Syntax in Language Production:

An Approach Using Tree-Adjoining Grammars

Fernanda Ferreira

Michigan State University

To appear in L. Wheeldon (Ed.), *Aspects of Language Production*

August 31, 1999

Syntax in Language Production:

An Approach Using Tree-Adjoining Grammars

I. Introduction

Any utterance consisting of more than one word requires the speaker to make decisions about word order. In the most typical situation, the speaker constructs an utterance corresponding to a sentence—a combination of a verb, its arguments, and any optional modifiers, as in

1) Simone was eating tuna yesterday.

Constraints concerning the words that may occur and their ordering arise from several sources. One is the lexical items making up the utterance. In the case of (1), the main verb *eating* requires both an appropriate subject and object. Another constraint comes from the general properties of the language (in this case English): The subject must occur before the verb and the object must occur after it. Other aspects of sentence form are less determined. For instance, grammatically the modifier *yesterday* may occur at the beginning or end of the sentence, and it is up to the speaker to choose a location. The theme of eating (*tuna*) can be the object of the sentence as it is in (1), or it can be the subject, in which case a passive structure would be required (*The tuna was eaten by Simone yesterday*). The choice of sentential position is based on a variety of factors, some of which will be reviewed in this chapter.

The syntactic information that provides the foundation for some of these decisions is consulted by speakers quickly and efficiently. The question for psycholinguists interested in language production, of course, is how this speed and efficiency is accomplished. The challenges include at least the following: First, we need to develop an empirical base of knowledge concerning how syntactic decisions are made. For example, what caused the speaker of (1) to use the active form rather than the passive? How did the speaker manage to make the form of the auxiliary verb *to be* agree with the singular subject *Simone*? And second, we need to develop theories that characterize how these decisions are made and suggest fruitful directions for conducting further work on syntactic production.

The goal of this chapter is to help the field of psycholinguistics meet some of these challenges by doing three things. First, I will review existing theories of syntactic production, focusing particularly on those motivated by human performance data such as speech errors, decisions about syntactic form, and reaction time performance. Second, I will describe an approach to syntax from the field of computational linguistics that provides an interesting perspective from which to view results in the production literature. This approach is known as tree-adjoining grammars (TAGs), and is associated with Aravind Joshi and his colleagues and students (Frank, 1992; Joshi, 1985; Joshi, Levy, & Takahashi, 1975; Kroch & Joshi, 1985). The important fundamental feature of this approach is that it assumes the existence of primitive, basic syntactic trees, which are combined in various constrained ways. This description of TAG will highlight the characteristics of elementary trees, the ways they may be combined, and the properties of the approach that are especially relevant to researchers interested in syntactic production.

Third, I will then review some of the literature on syntactic production, focusing especially on (a) lexical influences on syntactic form, (b) syntactic priming, (c) computation of agreement (e.g., subject-verb agreement), and (d) evidence concerning the size and characteristics of syntactic "planning units". This presentation will be interlaced with discussions of how the results can be neatly captured using a TAG approach. I will conclude by describing a model of syntactic production that assumes the basic TAG machinery, and I will discuss the implications of this approach for the widely held assumption that language production is "incremental"— the assumption that the smallest chunks possible are passed from one processing level to another as an utterance is being constructed (Levelt, 1989).

II. Models of Syntactic Production

As Bock (1995) points out, most researchers who work on language production assume that the formal grammatical structure proposed by linguists have proposed for different linguistic domains constitutes the knowledge that speakers consult when they create utterances. The psychologist's task, then, is to propose models of how such knowledge is put to use. Of course, matters become interesting when we take into account that the theories linguists have proposed are not all mutually compatible. For instance, in some theories (Chomsky, 1981), a phrase is sometimes described as having been "moved" from its canonical position, leaving behind a marker or "trace" of its previous location. According to these approaches, a passive sentence such as *The ball was kicked by the injured player* contains a trace after the word *kicked*, because *the ball* was moved from its original postverbal position to the front of the sentence. On other theories (e.g., Chomsky, 1981, 1986, 1995), the relation between an active and passive is captured lexically: It is assumed that the active and passive forms of the verb select for different syntactic arrangements of their arguments. The point, then, is that what a psycholinguist takes the content of the knowledge base to be will vary depending on what theory of linguistic structure he or she assumes.

But setting aside this complex issue, the most influential theories of syntactic production incorporate mechanisms for creating syntactic phrases, assigning grammatical functions to those phrases, and determining left-to-right order (Bock, 1982; Fromkin, 1971; Garrett, 1976). The standard architecture (see Bock & Levelt, 1994) uses two levels of processing to accomplish syntactic encoding in production, and these are generally referred to as the functional and positional levels of processing. At the stage at which a functional level representation is created, the syntactic and semantic aspects of a word's representation (so-called "lemmas") are selected and assigned grammatical roles such as subject and object. An error such as *I left my briefcase in my cigar* reveals what can occur when processing at this stage goes wrong: The lemmas for *briefcase* and *cigar* were accessed but their roles were misassigned. In the second stage of Garrett's model, word-forms (the phonological representations of words) are assigned to their linear position within a phrase. Garrett proposed that the syntactic encoder accesses prestored phrasal frames and then inserts word forms into them. The frames come complete with closed class items and slots for the open class words. For instance, for the phrase *in my cigar*, the frame would include the items *in* and *my*, and a slot for *cigar*. If the noun had been plural, the plural morpheme would have been present as well. This architecture was proposed to account for a different class of speech errors, so-called "stranding errors" such as *It waits* *to pay* (from Garrett, 1976). Obviously, what was intended was *it pays to wait*. Notice that although the content words *pay* and *wait* were misaligned, the affix is in its correct position. It appears, then, that closed class items such as function words and affixes are an intrinsic part of the phrasal frame, and so cannot move; the word forms for content words are then plugged into the slots in the frame, and under some conditions, can end up in the wrong locations. The result is an error such as *it waits to pay*.

