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LANGUAGE PRODUCTION
Grammatical encoding

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1. Introduction

The processes of language production can be divided into those that create the skeleton of an utterance and those that flesh the skeleton out. In this chapter we are concerned chiefly with the former, a set of processes which we term GRAMMATICAL ENCODING (Levelt, 1989). Grammatical encoding comprises both the selection of appropriate lexical concepts (entries in the speaker's vocabulary) and the assembly of a syntactic framework. It contrasts with PHONOLOGICAL ENCODING, which comprises the assembly of sound forms and the generation of intonation. The product of these processes is not speech itself, but a specification of an utterance that is adequate for controlling the processes of articulation or speech production.

The components of grammatical encoding are no more accessible to conscious experience than the corresponding components of comprehension. Just as in comprehension, we typically become aware only of disruptions. But unlike disruptions of comprehension, many disruptions of production are public events: A speaker who intends to say *meals on wheels* and instead says *wheels on meals* usually knows that something has gone wrong, as does anyone within earshot. Because of their ready availability, speech errors are a rich source of clues to how language production works (Cutler, 1988).

Deciphering these clues has been the focus of several pioneering studies (Dell & Reich, 1981; Fromkin, 1971; Garrett, 1975; Meringer & Meyer, 1895/1978). The details of the analyses diverge in important ways (some of which we touch on later), but there is reasonable agreement on the broad outline of production processes that is sketched in Figure 1. This outline roughly follows proposals by Garrett (1980, 1982, 1988) and, although it is motivated
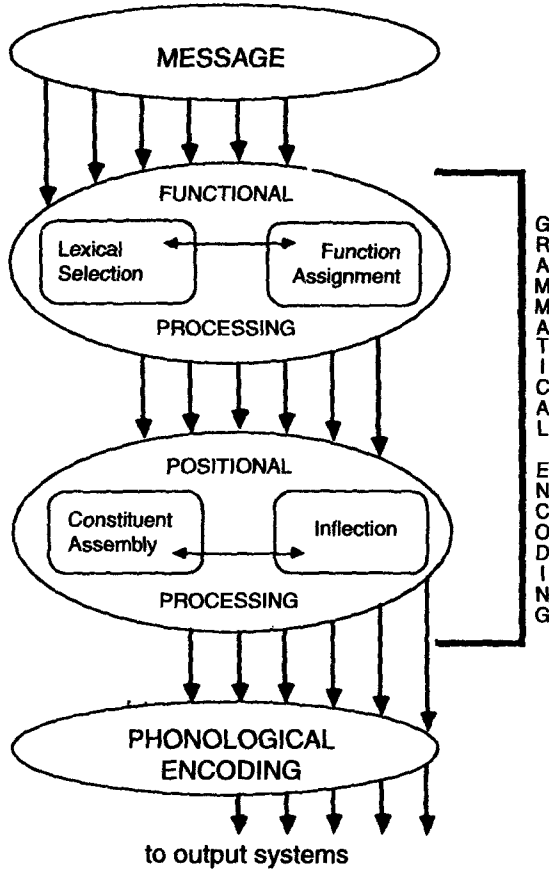
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Figure 1 An overview of language production processes.

primarily by analyses of speech errors, it is intended to provide an account of normal production. The bridge from errors to normal production is built largely on the existence of strong constraints on the forms of speech errors, which are taken to point to relatively immutable components of the production process.

We use the model in Figure 1 to organize and introduce the main topics of this chapter. It shows four levels of processing, the message level, the functional level, the positional level, and the phonological level. The message captures features of the speaker's intended meaning and provides the raw material for the processes of grammatical encoding. These processes are grouped into two sets, functional and positional. The primary subcomponents of functional processing are lexical selection (which involves the

identification of lexical concepts that are suitable for conveying the speaker's meaning) and function assignment (which involves the assignment of grammatical roles or syntactic functions). Positional processing involves the creation of an ordered set of word slots (constituent assembly) and morphological slots (inflection). Finally, phonological encoding involves spelling out the phonological structure of the utterance, in terms of both the phonological segments of word forms and the prosody of larger units.
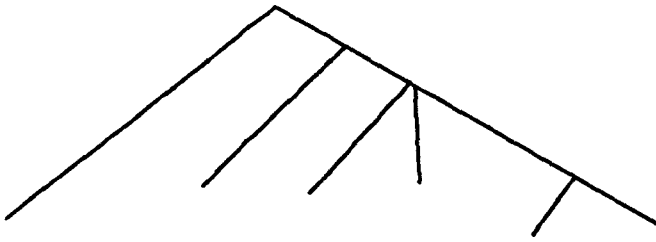
The processes of grammatical encoding can be more concretely specified by going through the steps involved in generating a simple utterance and constructing errors that might arise at each step. We number these steps for expository convenience, but the numbers are not intended to denote a strict ordering of implementation. As the target utterance we use *She was handing him some broccoli*. The message behind this utterance presumably includes notions about a past progressive event in which a female action-agent transfers by hand a nonspecific object from a certain class of vegetables to a male action-recipient.

The first step, lexical selection, involves identifying the lexical concepts and LEMMAS suitable for conveying the message. Lemmas carry the grammatical information associated with individual lexical concepts, such as their form class (noun, verb, etc.). For conveying the broccoli message, appropriate lemmas include masculine and feminine pronominal indices, a noun (*broccoli*), and a verb (*hand*) that relates the elements or ARGUMENTS of events involving an agent, a recipient, and a theme.[1] A common type of speech error that appears to reflect a problem of lexical selection is a SEMANTIC SUBSTITUTION, which would occur if our hypothetical speaker said *She was handing him some cauliflower*. These substitutions preserve general features of the meaning of the intended word (Hotopf, 1980) and are nearly always members of the same grammatical form class (noun, verb, adjective, adverb, or preposition). In Stemberger's error corpus (1985), 99.7% of all lexical substitutions represented the same form class as the target.

The second step is function assignment. This involves assigning syntactic relations or grammatical functions (e.g., subject–nominative, object–dative). During the formulation of *She was handing him some broccoli*, the feminine pronoun lemma should be linked to the nominative (subject) function, the masculine to what we will call the dative function,[2] the argument represented by *broccoli* to the accusative function, and *hand* to the main verb function. Errors of function assignment arise when elements are assigned to the wrong functions. For example, if the feminine and masculine pronoun lemmas were linked to the dative and nominative functions respectively, the resulting utterance would most likely be *He was handing her some broccoli*. These EXCHANGE errors, like other types of exchanges, involve constituents of the same type (both are noun phrases). They are not simple exchanges of word forms, as our example illustrates: The error is not *Him was handing she some broccoli*.

The next two steps constitute positional processing, so called because it fixes the order of the elements in an utterance. As this implies, the order may not be imposed during functional processing. One indication comes from a contrast in scope between the features of different types of errors (Garrett, 1980). Exchanges of whole words occurred within the same phrases only 19% of the time in Garrett's corpus (1980), implying that adjacency is not a strong conditioning factor. In contrast, when sounds are exchanged (as in *sot holdering iron*), they originated in the same phrase 87% of the time.

We consider constituent assembly first. This is the creation of a control hierarchy for phrasal constituents that manages the order of word production and captures dependencies among syntactic functions. For *She was handing him some broccoli*, the hierarchy can be depicted in this way:

The basic features of such hierarchies are largely predictable from the types of syntactic functions that have to be represented and from the syntactic features of the selected lemmas.

The last of the grammatical encoding processes, inflection, involves the generation of fine-grained details at the lowest levels of this structure. In English, many of these details involve elements that carry information about number, tense, and aspect but are bound to other words. So, the expression of the progressive feature on the verb *handing* requires elaboration of one node of the tree, as shown below:

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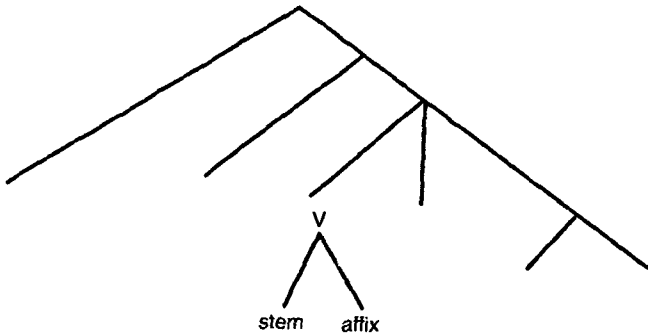
The generation of these details is in no strict sense distinguishable from the rest of constituent assembly, but we discuss it separately in order to showcase a debate over whether the elements dominated by the "twigs" of the structural tree behave uniquely.

One type of error that is identified with inflection is known as STRANDING. Stranding is illustrated in the utterance of a speaker who intended to say *You ended up ordering some fish dish* and instead said *You ordered up ending some fish dish* (Garrett, in press). In such errors, the bound suffixes (*-ed, -ing*) show up in their proper locations in the utterance but affixed to the wrong words, arguing that the inflections are positioned separately from their word stems. Another type of error that may arise during inflection is called a SHIFT (Garrett, 1975) and consists of the mislocation of an affix. Such an error could lead to the utterance of *She was hand himming some broccoli* by our hypothetical speaker. The elements involved in such errors are much more likely to be involved in errors than the final syllables of word stems, such as the *-id* in *morbid* (Stemberger, 1985), implying that strandings and shifts are not simple mislocations of syllables but mislocations of pieces of grammatical structure.

With all this done, it still remains necessary to spell out the phonological content of the utterance. That is the province of phonological encoding, which we will not treat here (see Gerken, this volume).

In the remainder of this chapter, we fill out the picture of grammatical encoding by critically examining each of its hypothesized subcomponents and marshalling evidence about them from different sources, including computer modeling and experimental research on production. The experimental work serves at least three essential purposes. First, it serves to test hypotheses derived from error observations under better controlled circumstances, making it possible to rule out alternative explanations of production processes. Second, it permits examination of features of language production that errors cannot illuminate, if only because those features are seldom or never involved in errors. Even the most familiar types of speech error are surprisingly rare events (Deese, 1984; Garnham, Shillcock, Brown, Mill, & Cutler, 1982; Heeschen, in press). And finally, experimental work makes it possible to explore whether the features of production that are postulated on the basis of error analyses hold equally under the circumstances that lead to normal, error-free production. Errors, by definition, reflect unusual circumstances that cannot straightforwardly be taken to represent the norm. So, any hypothesis that attributes a certain property to the production system in order to account for a particular sort of error is vulnerable to the objection that the property is in fact aberrant.[3]

At the outset, we adopt a very strong position about the nature of these processing systems. It is that each one is influenced only by information represented at the level directly above it. For example, we assume that the processes of lexical selection and function assignment are under the control

of information in the message and are unaffected by the sounds or phonological features of words. This is neither a majority view nor an obviously correct one, and there are compelling reasons to subject it to careful scrutiny (Dell, 1986; Stemberger, 1985). However, it is an assumption that is a testable and (perhaps all too easily) disconfirmable, so that its flaws can be readily corrected as further evidence about these processes accumulates.

