information about the word’s stress pattern are retrieved from the mental lexicon as described earlier. But the phonological form of a phrase is not just a concatenation of the forms of words as pronounced in isolation. Instead, the stored word forms are combined into new prosodic units (Nespor & Vogel, 1986). We have already discussed the syllable, a small prosodic unit. The next larger unit is the *phonological word*. Phonological words often correspond to lexical words. However, a morphologically complex word may comprise several phonological words, and unstressed items such as conjunctions and pronouns combine with preceding or following content words into single phonological words. Phonological words are the domain of syllabification. Thus, when a speaker says “find it,” two morphemes are retrieved, and these are combined to form one phonological word. In line with the tendency for the onsets of English syllables to contain as much material as possible, /d/ is assigned to the second syllable, yielding [fain] [dlt]. Thus syllables can, and often do, straddle the boundaries of lexical words.

The next level in the prosodic hierarchy is the *phonological phrase*. Phonological phrases often correspond to syntactic phrases, but long syntactic phrases may be divided into several phonological phrases. Like the phonological word, the phonological phrase is a domain of application for certain phonological rules. These include the rule of English that changes the stress patterns of words to generate an alternating pattern (as in the typical pronunciation of the phrase *Chinese menu*) and the rule that lengthens the final syllable of the phrase. Finally, phonological phrases combine into intonational phrases, which were mentioned in the discussion of spoken language comprehension. [ii]

Earlier, we discussed the decomposition of morphemes into segments. This may have appeared to be a vacuous process. Why should morphemes first be decomposed into segments that are later reassembled into syllables? The likely answer is that the same morpheme can be pronounced in different ways depending on the context. For instance, *hand* may lose its final consonant in “put your hand down” and may gain a final /m/ in “handbag.” *Hand* corresponds to a syllable in “I hand you the book” but not in “I am handing you the book.” There are phonological rules governing how words are pronounced in different environments. For these rules to apply, the individual segments must be available to the processor. In connected speech, the decomposition of morphemes and the re-assembly into phonological forms is not a vacuous process but yields phonological forms that differ from those stored in the mental lexicon.

Written language production

Many of the steps in the production of written language are similar to those in the production of spoken language. A major difference is that, once a lemma and its morphological representation have been accessed, it is the orthographic rather than the phonological form that must be retrieved and produced. Phonology plays an important role in this process, just as it does in the process of deriving meaning from print in reading. Support for this view comes from a study in which speakers of French were shown drawings of such objects as a seal (*phoque*) and a pipe (*pipe*) and were asked to write their names as quickly as they could (Bonin, Peereman, & Fayol, in press). The time needed to initiate writing was longer for items such as *phoque*, for which the initial phoneme has an unusual spelling (/f/ is usually spelled as *f* in French), than for items such as *pipe*, for which the initial phoneme is spelled in the typical manner. Thus, even when a to-be-spelled word is not presented orally, its phonological form appears to be involved in the selection of the spelling.

A number of the same issues that were raised earlier about the derivation of phonology from orthography in reading arise with respect to the derivation of orthography from phonology in spelling. For instance, issues about grain size apply to spelling as well as to reading. Kessler and Treiman (2001) have shown that the spelling of an English segment becomes more predictable when neighboring segments are taken into account. The largest effects involve the vowel nucleus and the coda, suggesting that rimes have a special role in English spelling. Feedback between production and comprehension is another issue that arises in spelling as well as in reading: We may read a spelling back to check whether it is correct.

Writing differs from speaking in that writers often have more time available for conceptual preparation and planning. They may have more need to do so as well, as the intended reader of a written text is often distant in time and space from the writer. Monitoring and revising, too, typically play a greater role in writing than in speaking. For these reasons, much of the research on writing (see Kellogg, 1994; Levy & Ransdell, 1996) has concentrated on the preparation and revision processes rather than on the sentence generation and lexical access processes that have been the focus of spoken language production research.

CONCLUSIONS

We have talked about language comprehension and language production in separate sections of this chapter, but the two processes are carried out in the same head using, presumably, many of the same representations and processes. In some cases, there have been strong claims that each of these two aspects of language relies heavily on the other. For example, some theories of speech perception (Liberman & Mattingly, 1985) maintain that listeners perceive speech sounds by making unconscious reference to the articulatory gestures of the speaker in a process referred to as *analysis by synthesis*. As another example, speech production researchers have described how speakers can listen to their own speech and correct themselves when necessary, and how speakers can even monitor an internal version of their speech and interrupt themselves before an anticipated error occurs (see Levelt, 1983; Postma, 2000).