We also assume that language production is incremental (Kempen & Hoenkamp, 1987; Levelt, 1989), so that variations in the order in which information is delivered from one component to the next can readily affect the order in which elements appear in speech (Bock, 1982). When higher level processing components drive lower level ones, incremental production implies that the higher levels need not complete their work on an utterance before the next level begins. This is illustrated in Figure 1 in terms of hypothetical temporal connections between the processing levels. The implementation of incrementality requires the formulation, at every level, of piecemeal units relevant to the form and content of the developing utterance, so our review touches on the information partitionings within each processing component.

II. Lexical selection

In fluent speech we normally produce two to three words per second (Maclay & Osgood, 1959), but there are occasional bursts (ANACRUSES) of up to seven words per second (Deese, 1984). Even at these rates, we retrieve the appropriate items from our mental lexicons. This is a surprising skill, given that we know tens of thousands of words (Oldfield, 1963) and that errors of lexical selection are rare: estimates of selection-error rates per thousand words of speech range from 0.25 (Deese, 1984) through 0.41 (Garnham et al., 1982) up to 2.3 (Shallice & Butterworth, 1977).

Empirical research in lexical selection relies on three sources of evidence. First, though selection errors are rare, they have been carefully collected and analyzed. Second, word finding can be particularly troublesome in aphasic patients; the ways in which they err can reveal processes of retrieval that are deeply hidden in normal speech. Third, lexical selection has increasingly come to be studied experimentally. The experiments often involve picture naming, with naming latencies measured under various conditions. In the following we address only the first and last sources of evidence (for studies in aphasia, see Garrett, 1992 and chapters in this volume by Caplan and by Zurif and Swinney) in terms of a theoretical framework developed by Levelt (1989; Levelt et al., 1991a) and Roelofs (1992). That framework is presented first.

A. A network model of lexical access

Our mental store of words and basic information about them is called the mental lexicon. It is obviously not the case that all possible words of our language are stored somewhere in our minds, because there is an infinity of possible words. Take the numerals. They form an infinite set and a corresponding infinite set of words, including compounds such as *twenty-three thousand two hundred seventy-nine*. This is unlikely to be an entry in the mental lexicon. Rather, such words are constructed when needed. Languages differ greatly in the use their speakers make of this ability: Speakers of Turkish, for instance, produce new words in almost every sentence (cf. Hankamer, 1989), whereas speakers of English rarely do so. When we talk about lexical access here, we sidestep this productive lexical encoding to focus on the retrieval of stored words from the mental lexicon.

Our knowledge of words involves three types of information. First, we know a word's meaning. We know that a sheep is a kind of domestic animal, that it has a wool pelt, that it produces milk, etc. These are all properties of our concept SHEEP.

Second, a word has syntactic properties. The word *sheep* is a noun. In French *mouton* is also a noun, but in addition it has male syntactic gender, in contrast to *chèvre* 'goat', which has female gender. A word's syntactic properties can be fairly complex. Verbs, in particular, are specified for the optional or obligatory arguments they command. For example, the verb *hit* typically takes a subject and a direct object (i.e., it is a transitive verb), and because this is something that a speaker knows about the verb *hit*, it is part of the mental lexicon. This type of information is called the verb's SUB-CATEGORIZATION FRAME. The verb *hand*, from our earlier example, has two subcategorization frames. The first one, the prepositional frame, includes a direct object position and an oblique (prepositional) object position (as in *She was handing some broccoli to him*), and the second one, the double object frame, maps the dative to the direct object position and the accusative to a so-called second object position (as in *She was handing him some broccoli*). The word as a syntactic entity is technically called a LEMMA.

Lemmas contrast with LEXEMES, which capture the word's form properties. These constitute its morphological and phonological shape. The word *sheep* is monomorphemic and consists of three phonological segments, /ʃ/, /i/, and /p/. The word *handing* consists of two morphemes, a stem and a suffix, and six phonological segments, /h/, /æ/, /n/, /d/, /ɪ/, and /ŋ/.

In the network model, these different types of information correspond to nodes within three levels of representation, the conceptual level, the lemma level, and the lexeme level. A part of this lexical network is shown in Figure 2. It depicts some of the knowledge we have about the words *sheep* and *goat*.

At the conceptual level, the nodes represent concepts. They are linked by labeled arcs that represent the nature of relationships. Since a sheep is an
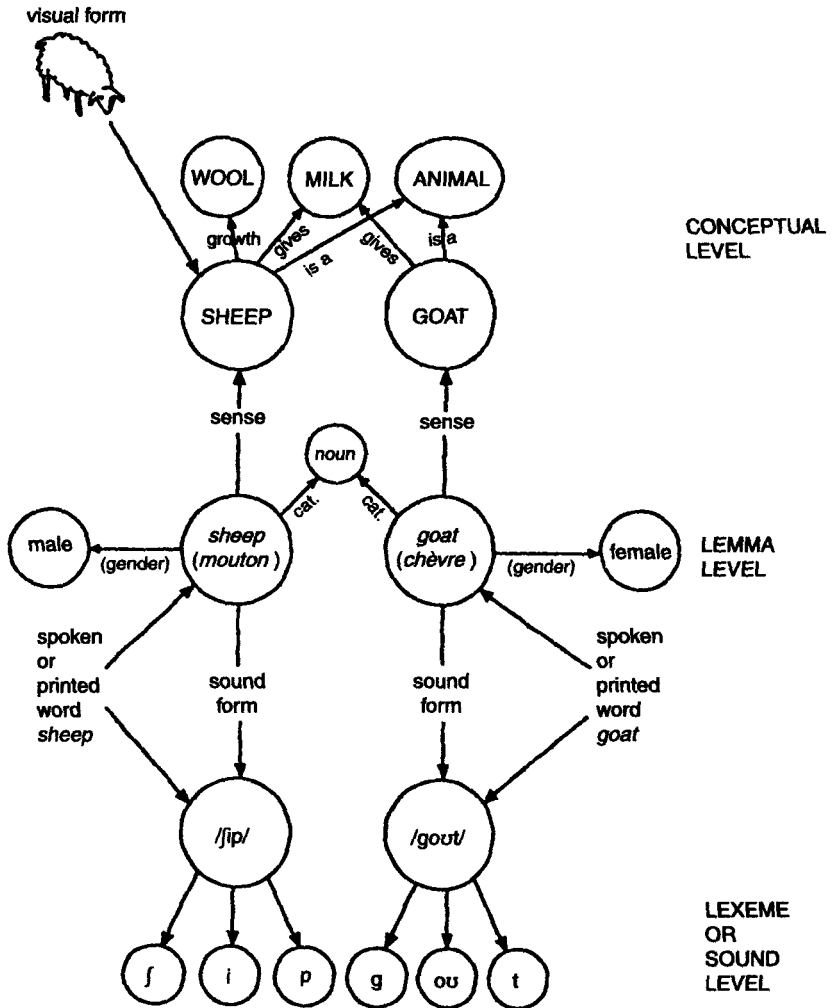
Figure 2 A part of the lexical network. Note that the arrows represent types of connections within the network, not the flow of information during production or comprehension.

animal, this is represented by an ISA connection between the nodes SHEEP and ANIMAL. A word's meaning as a whole is represented by such a network of relations (as introduced by Collins & Loftus, 1975, and Collins & Quillian, 1969), although individual lexical concepts themselves are represented by unitary nodes. In this respect, the model departs from a compositional representation of word meaning. We will not go into this

perennial issue in lexical representation (for further discussion, see Bierwisch & Schreuder, 1992; Fodor, Garrett, Walker, & Parkes, 1980; Levelt, 1989; McNamara & Miller, 1989).

Some conceptual nodes have direct connections to nodes at the second, lemma level. This subset of conceptual nodes represents lexical concepts. Not all concepts are lexical: DEAD TREE is a perfectly well formed concept, but one without a lexical concept. Yet English has a lexical concept for *dead body* (CORPSE).

The nodes at the lemma level represent syntactic properties. The lemma *sheep* has a category link to the noun node; in French the lemma *mouton* has a gender link to the male node, and so on. At the lexeme level, the network represents the word's form properties. The lexeme node /ʃip/ thus has labeled links to its constituent phonological segments, /ʃ/, /i/, /p/.

Lexical access in this model is represented by activation spreading from the conceptual level to the lemma level to the lexeme level (note that Fig. 2 does not depict the activation trajectories; the arrows in the figure characterize permanent relationships rather than processing dynamics). We will not consider how a speaker first conceives of the notions to be expressed (see Levelt, 1989, and for a very different view, Dennett, 1991), but beyond that, the first requirement for lexical selection in normal speech is the existence of an active lexical concept. A concept node can become activated in myriad ways. One simple procedure to induce this is to present a picture for naming. In an experiment, a subject can be given a picture (e.g., one of a sheep, as shown in Fig. 2) and asked to name it as fast as possible. The assumption is that the picture activates the concept.

An active lexical concept spreads its activation to all connected concept nodes. So if the SHEEP node is active, the GOAT node will receive some activation as well (either directly, or via mediating nodes such as ANIMAL or MILK). In addition, activation will spread from the lexical concept node to the corresponding lemma node. In this framework, lexical selection is selection of the appropriate lemma node. So, if SHEEP is the active lexical concept, the lemma *sheep* should be retrieved. It would be an error of selection if *goat* were retrieved. There is nonetheless a small chance for such a mishap, because some activation spreads from SHEEP to GOAT and from there to the lemma *goat*.

In Roelofs' (1992) implementation of this model, the probability that any given lemma will be selected during a specified time interval is the ratio of its activation to the total activation of all lemmas in an experimental set (i.e., the Luce ratio; Luce, 1959). This makes it possible to predict the time course of lexical selection under various experimental conditions (see below). Some of those conditions are designed to directly activate lemma nodes through the presentation of spoken or written words (see Fig. 2), creating competitors for other lemmas activated from the conceptual level.

The model as it is depicted deals only with lemmas for lexical concepts.

But not all words in fluent speech correspond to lexical concepts. In *listen to the radio, to* does not represent a concept. Rather, the lemma for the transitive verb *listen* requires the preposition *to*, so the lemma *to* must be activated via an indirect route at the lemma level. We refer to this as INDIRECT ELECTION.

The major joint in the model is between the lemma and lexeme levels of representation. Between lexical concepts and lemmas, there are systematic relations. So, a verb's meaning is regularly related to its subcategorization frame (Fisher, Gleitman, & Gleitman, 1991; Keenan, 1976). But between lemmas and lexemes, the relation is highly arbitrary (de Saussure, 1916/ 1955). There is no systematic reason why a SHEEP should be called *sheep* (or *mouton*). Still, there are some statistical relations between the syntactic and phonological properties of words (Kelly, 1992). Nouns, for instance, tend to contain more syllables than verbs; they also contain front vowels more often than verbs (Sereno & Jongman, 1990). Kelly (1992) argues that language learners and users may sometimes rely on such statistical relations in parsing and speech production.

The most dramatic reflection of the rift between the lemma and lexeme levels is the so-called tip-of-the-tongue (TOT) phenomenon. It was described by William James in 1890 in one of the most frequently quoted passages in cognitive psychology:

> Suppose we try to recall a forgotten name. The state of our consciousness is peculiar. There is a gap therein: but no mere gap. It is a gap that is intensely active. A sort of wraith of the name is in it, beckoning us in a given direction, making us at moments tingle with the sense of our closeness, and then letting us sink back without the longed-for term. If wrong names are proposed to us, this singularly definite gap acts immediately so as to negate them. They do not fit into its mould. And the gap of one word does not feel like the gap of another, all empty of content as both might seem necessarily to be when described as gaps. . . . The rhythm of a lost word may be there without a sound to clothe it; or the evanescent sense of something which is the initial vowel or consonant may mock us fitfully, without growing more distinct (1890/1950, pp. 251–252).

The TOT phenomenon was later discussed by Woodworth (1938) and systematically studied for the first time by R. Brown and McNeill (1966). R. Brown and McNeill presented the definitions of infrequent words such as *sextant* and asked subjects to produce the defined word. Whenever subjects entered a tip-of-the-tongue state, they reported whatever came to mind about the target word. In many cases the subjects knew the initial consonant or vowel, the number of syllables, and the stress pattern. Related words might come to mind that shared these properties (such as *secant* for *sextant*). These

findings have been confirmed and elaborated in many subsequent studies (see A. S. Brown, 1991, and Levelt, 1989, for comprehensive reviews). Most of these studies deal with TOT states in normal speakers, but there are also clinical conditions that persistently arouse TOT states. These are called anomias (see Butterworth, 1992, and Garrett, 1992, for further discussion).

In terms of the network model, the TOT phenomenon is a failure to access the lexeme from the lemma. The speaker knows the meaning to be expressed (i.e., the concept) and the word's syntax (that it is a plural noun, a transitive verb or whatever; i.e., the lemma). Only the word form is blocked. Some aspects of the form may surface, revealing something about the process of phonological encoding (see Levelt, 1989, and Gerken, this volume, for reviews). Because TOTs appear to arise subsequent to lemma activation, they are not problems of lexical selection, but of lexeme activation.

B. Errors of lexical selection

There are three major types of lexical selection errors, called substitutions, blends, and exchanges. In all three cases a nontarget lemma is activated and an incorrect word form is produced. But there are different ways in which this derailing activation can come about. Consider examples (1)–(6) of substitutions.

(1) ... *carrying a bag of cherries. I mean grapes* (Stemberger, 1985)
(2) *He's a high–low grader* (Fromkin, 1973)
(3) *Get out of the clark* [intended: *car*] (Harley, 1984)
(4) *A branch falling on the tree* [intended: *roof*] (Fromkin, 1973)
(5) *He's the kind of soldier a man ... wants to emanate* [intended: *emulate*] (Bock, 1987)
(6) *I urgently request you to release the hostages unarmed–unharmed* (Fromkin, 1973)

One potential cause of a substitution error is that an alternative lexical concept is activated along with the target. In (1) the speaker intended to express the notion GRAPE, but CHERRY was activated at the same time. This may result from activation spreading at the conceptual level. Because GRAPE and CHERRY are semantically related (both are small round fruits), there is some linkage between them in the conceptual network. If both lexical concepts then activate their lemmas, there is a chance for the unintended one *(cherry)* to be accidentally selected (given a probabilistic selection rule like that of Roelofs, 1992).

Example (2) also involves a semantic relation: *high* and *low* are antonyms. Antonyms and other semantic oppositions in fact form the most frequent type of word substitution. Their causation may be similar to the above case, but there is an additional feature. *High* and *low* are strong associates

(stronger than *grape* and *cherry*). It is not clear where word association should be represented in a network model such as the one in Figure 2. It may be a special form of conceptual relation, but it might also involve direct lemma-to-lemma connections.

Example (3) has a different etiology. The speaker intended to say *Get out of the car* to someone but at that moment glanced up at a storefront with the word *Clark's* printed on it. Then *clark* intruded, creating an environmental contamination (Garrett, 1980). There was no conceptual spreading of activation from CAR to CLARK. Rather, the printed word *Clark* seems to have activated the corresponding lemma.

Example (4) has a still different cause. It appears that *branch* may have activated its associate *tree*, allowing the lemma *tree* to be selected instead of the target lemma *roof*. Again it is unclear whether activation spread at the conceptual level (from BRANCH to TREE), at the lemma level (from *roof* to *tree*), or both. Was the speaker really thinking of a tree when the error occurred? We will never know.

Example (5), in which the target word was replaced by a sound-related word, is due neither to conceptual- nor to lemma-level priming. In fact, it is not strictly an error of lexical selection under our present definition because, in terms of the model, the error need not have involved the activation of a nontarget lemma (i.e., the lemma *emanate*). Fay and Cutler (1977) called this type of error a malapropism and argued that such errors arise during lexeme processing. At that level the lexicon is organized in terms of form, not meaning. And indeed, malapropisms show no systematic meaning relation to the corresponding targets (Garrett, 1980), as testified by such cases as *sympathy* for *symphony, bodies* for *bottles*, and *garlic* for *gargle*. Revealingly, there is a strong similarity to the "wrong names" that occur during TOT states, which also seem to arise during lexeme processing.

The final example, (6), is a mixed error: The error *unarmed* and the target *unharmed* have both a semantic and a phonological connection. Mixed errors such as *dictionary* for *directory* and *oyster* for *lobster* are controversial. In their corpus of naturally observed errors, Dell and Reich (1981) found that the probability of a mixed error was higher than would be predicted if semantic and phonological errors have independent sources. They concluded that phonological similarity increases the probability of a semantic substitution. This conclusion has been supported in other research (Harley, 1984; Martin, Weisberg, & Saffran, 1989; Stemberger, 1983; but see del Viso, Igoa, & García-Albea, 1991).

In a network model such as the one developed by Dell (1986) or the one depicted in Figure 2, this can be handled by postulating feedback from the lexeme to higher levels, crossing the lexeme/lemma rift (rather than the purely top-down flow that we have thus far assumed). However, that move may be unnecessary. First, there is experimental evidence from error-free speech (Levelt et al., 1991a) that is inconsistent with this option. We return to this

below. Second, mixed errors may be predominantly environmental contaminations, as suggested by Garrett (in press). If so, it may be that their origin is special, not the consequence of general feedback between lexemes and lemmas. Third, the overrepresentation of mixed errors could result from a mechanism of self-monitoring. According to Levelt (1989), self-monitoring can begin as soon as there is a phonetic plan for the word, and so before articulation is initiated. If *unarmed* is internally but erroneously planned, a cohort of sound-related words will be activated in the speaker's comprehension system, among them *unharmed*. Its meaning can be activated via this phonological route, and in addition via a semantic route, allowing the activated notion UNARMED to prime the related notion UNHARMED even further. Since that is the intended meaning, the monitor may pass the (erroneous) item.

Let us now turn to a second type of lexical selection error, blends (7)–(8).

(7) *The competition is a little stougher [stiffer/tougher]* (Fromkin, 1973)
(8) *The sky is shining [The sky is blue/The sun is shining]* (Harley, 1984)

Most blends are of type (7), the fusion of two words that are near-synonyms in the context of conversation. Whereas substitutions reveal a predilection for antonyms and close associates, blends of antonyms are exceptional (Hotopf, 1980; Levelt, 1989). Instead, it is quasi-identity of meaning that characterizes the blending components. The source of blends may therefore be earlier than substitutions.

This makes blends something of a puzzle (Garrett, 1980). Their antecedents are early, but the errors themselves—the phonological merging of two word forms—are late. The merging is phonologically systematic, respecting the syllable constituency of both components (MacKay, 1972; Wells, 1951). It is possible that this late merging is the result of the parallel encoding of two different utterances (Butterworth, 1982; Garrett, 1980; Harley, 1984) triggered by the speaker's conceptual indecision. This possibility is reinforced by the existence of sentence blends such as (8), which likewise appear to result from the parallel encoding of two related notions.

The third type of selection error includes exchanges such as (9)–(12).

(9) *Seymour sliced the knife with a salami* (Fromkin, 1973)
(10) *I got into this guy with a discussion* (Garrett, 1980)
(11) *a hole full of floors* (Fromkin, 1973)
(12) *threw the window through the clock* (Fromkin, 1973)

In (9), *knife* slipped into the noun slot in the direct object noun phrase in place of *salami* (perhaps because it was at that moment more activated). So far, this is simply a sort of word subsitution. But then, because *knife* was no longer available for the next noun slot, *salami* was inserted in its stead to

create a second error. Because insertion in the wrong syntactic slot is possible only if the syntactic category of the word is the same, word exchanges usually occur between words of the same form class (over 80% of the time; Garrett, 1980; Stemberger, 1985).

In (9), the exchange involved words, not whole phrases. A whole-phrase exchange would have yielded *Seymour sliced a knife with the salami*, in which the articles accompany their respective nouns. Phrase exchanges do occur, however, as example (10) shows. Here the phrases *this guy* and *a discussion* were exchanged. The existence of such exchanges complicates the picture, because it can be difficult to tell a word exchange from a phrase exchange. A clear case is shown in example (11) which, like (9), is a word exchange. The target was *a floor full of holes*, and when the nouns *floor* and *hole* exchanged, *hole* left its inflectional marking behind. This is characteristic of unambiguous word exchanges: they strand other parts of their phrases, including adjectives and closed-class[4] elements (see Berg, 1987, for further discussion). However, when all the phrasal elements that accompany the exchanging words are the same, as they are in (12), it is impossible to tell whether the exchange is lexical or phrasal.

Such ambiguities are problematic because the exchange straddles the boundary between lexical and syntactic processing. Genuine phrase exchanges may have a different etiology than genuine word exchanges, one more similar to the one sketched for pronoun exchanges in the introduction. Some support for this conjecture comes from an informal survey of the word exchanges in Fromkin's (1973) Appendix, which showed that unambiguous word exchanges (e.g., *takes plant in the place*) are more likely to exhibit sound similarities and less likely to exhibit meaning similarities than exchanges which could be phrase exchanges (e.g., *used the door to open the key*).

C. *Experimental studies of lexical selection*

There is a long tradition of experimental research in lexical selection that falls under the heading of "object naming" and dates back to Cattell (1885). Cattell found that subjects were slower in naming pictures than in reading words. This result finds a natural explanation in the network model of Figure 2. Written words have direct access to lemmas, whereas picture information has to be relayed via concepts.

Cattell's result has been extensively studied. One of its offshoots is research on interference between words and pictures, as embodied in what is now known as the picture interference paradigm (Lupker, 1979; see Glaser, 1992, for an excellent review of this literature since Cattell). This is a double stimulation paradigm. The primary stimulus is a picture, which the subject is instructed to name as fast as possible. The secondary stimulus is a printed or spoken distractor word, which the subject is instructed to ignore. Subjects are rarely completely successful in carrying out this latter instruction, however:

The picture-naming latencies are normally affected by the presence of the distractor.