Although researchers have described how comprehension and production may interact in particular tasks, the two areas of research have not always been closely connected. One reason for this separation is that, traditionally, different methods have been used to study comprehension and production. Language comprehension researchers have often measured how long it takes people to carry out tasks such as word naming, lexical decision, or reading for comprehension. These experimental paradigms are designed to tap the time course of processing. Language production research has traditionally focused on product rather than process, as in analyses of speech errors. However, researchers in the area of language production are increasingly using reaction time paradigms (e.g., the structural priming technique mentioned earlier) to yield more direct evidence about the time course of processing. Stronger connections between the two areas are expected to develop with the increasing similarity in the research tools and the increasing interest in time-course issues in the production arena.

Another reason that production research and comprehension research have been somewhat separate from one another is that researchers in the two areas have sometimes focused on different topics and talked about them in different ways. For example, the concept of a lemma or syntactic word unit plays a central role in some theories of language production, with theorists such as Levelt et al. (1999) assuming that lemmas are shared between production and comprehension. However, most researchers in the area of comprehension have not explicitly used the concept of a lemma in discussing the structure of the mental lexicon and have not considered which of the representations inferred through comprehension experiments might also play a role in production. An important direction for the future will be to increase the links between theories of comprehension and production.

Despite these gaps, it is clear that both comprehension and production are strongly driven by the mental lexicon. When listeners hear utterances, they rapidly map the speech stream onto entries in the lexicon. As each word is identified, semantic and syntactic information becomes available. This information is immediately used to begin constructing the syntactic structure and meaning of the utterance. Similarly, when speakers generate utterances, they select words from the lexicon. Each word brings with it syntactic and morphological properties, and these properties are taken into account when additional words are chosen. A theory based on analysis by synthesis is probably not appropriate for syntactic comprehension, but there may be strong similarities between the routines involved in parsing and those involved in grammatical encoding in language production (Vosse & Kempen, 2000). Given the importance of the lexicon in all aspects of language processing, the nature and organization of the stored information and the processes that are involved in accessing this information are likely to continue as major topics of research.

In addition to developing closer ties between comprehension and production, it will be important to build bridges between studies of the processing of isolated words and studies of sentences and texts. For example, theories of word recognition have focused on how readers and listeners access phonological and, to a lesser extent, 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. [iii]

Many of the theoretical debates within the field of psycholinguistics apply to both comprehension and production and to both spoken language and written language. For example, issues about the balance between computation and storage arise in all of these domains. Clearly, a good deal of information must be stored in the mental lexicon, including the forms of irregular verbs such as *went*. Are forms that could in principle be derived by rule (e.g., *walke*d) computed each time they are heard or said, are they stored as ready-made units, or are both procedures available? Such issues have been debated in both the comprehension and production literatures, and will be important topics for future research. Another broad-based debate is that between interactive and modular views. As we have seen, there is no clear resolution to this debate. It has been difficult to determine whether there is a syntactic component in language production that operates independently of conceptual and phonological factors. Similarly, comprehension researchers have found it difficult to determine whether an initial analysis that considers a restricted range of information is followed by a later and broader process, or whether a wide range of linguistic and nonlinguistic information is involved from the start. The speed at which language is produced and understood may make it impossible to resolve these questions. However, asking the questions has led researchers to seek out and attempt to understand important phenomena, and this may be the best and most lasting outcome of the debate.

The debate between rule-based and statistical views of language processing provides a good example of how theoretical tensions and the research they engender has furthered progress in psycholinguistics. Statistical approaches, as embodied in connectionist models, have served the field well by emphasizing that certain aspects of language involve probabilistic patterns. In reading, for example, *-ove* is often pronounced as /ov/ but is sometimes pronounced as /öv/ (as in *love*) or /uv/ (as in *move*). People appear to pick up and use statistical information of this kind in reading and other areas of language processing. In such cases, we do well to go beyond the notion of all-or-none rules. We must keep in mind, though, that many linguistic patterns are all-or-none in nature. 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.

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[i] Chuck – it originally said at the end of this sentence "as is the Tanenhaus et al. (1993) research on long-distance dependencies." No study by Tanenhaus et al. (1993) was mentioned earlier, though, which could confuse a reader. Should this phrase be dropped, as I did? Or perhaps the Boland et al. (1995) study mentioned above is the one you meant to refer to here. I looked back at your first draft and there it cited Tanenhaus et al. (1993) as the authors of the public library/liquor study in the preceding paragraph, not Boland et al.

[ii] Antje – Alice asked for one or two references in this paragraph and/or the following paragraph. In your first draft, you had cited Kelly and Bock 88 for stress alternation and Ferreira 93 and Meyer 94 for phase final lengthening. Do you want to put some of these back? Is there a reference that would be appropriate for the next paragraph?

[iii] This paragraph is the only one that is all new.