There are usually two variables in such an experiment. The first is the relation between the distractor and target word (the picture's name). When the picture is one of a sheep, the distractor may be a superordinate (*animal*), the identical word (*sheep*), a subordinate (*ram*), a cohyponym (*goat*), a sound-related word (*sheet*), or an unrelated word (*house*). The second variable is the stimulus onset asynchrony or SOA. This is the interval between picture onset and distractor onset. If it is negative, the distractor precedes the picture onset; if it is positive, the distractor follows the picture onset.

A classic picture-interference study is Glaser and Düngelhoff's (1984). In one of their experiments they used an SOA range from − 400 to + 400 ms in steps of 100 ms. A printed distractor word was either semantically related to the target (a cohyponym) or unrelated (there was also an identity condition which we ignore here). All distractors were names of pictures in the response set. The REAL line plotted in Figure 3 shows the difference between the related and unrelated conditions in naming latencies over the whole range of SOAs.

Clearly, the naming response was sometimes delayed when semantically related distractors were presented, compared to when the distractors were unrelated to the target word. This is called SEMANTIC INHIBITION, and it can be understood in terms of the network model (see Fig. 2). When the picture
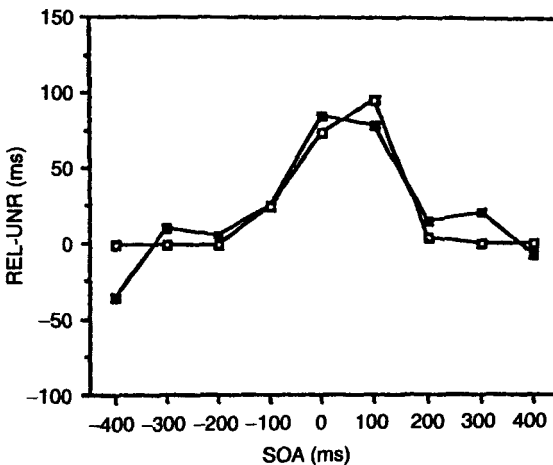

Figure 3 Picture naming in the picture-word interference paradigm at nine stimulus-onset asynchronies (SOAs). The REAL data (*filled squares*) are from Glaser and Düngelhoff (1984); the SIM data (*open squares*) are a simulation reported by Roelofs (1992). In the related (REL) condition the interfering probe word was semantically related to the picture target, and in the unrelated (UNR) condition it was not.

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depicts a sheep, activation spreads to the concept SHEEP, and thence to the lemma *sheep*. An unrelated distractor word such as *house* directly activates the corresponding lemma *house*. Because there are now two active lemmas, and both are possible responses in the experiment (i.e., *house* is sometimes a target), the probability of selecting *sheep* at any one moment is smaller than if there were no distractor (because the Luce ratio is smaller). If a related distractor is presented (e.g., *goat*), the delay should be even greater. This is because activation from the concept SHEEP spreads to the concept GOAT and down to the lemma *goat*. The latter will therefore be more activated than *house* is in the unrelated condition. The results of Roelofs' (1992) simulation of Glaser and Düngelhoff's experiment is shown in Figure 3 as the SIM line. The fit is statistically perfect. Roelofs' own experiments produced further support for this model.

In a very similar study, but with spoken distractor words, Schriefers, Meyer, and Levelt (1990) found a comparable semantic inhibition effect. In addition, they showed that semantic inhibition disappeared when the subject's task was not picture naming but picture recognition. In the recognition task, the subject was first shown the pictures (as in the picture naming experiment). Then the pictures were presented among a set of new ones. The subject's task was to push a *yes* button when the picture was an old one and the *no* button when it was new. The pictures and distractors were the same ones used in the naming experiment, but now there was no trace of semantic inhibition. This implies that the effect is lexical, not conceptual. Because semantic inhibition cannot be merely a word form effect, this finding points to the involvement of lemma representations even in picture naming, when the subject is not constructing sentences. A similar disappearance of semantic inhibition in a recognition task was observed by Levelt et al. (1991a).

Schriefers (1990) was also able to separate conceptually and lexically induced latency effects in an experimental setting. The subjects viewed two geometrical shapes of different sizes (e.g., a large and a small triangle), one of which was marked by a cross. The task was to say *bigger* when the marked shape was the bigger one and *smaller* when it was the smaller one of the two. When both shapes were rather large the *bigger* response was facilitated, and when both were rather small the *smaller* response was facilitated. Schriefers argued that this congruency effect is of conceptual, nonlexical origin, because it was also found when the response was nonverbal (made by push buttons), when no lexical access was required. The situation was quite different for another effect, the markedness effect: *Bigger* responses were usually faster than *smaller* responses (and similarly for other marked versus unmarked adjectives; see Bierwisch, 1969, for an analysis of this distinction), but this markedness difference disappeared when subjects responded nonverbally. On the basis of these and other findings, Schriefers suggested that markedness is a property of adjective lemmas.

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Earlier we argued that the major rift in lexical access is between the lemma and the lexeme levels of processing. In their picture naming study, Schriefers et al. (1990; see above) used not only semantic distractor words, but also phonological ones in the picture-word interference task. The semantic distractors caused inhibition at an SOA of −150 ms (i.e., the onset of the spoken word preceded the picture by 150 ms). Phonological distractors (e.g., *sheet* when the picture was one of a sheep) produced a facilitatory effect at SOAs of 0 and + 150 ms (in agreement with findings by Meyer, 1990, 1991). But there was no trace of phonological facilitation at the SOA of −150 ms. The implication is that phonological encoding strictly follows lexical selection.

The two-stage theory that is suggested by this result was reconfirmed by Levelt et al. (1991a). A different type of dual stimulation task was used but, as in the previous experiments, the subjects' main task was picture naming. On about one third of the trials, a spoken probe (a word or nonword) was presented at one of three SOAs. The subjects' secondary task was lexical decision: They pushed a *yes* button when the probe was a word and a *no* button when it was a nonword. The dependent variable was the latency of this response. Among the probes were semantically related ones (e.g., *goat* when the picture was one of a sheep) and phonologically related ones (e.g., *sheet*). Assuming that the processes of lexical selection affected latencies for semantic probes and that lexeme encoding affected latencies for phonological probes, Levelt et al. were able to examine whether the data fit their two-stage model better than a connectionist network model which allows for feedback from the lexeme to the lemma level (Dell, 1986). That turned out to be true (see Dell & O'Seaghdha, 1991, 1992; Levelt, 1992, and Levelt et al., 1991b, for detailed discussion of these controversial issues). Further findings from this research indicated that a lemma spreads activation to its lexeme only after it has become selected; lemmas that are merely active do not spread activation to the lexeme level. This contradicts predictions from both connectionist (Dell, 1986; MacKay, 1987) and cascade-type models (Humphreys, Riddoch, & Quinlan, 1988).

The conclusion was that the lexical access system for production has a highly modular organization. Lexical selection strictly precedes and is unaffected by phonological encoding. And that makes good sense. Lexical selection and phonological encoding are dramatically different: Lexical selection involves a semantically driven search through a huge lexicon, whereas phonological encoding involves the creation of a pronounceable phonetic pattern for each individual word. Interactions between such processes pose the threat of mutual disruption, yet lexical access is remarkably fast and accurate. Modularity may be nature's protection against error.

A final question about lexical selection concerns word frequency. Frequency seems to have reliable effects on production, as reflected in picture naming times. Oldfield and Wingfield (1965; also see Lachman, Shaffer, &

Hennrikus, 1974) found a high correlation between the latency to name a pictured object and the frequency of the object's name in the language. So, the average speech onset latency was 640 ms for high-frequency *basket*, compared to 1080 ms for low-frequency *syringe*. What is the locus of this effect in the network model? Is it the concept, the lemma, the lexeme, or all three? It could even be a very late phenomenon, having to do with the initiation of articulation. Wingfield (1968) excluded the first alternative by measuring recognition latencies for the pictures—a conceptual process—and found no effect of frequency. Going from picture to concept therefore does not create the frequency effect; lexical access is apparently essential.

At the other extreme, articulatory initiation, the chief evidence for a word frequency effect comes from Balota and Chumbley (1985). They asked subjects to read a word, but to utter it only after a *go* signal which appeared at SOAs ranging from 150 to 1400 ms. Under these conditions one probably measures articulatory initiation rather than selection or phonological encoding, but there was a frequency effect of 26 ms averaged across SOAs in two experiments (for further discussion, see Balota & Chumbley, 1990; Monsell, 1990; Monsell, Doyle, & Haggard, 1989). Clearly this is not the full word frequency effect, as measured by Oldfield and Wingfield. And perhaps it is not a word frequency effect at all, but a syllable frequency effect. Levelt and Wheeldon (in press) found that word and syllable frequency contribute independently and additively to production onset latencies. It may be, then, that most or all of the "real" word frequency effect has its origin somewhere between conception and articulation.

How, then, to distinguish between the lemma and lexeme levels as sources of word frequency effects? Jescheniak & Levelt (in press) assessed the contribution of lemmas with a gender decision task using Dutch words which, like French words, come in one of two grammatical genders. In this task, Dutch-speaking subjects saw pictures and indicated the gender of the word that named the depicted object. They did this by pressing one of two buttons, thereby judging the gender of the target noun without actually uttering it. In another task they simply named the pictures. Each picture appeared three times under both task conditions, and in both there was an initial frequency effect. But in the gender decision task the frequency effect dissipated, disappearing entirely on the third trial. In naming, however, the frequency effect remained undiminished over trials. From these and other experiments, Jescheniak & Levelt concluded that the persistent frequency effect is a lexeme effect. The ephemeral effect of frequency on gender judgment may have its origin in the connection between the lemma and gender nodes (see Fig. 2) and is perhaps only a recency effect. After a lemma's gender is accessed, that information may be readily available for reuse.

In conclusion, the lexeme may be the primary locus of the frequency effect. This conclusion is consistent with findings on prelexical hesitations in spontaneous speech (Butterworth, 1980; Garrett, 1975; Levelt, 1983).

III. Function assignment

As message elements are mapped onto concepts and lemmas, they must also be assigned to syntactic functions. The primary problem of function assignment is to specify which elements will serve as the subject of the incipient utterance and which, if any, will serve as objects of various kinds. It is obviously necessary to separate this problem from lexical selection, since the same words may serve different functions in different sentences (e.g., *Girls like boys* versus *Boys like girls*) and even in the same sentence (e.g., *People need people*). It is also useful to treat this problem as one of grammatical encoding rather than one of message formulation, because very similar messages may be expressed in ways that differ only in the assignments of grammatical functions (e.g., *She was handing him some broccoli* vs. *She was handing some broccoli to him*). But just as the selection of lemmas is heavily influenced by the content of a message, so is the process of function assignment.

Function assignment should also be separated from constituent ordering for reasons that can be difficult to appreciate for speakers of English. English observes a relatively rigid ordering of the constituents that play different roles, but in languages with more flexible constituent orders, constituents can appear in different positions serving the same grammatical functions (often signaled by differences in case). Even in English, there are deviations from canonical word order which point to a function assignment process that is different from the ordering process. For example, a speaker can emphasize an object by "fronting" it, as in *Him I can't stand*, and if, as in this example, the fronted constituent is a pronoun (the only type of English element that reliably marks grammatical function), it will retain its objective case.

The problems that have to be addressed by a theory of function assignment have to do with the nature of the functions that are assigned, the kinds of information that control the assignment, the nature of the elements that the functions are assigned to, and the organization of the processes that carry out these operations. The first three of these problems are matters of intense debate in linguistics, and the last, more obviously the province of psycholinguistic research, has received little systematic attention. We briefly examine the first two and the last one in turn, from the perspective of the kinds of psycholinguistic data that have been brought to bear on them (the third problem remains unaddressed in the psycholinguistic literature). Again, the data come from experiments on normal speech and from observations of speech errors. However, because speech errors that are unambiguously attributable to syntactic problems are woefully scarce (Fay, 1980; Garrett, 1975; Stemberger, 1983, 1985), we rely heavily on experimental data.

A. What functions are assigned?

The most familiar candidate functions are those known as the SUBJECT and DIRECT OBJECT (and, less familiarly, INDIRECT and OBLIQUE objects). The familiarity of these labels disguises enormous linguistic problems of specification and definition that we cannot begin to address (for discussion, see Bresnan, 1982; Marantz, 1984; Perlmutter, 1982; Williams, 1981), but we assume that an adequate account of grammatical functions will highlight something close to the traditional set, and that they are marked morphologically in case languages and structurally in configurational languages (such as English). To simplify the discussion, we use traditional case terminology to refer to the grammatical functions that are assigned (e.g., nominative, accusative, dative, genitive), and traditional grammatical relations terminology (subject, direct object, etc.) to refer to where the elements that are assigned these functions actually appear in English sentences (since most of the work that we consider is on English).[5] So, in English, the element that is assigned the nominative function appears in subject position.

This apparently innocuous statement disguises a substantive theoretical claim about the process of function assignment. The claim is that, within grammatical encoding, there is no level of processing at which the element that serves as the subject of the sentence plays a role that can be realized as a different grammatical relation. On this argument, there is no point at which (for example) the direct object of an active sentence (e.g., *the bone* in *A dog carried the bone*) has the same representation as the subject of its passive paraphrase (e.g., *The bone was carried by a dog*).

This claim runs counter to a traditional conception of deep structure in psycholinguistics (see Foss & Hakes, 1978, for a review), according to which "underlying" objects may be realized as subjects. The problem with this conception is that there is no evidence that function assignments normally undergo changes during grammatical encoding, and some evidence that they do not (Bock, Loebell, & Morey, 1992; Tannenbaum & Williams, 1968). Because relation changing operations (such as transformations) are likely to introduce considerable processing complexity (see Bresnan & Kaplan, 1984, for discussion), it is more parsimonious to assume that the relations are assigned just once and maintained throughout the grammatical encoding process.

This does not deny the existence of a level at which—to return to the example above—there is some uniform representation of the bone in *A dog carried the bone* and *The bone was carried by a dog*. However, we would prefer to locate this uniformity within nonlinguistic cognition (cf. Bransford, Barclay, & Franks, 1972), either in the conception of the event itself or in the components of the message. The referent of the phrase *the bone* may play the same part in a mental model of the event, regardless of how the event is described.

Likewise, the rejection of relation changing operations does not mean that there can be no underlying grammatical representation for utterances. It implies only that there is a one-to-one correspondence between the underlying and surface roles. In our minimalist conception, the underlying roles are the ones assigned during functional processing and the surface roles are the ones assigned during positional processing. Figure 4 sketches this arrangement.

Phrase exchanges (e.g., *I went to the mechanical mouse for an economy five and dime* instead of *I went to the economy five and dime for a mechanical mouse*; Garrett, 1980) represent a type of error that may arise from missteps of function assignment. They have two properties which point to something other than a simple misordering of words. The first, noted briefly in the introduction, is restricted to errors in which the inverted phrases are made up of pronouns (e.g., *you must be too tight for them* instead of *they must be too tight for you*; Stemberger, 1982), because only pronouns exhibit their function assignments. The distinctive feature of pronoun errors is that the pronouns bear the appropriate case for the position in which they erroneously appear, rather than the case for the position in which they should have appeared. According to Stemberger (1982), this is the norm for such errors in English, and Berg (1987) reports a similar trend for German.

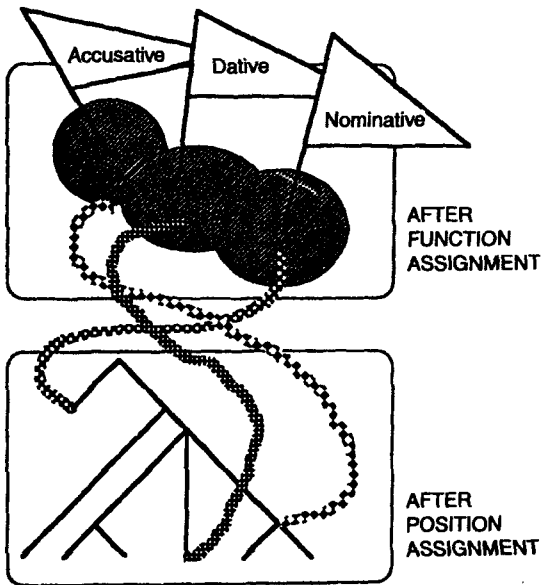The second property of phrase exchange errors that appears to favor

Figure 4 The relationship between grammatical functions (after function assignment) and grammatical relations (after position assignment).

function assignment as the source of the problem is that the verbs in the error-bearing utterances tend to agree with the subject that is actually produced rather than with the subject that was intended (e.g., *that's supposed to hang onto you* instead of *you're supposed to hang onto that* and *most cities are true of that* instead of *that's true of most cities*; Stemberger, 1982). Stemberger (1985) reports that this occurred in 6 of the 7 relevant errors in his corpus. It suggests that the element that appears in subject position in the error also bears the role of subject during the formulation of the agreeing verb, compatible with the hypothesis that a function assignment error is the source of the exchange. The element's appearance in an incorrect position is only a secondary consequence of a deeper malfunction.

Experimental evidence consistent with the separation between functional and positional assignments comes from Bock et al. (1992). They used a sentence structure priming paradigm in which speakers first produced a priming sentence in one of two different syntactic structures and then saw a conceptually unrelated event which they described with a single sentence. The event was designed to be describable in either of the two primed structures (see Bock, 1990, for a more complete description of the paradigm). The results revealed separate, independent effects of the primed structure itself and of the conceptual features of the elements that served different grammatical functions. In the present scheme, these separate effects may be traced to positional and functional processing, respectively.

B. *What information controls functional assignments?*

Most discussions of the controllers of function assignments have focused on subject assignments (e.g., Bates & MacWhinney, 1982; Bock, 1982), although object assignments are receiving increasing attention (e.g., Bock & Warren, 1985; Gropen, Pinker, Hollander, & Goldberg, 1991; Gropen, Pinker, Hollander, Goldberg, & Wilson, 1989). The sets of controllers that dominate these discussions are (a) thematic or EVENT roles coupled with the primitive conceptual features that may help to individuate these roles and (b) discourse or ATTENTIONAL roles. We assume that these kinds of information are represented in the message, and that their effects on the process of function assignment are in part mediated by the structural and semantic conventions of the speaker's language, importantly including the subcategorization conventions or argument structures of lemmas represented in the lexicon.

1. *Event roles*

The sets of event roles proposed in the literature vary widely, with little agreement about appropriate criteria for individuating them. Most of the sets include something corresponding to an agent (the instigator of an event), a patient or theme (a person or object that is affected, moved, or

located), a recipient or goal (a beneficiary or moved-to location), an experiencer or instrument (the vehicle of an event or action), as well as other roles such as time and source.

There is a seductive and well-known correspondence between event roles and grammatical relations. Agents are often subjects, patients are often direct objects, and recipients are often indirect objects. However, there are both systematic and idiosyncratic violations of these correspondences: Agents sometimes appear as the oblique (*by*) objects of passive verbs and patients, recipients sometimes serve as subjects of certain active verbs (e.g., *undergo, receive*), and the same participants standing in roughly the same conceptual relationship sometimes appear in different grammatical relations (e.g., *Many people fear snakes; Snakes frighten many people*). Because the mapping between event roles and functional roles seems to be heavily influenced by the specific requirements of different verbs and verb forms (Grimshaw, 1990), one of the most important factors in the control of functional role assignment is the choice of the verb during lexical selection. This has so far received little attention in production research (but see Jarvella & Sinnott, 1972; Gropen et al., 1989, 1991).

The difficulty of specifying a uniform set of event roles has led to various linguistic proposals for reducing them to more primitive meaning relations (Bierwisch, 1986; Jackendoff, 1987). An array of psycholinguistic evidence suggests that these relations are in some way bound up with such substantive notions as animacy (see Bock et al., 1992, for review) and concreteness (Bock & Warren, 1985; Clark & Begun, 1971; C. T. James, Thompson, & Baldwin, 1973). In general, this work suggests that the more animate or concrete the participant in an event, the more likely it is to appear in the subject relation in an utterance.

The simplest interpretation of many of these results is that animate or concrete elements are more likely to appear early in a string of words. However, there is evidence that implicates functional role assignment rather than serial positioning in these effects. It comes from experiments in which the effects of animacy and concreteness on word order in conjunctions (where the role assignments are the same but the positions of the words differ; e.g., *the farmer and the refrigerator* vs. *the refrigerator and the farmer*) were contrasted with their effects on the order of constituents in sentences (where the roles as well as the positions differ; e.g., *The farmer bought the refrigerator* vs. *The refrigerator was bought by the farmer*). The results show that the simple word ordering impact of these factors is weak to nonexistent, whereas the ordering variations that follow from changes in grammatical role assignment are robust (Bock & Warren, 1985; McDonald, Bock, & Kelly, 1993).

2. Attentional roles

Event roles and attentional roles are intimately related, insofar as different event roles naturally vary in attentional values. For example, Osgood (1980) emphasized the natural perceptual prominence of agents that derives from their movements, and studies of visual attention have confirmed such a tendency in young children (Robertson & Suci, 1980). Still, relative attentional values may vary with changes in the relative prominence of participants, with corresponding consequences for functional role assignments.

This is a natural expectation that has surprisingly weak confirmation in studies of event or scene descriptions (Bates & Devescovi, 1989; Flores d'Arcais, 1987; Osgood, 1971; Sridhar, 1989). The general finding from such studies is that when the elements' event roles and animacy (for example) are equated, variations in the prominence of elements within events have only weak effects on function assignments.

A much more powerful influence is found when prominence is manipulated by discourse or conversational means. Perhaps the most potent device is a question. Imagine that a person observes a scene in which a girl chases a boy and then is asked *What was going on with the girl?* or *What was going on with the boy?* Many studies have shown that in these or similar circumstances, the questioned entity tends to be assigned the subject role in the answer (Bates & Devescovi, 1989; Bock, 1977; Carroll, 1958). Pictures of individual event participants or single words referring to them, presented as cues for the description of previously or subsequently apprehended events, seem to have similar effects (Bock, 1986a; Bock & Irwin, 1980; Flores d'Arcais, 1975; Perfetti & Goldman, 1975; Prentice, 1967; Turner & Rommetveit, 1968).

It is a short step to the information structure of sentences in discourse. By information structure, we mean the distribution of given (or topical) and new information (Clark & Haviland, 1977; Halliday, 1970). The linguistic marking of given information differs from that of new information in a variety of ways, including prosody (Cutler & Isard, 1980; Fowler & Housum, 1987; Needham, 1990; but see Eefting, 1991) and positioning within sentences (MacWhinney & Bates, 1978; Smith, 1971). Linked to given information's general tendency to appear early in sentences is its affinity for the subject relation (Tomlin, 1986).

It seems likely that the sentence-level effects of topicalization are attributable to forces similar to those responsible for the effects of concreteness of individual entities. Both may be regarded as increasing the definiteness or relative mental prominence of participants in the events that sentences describe. Bock and Warren (1985) termed this mental prominence CONCEPTUAL ACCESSIBILITY.

Although grammatical functions could in principle be assigned in any order or even all at once, there are reasons to suspect that, at least in English, there is a preference for combinations of elements that permit the nominative

function to be assigned first. Elements that are accessible (in the senses described above) tend to appear as subjects more often than as objects (see Bock, 1987, for review), particularly when accessibility arises from the message or the meaning rather than from factors that primarily affect the word form (such as frequency or phonological simplicity; see Bock, 1986a; Levelt & Maassen, 1981; McDonald et al., 1993; Streim & Chapman, 1987). This tendency finds a reflection in proposals about hierarchies of grammatical functions or relations (Keenan & Comrie, 1977), in which subjects dominate all other functions. From a processing standpoint, the advantage of such an arrangement is clear: Things that present themselves more prominently or more readily are given a function that allows them to lead in the utterance itself.

C. What is the nature and organization of the processes that carry out function assignments?

Woven into the preceding discussion was a claim about the organization of function assignment that we now consider explicitly. It is that verbs somehow control function assignment.

A verb's specification of its normally expressed arguments may serve to organize function assignment around a unit that is roughly equivalent to the clause. A simple one-clause sentence such as *She was handing him some broccoli* consists of a single main verb and its arguments. The verb *hand* requires three arguments, an agent, a recipient, and a theme. During functional processing, the element corresponding to the agent should be assigned the nominative function, the one corresponding to the recipient should be assigned the dative function, and the one corresponding to the theme should be assigned the accusative function. The realization of these as the subject, first object (the object that immediately follows the verb), and second object creates a full or simple clause.

One of the implications of this view of the organization of production was examined by Bock and Cutting (1992). Their method involved the elicitation of a type of verb agreement error called an ATTRACTION ERROR. Such errors occur when the head of the subject noun phrase is separated from the verb, as are *generalization* and *are* in the observed error *The only generalization I would dare to make about our customers are that they're pierced.* Bock and Cutting's speakers were asked to convert complex subject phrases into full sentences by completing them. The phrases contained a head noun (e.g., *The claim*) followed either by a phrase postmodifier of the head (as in *The claim about the newborn baby . . .*) or a clause postmodifier of the head (as in *The claim that wolves had raised the baby . . .*). Although these subject phrases differed in structural complexity, they were equated in length (in terms of numbers of syllables). The critical fragments ended in a plural noun (*babies*) intended to elicit verb agreement errors in the completions (cf. Bock &

Miller, 1991). The question was whether the clause postmodifier would promote or retard this tendency relative to the phrase postmodifier.

A simple sequential view of production suggests that the clause imposes a processing load analogous to the problems created by clauses in comprehension (Caplan, 1972; Jarvella, 1971), predicting an increase in errors after clauses. Alternatively, if production is hierarchically organized, guided by the requirements of verbs, the prediction is that clause postmodifiers will actually reduce the number of errors. Consider a fragment completion along the lines of *The claim that wolves had raised the babies was rejected.* Here, agreement in the outer clause (e.g., *The claim was rejected*) may be partially protected from the material in the inner clause (*wolves had raised the babies*). Because the error-eliciting word *babies* occurs within a different clause (bound to a different verb) in *The claim that wolves had raised the babies was rejected* than in *The claim about the newborn babies was rejected,* the agreement operation may be protected from the irrelevant plural. The results from three experiments supported the "protection" hypothesis: Errors were more likely to occur after phrase than after clause postmodifiers. This points to clauses as important organizing forces in functional processing.

The centrality of the verb to this organization becomes even clearer when the straightforward equation between verbs and clauses breaks down. Not all clauses are full, simple ones, and these divergences offer a better glimpse of the role that the verb may play.

Ford and Holmes (1978; also see Ford, 1982; and Holmes, 1988) examined such cases in a study in which subjects spoke extemporaneously on a prescribed topic while at the same time monitoring for a randomly presented auditory tone. The reaction times to the tones were then analyzed as a function of their location in the subject's speech stream. The critical locations were the beginnings and ends of functional verb units that did and did not straightforwardly correspond to the beginnings and ends of simple clauses. For example, *I began the book* is a simple clause with only one functional verb unit, whereas *I began working a lot harder* contains two functional verb units, one for the finite (tensed) verb *began* and a second for the nonfinite verb *working.* The results revealed a reliable increase in tone detection latencies at the ends of functional verb units, regardless of whether those units corresponded to simple clauses.

Other results consistent with verb-centered control of function assignment comes from evidence about the minimum scope of advance preparation in production (Lindsley, 1975), which seems to require at least some planning of the verb. Evidence about the maximum scope comes primarily from contextual speech errors, errors in which the source seems to be interference from another element of the intended utterance. The wide majority of such errors originate from material in the same clause (Garrett, 1980). However, word exchange errors originate in adjoining clauses 20% of the time, leading Garrett (1980) to the suggestion that no more than two clauses may be

planned at once. Holmes (1988) discusses whether such two-clause errors typically involve verbs that take clausal arguments (and so require the formulation of two clauses at once), but the question remains open.

Finally, there is an intriguing (but inconclusive) asymmetry between verbs and the other major grammatical categories (nouns, adjectives, and adverbs) in their susceptibility to semantic substitution. Hotopf (1980) reported error data from both English and German which suggests that the tendency for verbs to undergo semantic substitution is vastly lower, both in actual incidence and as a percentage of opportunities. This resistance to substitution could stem from the centrality of the verb to higher level production processes. But it could also be because the lexical organization of verbs is different from that of nouns (Huttenlocher & Lui, 1979) or because the nature of meaning relationships among verbs makes the diagnosis of a substitution more difficult (Gentner & France, 1988).

D. Summary of functional processing

Functional processing, as we have described it, yields an activated set of lemmas and a set of syntactic functions, linked together via the argument structures of the lemmas (notably that of the verb). This is illustrated in Figure 5. Beyond this, there must be a specification of individual elements, such as the indefiniteness of the "broccoli" argument indicated by *some*, the past progressive nature of the action, and the singularity of the verb. We show some of these specifications as annotations on the argument structure in Figure 5 but postpone their discussion until we get to the topic of inflection below.

IV. Constituent assembly

The partial functional structure in Figure 5 consists of temporary (and therefore labile) linkages among stored elements and carries no intrinsic order. To convert this into an utterance, something has to impose a sequence on the elements. There is a great deal of evidence that in order to do this, speakers follow something like the scheme specified in a hierarchical constituent structure. The evidence comes from formal analysis, from pauses in speech, and from errors in sentence recall.

Formal linguistic analysis provides the traditional arguments for hierarchical structure. Without such a notion it is difficult to explain structural ambiguity (as found in the alternative readings of *The old [men and women] were left behind in the village* vs. *The [old men] and [women] were left behind in the village*), or sentence segmentation (why a sentence such as *The girl that kissed the boy blushed* is not understood to assert that a boy blushed, despite the fact that it contains the sequence *the boy blushed*), or verb agreement (verbs agree not with what immediately precedes them, in a positional sense,
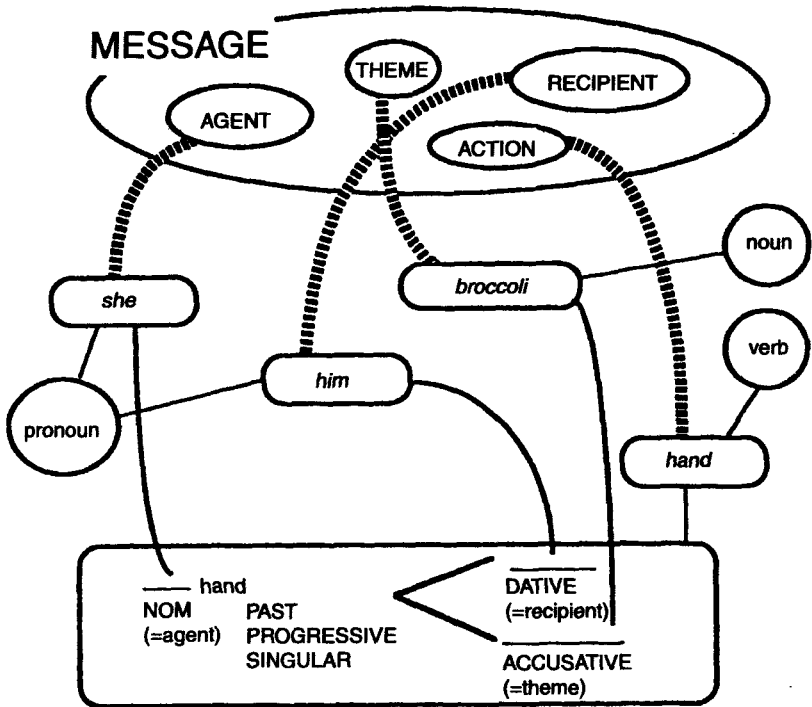
Figure 5 The products of functional processing.

but with a particular constituent structure category, roughly, the highest noun phrase in the same clause; compare *The boy who watched the clowns* **was** *amused* and *The boys who watched the clown* **were** *amused*).

Data from language performance indicate that such structures somehow characterize the products of speech production processes. Normal prosodic patterns (Cooper, Paccia, & Lapointe, 1978; Grosjean, Grosjean, & Lane, 1979) and hesitations (Boomer, 1965; Butterworth, 1980; Butterworth & Beattie, 1978; Maclay & Osgood, 1959; see Garrett, 1982, for review) have been argued to reflect structures that are larger than individual words but smaller than full clauses. Although pause patterns are multiply determined, reflecting forces other than syntactic structure (Gee & Grosjean, 1983; Levelt, 1989; Selkirk, 1984), they appear to be heavily influenced by phrase structure. Likewise, the products of sentence recall (which are also products of language production) indicate that speakers organize sentences in terms of phrasal constituents (Johnson, 1965, 1966a, 1966b).

Such things help to establish that speakers create utterances that have hierarchically organized phrase groupings, or frames. However, they say nothing

about the information that is encoded or elaborated in frames or about the processes that create them. The next two sections review those questions.

A. What's in a frame?

The structure of a sentence could in principle reflect the structure of any of several different sorts of information, including event role information, syntactic function information, and prosodic information. Since phrase structure often confounds these possibilities, it is difficult to disentangle them by observation alone. Bock and Loebell (1990) employed an experimental approach to this issue that relies on a tendency among speakers to use the same form repeatedly, sometimes with different words (Bock, 1986b; Levelt & Kelter, 1982; Schenkein, 1980; Tannen, 1987; Weiner & Labov, 1983). Bock and Loebell examined whether the form repetition tendency changed when the repeated structures represented different event roles or different prosodic patterns. They found no effects of these variations, although the form repetition tendency itself was clearly in evidence. Together with the findings of Bock et al. (1992), the appearance is that the structure is formed under the control of information that is not readily interpretable as conceptual, semantic, or prosodic.

The obvious alternative candidates are the syntactic functions and the grammatical categories of the lemmas that realize them. For example, subjects are typically configured in one way within a sentence structure and direct objects in another. Nouns occur as the heads of noun phrases, verbs as the heads of verb phrases, prepositions as the heads of prepositional phrases, and so on. So, given the nominative function and a noun lemma to fill it, adequate information is available to create or retrieve the rudiments of a subject noun phrase in the proper position in an utterance frame.

B. The processes of constituent assembly

An influential theory of phrase structure elaboration was proposed by Yngve (1960). According to the model, production processes generate a phrase structure tree from top to bottom and left to right, so the first part of the sentence to be elaborated is the leftmost daughter. As the processor traverses this branch, it stores information about commitments to rightward branches that have yet to be elaborated. For example, to produce the simple structure shown below (which would be appropriate for an uninflected version of a sentence such as *Our dog chases squirrels*), the generator starts at the top, where a commitment must be made to one rightward elaboration (the verb phrase) and proceeds leftward past the first node (the noun phrase), where it incurs another commitment to a rightward elaboration (the head noun) and terminates at the determiner branch. The number of commitments at this point, two, is shown in parentheses. The generator then returns to elaborate

(2) (1) (1) (0)
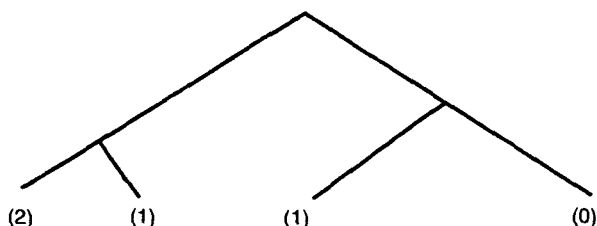
the noun phrase by creating the noun branch. Finally, it returns to the top and proceeds to elaborate the verb phrase.

Yngve's theory makes a very concrete prediction about the effects of branching on the difficulty of producing a sentence. Since commitments to right branches are stored while the generator elaborates other branches to the left, the cost of storage may appear as an impairment to fluency, perhaps as a slowing of speech rate or as an increase in the probability of error. The number of such commitments grows as a function of the depth in the tree of the left branches, with a corresponding increase in the storage cost. Storage cost is typically assessed by counting the number of left branches dominating each terminal element (word) of the sentence (which yields the number of right-branching commitments) and dividing by the total number of words (which yields a measure of mean depth). For the structure above, the mean depth is 1.0.

This model has been examined by a number of investigators, including Johnson (1966a, 1966b), Martin and Roberts (1966, 1967; Martin, Roberts, & Collins, 1968), and Perfetti (1969a, 1969b; Perfetti & Goodman, 1971). Little consistent support has been found for the detailed predictions of the depth hypothesis (see Fodor, Bever, & Garrett, 1974, Chaps. 5 and 6, and Frazier, 1985, for review and further discussion), perhaps because mean depth is insufficiently sensitive to structure assembly. The measure is a global one, whereas disruptions of surface syntactic elaboration may be local. Likewise, most tests of the depth hypothesis have employed methods (such as sentence recall) that are not suited to the detection of a speaker's transient encoding problems.

Some support for a broader implication of Yngve's model came from experiments by Forster (1966, 1967, 1968a, 1968b). Forster looked at the ease and speed of completing sentences that had words deleted at the beginning or end. He found that it was more difficult to create the beginnings of sentences, as would be expected if the existence of rightward commitments burdens the generation of sentences. Evidence that this was not exclusively the result of practice in generating sentences from left to right came from comparisons of sentence completion performance across languages that differed in the degree to which their sentences characteristically branch to the left.

Still, there is something highly artificial about the task that Forster employed, although it is an artificiality that is built into Yngve's model. Speakers may rarely know exactly how their sentences will end before they begin them, but depth calculations cannot be made precisely unless they do. So, while Forster's experiments generally supported the original theory, they involved a task that diverges from ordinary production in just the way that the theory does, making it unclear whether the results can be generalized to normal formulation processes.

A related form of support for Yngve's theory comes from the tendency for "heavier" or more complex constituents to appear later in sentences, which reduces their depth. Thus, the sentence *The clerk showed the woman a book with a picture on its cover of Nancy Reagan glaring at Raisa Gorbachev* sounds much more natural than *The clerk showed a book with a picture on its cover of Nancy Reagan glaring at Raisa Gorbachev to the woman*. There is no comparable disparity between the formally similar sentences *The clerk showed the woman a book* and *The clerk showed a book to the woman*. A related phenomenon occurs in language acquisition, where subject-elaborated noun phrases have been found to appear later in the course of development than object-elaborated noun phrases (Pinker, 1984). However, as Frazier (1985) pointed out, these facts are compatible with any approach which predicts that complex constituents tend to appear at points of low complexity within a sentence.

A computational model that avoids the pitfalls of Yngve's approach has been proposed by de Smedt (1990; also see Kempen & Hoenkamp, 1987; Lapointe & Dell, 1989). What distinguishes the model is that it permits incremental production. It does this by building pieces of phrase structure as the lemmas and function assignments that demand particular phrasal fragments become available, and fitting the fragments together according to constraints on possible unifications (see Kay, 1985, for a discussion of unification procedures). The phrase structure is thereby assembled in a piecemeal and heuristic fashion under the control of lemmas and their functions, rather than by means of an algorithm that generates a tree into which words must be inserted. The predictions of the model seem most likely to concern problems that might arise during unification attempts among incompatible fragments, but these predictions remain to be worked out and tested.

V. Inflection

In order to examine a heated controversy in the production literature, we consider under the heading of inflection not only inflection proper, but also the formulation of the function words that are often associated with grammatical phrases of different types (e.g., determiners for noun phrases, auxiliaries for verb phrases, and prepositions for prepositional phrases). Function words and inflectional affixes (together with derivational affixes,[6]

which we will largely ignore) constitute the elements of the CLOSED CLASS, so called because its inventory (both in the language and in the vocabulary of individual adult speakers) undergoes change much more slowly than the inventory of the open class (nouns, verbs, adjectives, and adverbs).

One source of the controversy is a relatively undisputed fact about speech errors: The elements of the closed class are less likely to be involved than elements of the open class. So, the words in blends, in semantic and phonological substitutions, and in exchanges tend to be members of the open class. Even sound errors, which are much more likely to be indiscriminate about syntactic classifications than word errors, seem to be constrained by open and closed class membership, occurring principally within open class words in spontaneous speech.

At issue is how to account for this regularity. Open and closed class words differ in many other ways, and these differences suggest alternative accounts for their behavior. So, open class words by and large occur less frequently than closed class words, they are learned later in language acquisition, they are longer, and they are more likely to bear stress. Such factors, alone or together, could create a predisposition to error that has nothing to do with word class per se.

In the following sections, we present two alternative accounts of how the elements of the closed class receive their places within a sentence structure. Along with these accounts we consider some of the other evidence that has been brought to bear on the issue.

A. Inflections as frame features

Beyond the general features of the behavior of closed class elements in errors, Garrett (1982) has called on another disparity between them and open class elements in arguing that the closed class is a special word class or separate vocabulary. Among some aphasics, the closed class is disproportionately absent from speech (Saffran, Schwartz, & Marin, 1980), despite the general rule that high-frequency words are more likely to be preserved in aphasic speech. Garrett has also presented an analysis of normal speech errors which suggests that they are more likely to occur among open class words even when frequency is controlled (Garrett, 1990).

To account for such evidence, Garrett (1982) argued that the elements of the closed class are intrinsic features of the grammatical frame. Unlike open class words, which have to be linked to the frame in some fashion (e.g., by being assigned a grammatical function or a position), the closed class elements in an important sense are the frame, serving to define as well as mark the functions and grammatical features (e.g., definite, plural, past tense, and so on) of the open class words.

For this to happen, we might imagine that during functional assignment, each function is tagged with additional specifications appropriate to its real-

ization. For example, if the subject is specified as definite and plural, the frame generated for the subject noun phrase should include, in addition to a branch for the head noun itself, a definite determiner branch and a branch for the plural inflection, along the lines of
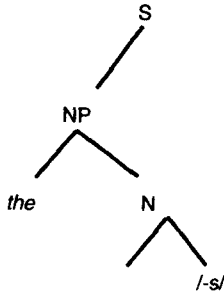
Since the additional branches are nothing more than the corresponding closed class elements themselves, they may be directly encoded after a few minor morphophonological adjustments.

B. A mixed model

The challenges to the frame view come from at least two directions. One focuses on an alternative explanation for the disparate behaviors of open and closed class elements in speech errors, seeking to attribute them to the differences in frequency of the class members. These differences are enormous: In the CELEX database (which includes almost 18 million words of English text; Burnage, 1990), the 70 most frequent English words are function words (though some of them, like *can*, have content usages) and range from 60,958 occurrences per million (*the*) to 1,798 per million (*now*); the first unambiguously open class word (*time*) has a frequency of 1,791 per million. Examinations of the relationship between word frequency and error proclivity have shown that infrequent forms are more likely to participate in errors than frequent forms (Dell, 1990; Stemberger & MacWhinney, 1986), consistent with a frequency hypothesis.

A second challenge is directed at the claim that closed class words define the frame. To test this, Bock (1989) examined whether structural repetition (the tendency to repeat similar phrase structures across successive sentences) is dependent on identity of closed class elements. She found equally strong structural repetition when the closed class members of sentences were different or the same, suggesting that the phrasal configurations of sentences are controlled by forces that are not fully equatable with their closed class elements.

To accommodate such challenges to Garrett's view of the inflection

process, Lapointe and Dell (1989) offered a modified account that distinguishes between the free standing elements of the closed class (such as determiners and auxiliaries) and inflectional affixes (such as the plural and past tense). In their model, only the affixes are given directly in the frame. The freestanding function words have to be inserted by an additional operation, so that the frame for the noun phrase shown above would appear as something closer to the following.
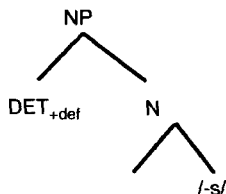
The motivation for this treatment was an analysis by Lapointe (1985) of simplification errors in the speech of English- and Italian-speaking aphasics. Within the errors, Lapointe noted a difference in the behavior of freestanding function words and affixes. Whereas function words tended to be omitted, affixes tended to be replaced with other affixes, suggesting that affixes are in some sense more intrinsic to the frame than function words.

The model's treatment of function words nonetheless distinguishes them from content words as well as from affixes. They differ from content words in the mechanism by which their phonological or morphosyntactic representation is linked to the frame, prior to phonological encoding, maintaining something of the spirit of the separate class view.[7] Specifically, the assumption is that for each designated function word slot there is only one filler, so that there is no competition among candidates. However, during phonological encoding, function and content words undergo the same operations, suggesting that, other things equal, open and closed class words should be equally prone to sound errors. This prediction received support from experimental studies of error elicitation reported by Dell (1990).

C. The generation of bound inflections

Spontaneous speech errors strongly suggest that bound inflected forms are accessed separately from stem forms during generation. Most of the evidence for this comes from stranding errors such as the one cited in the introduction (*You ordered up ending some fish dish*; Garrett, in press). Stemberger (1985) found that inflectional affixes were stranded in 88.9% of the errors in which it was possible in his corpus. Both the frame model and the mixed model imply that stranding is a consequence of normal frame generation coupled with some failure of lexical access, and not a frame generation problem, in agreement with Stemberger (1985). The question to be addressed here, then, is

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how the hierarchical framework comes to have the appropriate configuration to control the appearance of the bound elements of the closed class.

For many elements of the closed class, including the freestanding ones, the notion of indirect election can be called on to explain how such elements become part of the frame. As discussed in the section on lexical selection, certain lemmas carry specifications about the closed class elements that can or must accompany them. These specifications may be represented in a way that can be directly incorporated into a structural frame, so that the choice of a lemma that carries such information guarantees the compilation of the element into the developing utterance. For example, if the plural form of *goat* (*goats*) is selected, the lemma should mandate the construction of a noun phrase in which the stem of the head noun is affixed with the plural /-s/. However, if the choice were the plural form of *sheep* (*sheep*), no affix would be called for.

A related but more difficult question has to do with the circumstances that lead to the selection of lemmas that require closed class elements. In some cases these selections may be under direct control of message elements, as when a verb is specified for past tense. But in others the connection to message features can be less straightforward, as when there are syntactic dependencies among inflectional features. So, why do speakers say *She* **was** *handing him some broccoli* rather than *She* **were** *handing him some broccoli?* In such dependent relationships, two (or more) constituents of a sentence reflect a value of some feature that triggers an inflectional variation. These constituents need not be adjacent: In subject–verb agreement, for example, agreement can cross an indeterminate amount of intervening material. What is necessary is that the agreeing constituents stand in appropriate structural or syntactic-functional relationships (so in English, agreement operates between the head of the subject noun phrase and the finite verb).

Indirect evidence about the workings of the agreement operation in production comes from studies of errors of attraction. As noted above, attraction errors have the property that the number of the verb agrees with the number of some (usually plural) constituent of the sentence other than the head noun phrase. Assuming that such errors are constrained by the factors that control normal agreement (an assumption that obviously may be wrong), Bock and Miller (1991) and Bock and Eberhard (1993) explored how various number characteristics affect the incidence of attraction errors in speech. These characteristics included the "multipleness" of the reference of the subject (as it might be represented in the message; cf. Pollard & Sag, 1988), the semantic multipleness versus grammatical plurality of the attracting noun phrase, the regularity of plural marking, and spurious surface features of plurality (plural-like pronunciation, as in the word *rose*). The only factor that reliably created attraction errors was grammatical plurality (i.e., subcategorized plurality) of the attracting noun. Because grammatical plurality is a property of lemmas rather than of nonlinguistic concepts or

messages, lemmas may be the principal source of number agreement features in English utterances.

The obvious place to state this dependency in the general architecture we have set out is within functional processing, since it is there that the relevant relationships are represented. In functional processing terms, the creation of the dependency requires that the finite (tense and number carrying) verb and the noun lemma linked to the nominative function have the same number. For this to happen, the verb must inherit the subject's number feature, or the subject must inherit the verb's number feature, or both must inherit the same value of a feature that is stated elsewhere (one possible locus is in the message, on a linguistic argument persuasively developed by Pollard & Sag, 1988). The distribution of attraction errors, both in spontaneous and elicited speech, points toward the first of these alternatives.

Linked to the question of the origins of the frame features that control the appearance of inflections is a current controversy over the representation of regularly and irregularly inflected forms in the lexicon (Kim, Pinker, Prince, & Prasada, 1991; Pinker, 1991; Rumelhart & McClelland, 1987). One position in this debate is that regular and irregular forms are represented in the same way,[8] so that there is no explicit sense in which inflected regular forms consist of a stem and an affix. As Stemberger (1985) observed, this position is challenged by the evidence that inflected forms in complete utterances tend to be created—or to fall apart—in a piecemeal way, along morphological rather than phonological lines. Such evidence adds weight to the alternative, a rule-based origin for the production of inflected forms in connected speech.

VI. Conclusion

By way of summary, Figure 6 sketches the products of each set of grammatical encoding processes that we have discussed, taking the (by now hackneyed example *She was handing him some broccoli* as the target utterance. Functional processing serves to integrate a set of lexical specifications with a set of syntactic functions, which in turn guide the creation of a framework for the positioning of words. This framework controls positional processing, the output of which is an ordered set of word forms and their inflections.

We have reviewed several types of evidence in developing this picture, among them the constraints that have been observed on errors in spontaneous and elicited speech. In closing we should pointout one notable absence from this discussion. Missing is Freud's (1917/1976) account of errors such as the parliamentarian's *Gentlemen, I take notice that a full quorum of members is present and herewith declare the sitting closed.* Because Freud's account has become part of the fabric of popular culture, it is important to consider its bearing on an explanation of how people talk. The
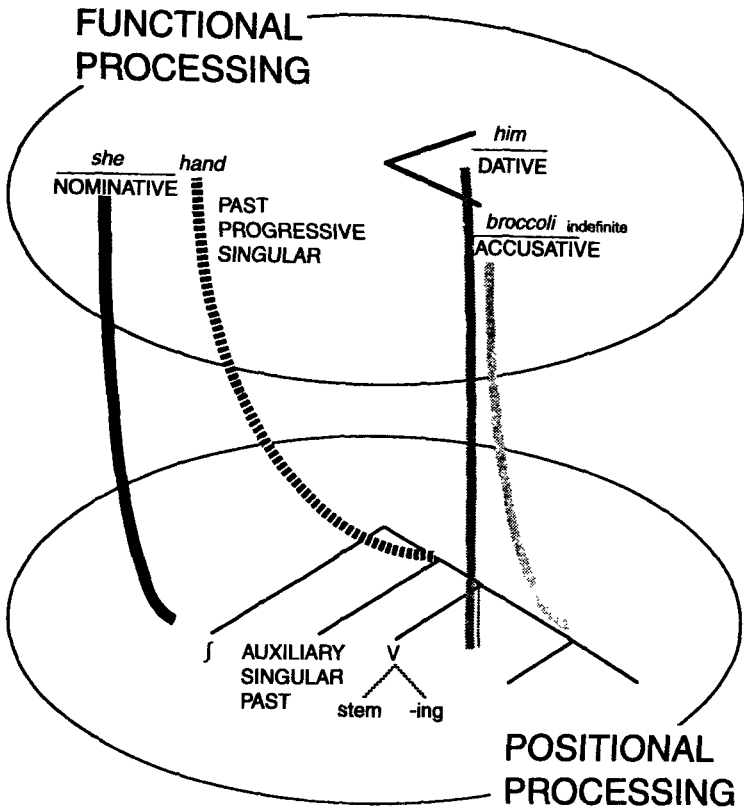
FUNCTIONAL
PROCESSING

she ___ *hand*
NOMINATIVE

PAST
PROGRESSIVE
SINGULAR

him
DATIVE

broccoli indefinite
ACCUSATIVE

AUXILIARY
SINGULAR
PAST   stem -ing

POSITIONAL
PROCESSING

Figure 6 An illustration of the events of grammatical encoding.

main drawback of Freud's analysis, as Freud himself acknowledged, is that few speech errors have discernible psychodynamic content. Yet most speech errors, whether or not they carry clues to a speaker's unconscious impulses, display an impressively regular set of linguistic restrictions (note that the parliamentarian's slip is a thoroughly ordinary semantic substitution). It follows that errors of speech may carry fewer clues to the mysteries of unconscious motivation than to the mundane and relatively mechanical underpinnings of speech.

Unfortunately, the clues about these underpinnings are sometimes ambiguous or conflicting and are always open to alternative interpretations. For such reasons, computational and experimental approaches have assumed increasing importance in the study of language production. Computational models like those of Dell (1986; Dell, Juliano, & Govindjee, 1993), de Smedt (1990), Kempen and Hoenkamp (1987), and Roelofs (1992) offer concrete

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proposals about the organization of processing and, in the best cases, generate specific predictions about the consequences of the mechanisms they embody. Because the overt characteristics of language production are readily observable and quantifiable, the predictions made by these models are amenable to testing across a wide array of data. For such reasons, the computational approach to production offers great promise.

Systematic, controlled empirical testing is a necessary complement to computational models, and here too, there have been promising developments. As the present review suggests, there is now an array of experimental methods that strategically target the underlying dynamics of production, most of them relying on techniques (like interference and priming) that transiently sideswipe or enhance specific subcomponents of formulation between messages and articulation. These developments are nonetheless fairly new and narrowly spread over the range of issues in production, in part because of the challenge of manipulating the language production process without disrupting the fundamental features of the underlying communicative intention.[9] Critical observations are therefore sparse at many points, making the research we have reviewed little more than a preliminary step toward the understanding of grammatical encoding.

Acknowledgments

Notes

1 In event-role terminology, the theme is the object in the event that undergoes movement. This sense of theme should not be confused with the unrelated sense of discourse theme.
2 The dative is roughly the same as the traditional indirect object.
3 It is for this reason that the most persuasive hypotheses that emerge from error analyses are based on what stays right in an utterance when something else goes wrong.
4 The members of the closed class include function words and inflectional morphemes.
5 Since nonconfigurational languages lack strict isomorphisms between functions and positions, it is important to remember that the relations here refer to positions only in English sentence structure.
6 The distinction between derivational and inflectional affixes is based in part upon whether they change the grammatical category of the word to which they apply. By this criterion, the plural affix for nouns and number, tense, and aspect affixes for verbs are inflectional, whereas derivational affixes change verbs into nouns (e.g., -tion, as in creation), nouns into verbs (e.g., -ate, as in pulsate), nouns into adjectives (e.g., -ly, as in princely), and so on. However, not all derivational affixes change form class (e.g., un-, mis-).

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7 However, this separate class does not constitute a separately stored vocabulary, but a class of words whose use is heavily constrained by syntactic features.

8 In a certain sense, they may not be represented at all as lemmas or lexical forms (Seidenberg & McClelland, 1989).

9 The assumption that this is possible is itself a point of controversy (Butterworth & Hadar, 1989; McNeill, 1985, 1987, 1989).

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