Garrett assumed a modular organization for syntactic analysis in production, and this is one of the points on which his theory has been challenged. In the original model, it should not be possible for phonological information to influence the syntactic shape of an utterance, because grammatical functions are decided before phonological information becomes available. This aspect of his theory has been challenged on a couple of grounds. One finding that compromises the modularity assumption is that, at least under some conditions, a phonologically primed word tends to occur late in a sentence, and the late placement may force an adjustment in the global syntactic organization of a sentence. For example, Bock (1987a) found that if a speaker hears and repeats the word *trump* and then sees a picture of a truck towing a car, that person will tend to create a sentence in which the phonologically primed concept *truck* occurs later in the sentence. A second result that challenges the assumption of modularity concerns not so directly the syntactic procedures in production, but rather the proposal that lemma selection takes place during a distinct stage that is encapsulated from phonological information. The challenging finding is that words participating in errors such as substitutions are occasionally both semantically and phonologically related (Dell & Reich, 1981). Thus, it does not appear that lemma selection is discrete and isolated from access of word forms. (See Levelt, Schriefers, Vorberg, Meyer, Pechmann, & Havinga, 1991, and Dell & O'Seaghdha, 1991, for further empirical and theoretical explorations of this controversial topic.)

Another aspect of Garrett's theory that has been questioned is the notion that positional level planning frames include both inflectional affixes and function words. Stemberger (1985) observed the occurrence of inflectional exchanges, an event that should not be possible according to the original Garrett architecture (that is, because inflections are intrinsic parts of the frame, it should not be possible for them to move). And using a syntactic priming technique (to be described in more detail in Section IV), Bock (1989) reported that positional level frames with different prepositions (a particular type of function word) were interchangeable, indicating that they are not necessarily part of the frame.

Yet, despite these challenges, it is clear that more than just the outlines of Garrett's original architecture for language production are still widely assumed in current models. For example, the Bock and Levelt model (1994; see also Bock, 1995) consists of three main parts: a message level component, where the semantic intention behind an utterance is developed; a grammatical component, where the syntactic structure is encoded; and a phonological component, where the sound of the utterance is created. The grammatical component has two distinct subparts: A place where functional processing takes place, and a place where positional processing occurs. In the former module, lexical (lemma) selection occurs along with function assignment (establishment of grammatical roles such as subject and object). In the second module, lexical retrieval takes place (retrieval of word forms), together with constituent assembly (fleshing out of phrase-sized frames). Thus, clearly, the broad outlines and even many of the details of the original Garrett model survive even more than twenty-five years later.

Earlier, I made the point that not all linguistic theories of grammar are compatible, and that the theory a psycholinguist adopts has implications for the processing that is assumed to take place. (For example, if one's theory of grammar does not include traces of moved constituents, then one does not need a mechanism in processing to keep track of phrase-trace referential dependencies.) Here I will note that the influence perhaps might go the other way as well—that is, from production theories to assumptions about linguistic representation. What I have in mind is that many current and prominent theories of syntactic production assume that, at the functional level stage of processing, grammatical roles such as subject and object are assigned to lemmas (and the constituents which they head). Interestingly, not all theories of linguistic analysis treat grammatical roles as primitives: Theories such as relational grammar and lexical-functional grammar do, but all the versions of generative grammar (the original Standard Theory, the Extended Standard Theory, Government and Binding Theory, and Minimalism) do not. Does the widespread adoption of grammatical roles as explanatory constructs for language production imply that they are indeed critical linguistic representations, such that any linguistic theory that eschews them is inadequate? In the next section, I will describe a computational model of grammar that follows generative grammars in not assuming that grammatical roles are representationally primitive. As will be seen, the structure-creating mechanisms allow lemmas (and associated syntactic structure) to be organized into positions in which they receive interpretations corresponding to subject, object, and so on, but this occurs without explicitly assigning those labels during processing. This approach has other interesting properties as well that make it perhaps appropriate as inspiration for a detailed model of syntactic encoding. I will now describe this computational model and offer proposals for how it can be adapted to explain normal language production.

III. Tree-Adjoining Grammar (TAG)

Despite what one might assume from the name “Tree-Adjoining Grammar”, TAGs are really a formal meta-language in which to express syntactic generalizations (Frank, 1992). One can adopt the basic Principles and Parameters theory associated with Chomsky and his colleagues (Chomsky, 1986, 1991) or the more recent Minimalist framework (Chomsky, 1992, 1995), for example, and work with TAG as well. The reason for this is that a theory like Principles and Parameters or Minimalism provides the syntactic analyses, including information about the sorts of empty categories that exist and the constraints on their occurrence, as well as the structure of phrases and clauses. A computational grammar like TAG instantiates those analyses in a formal notation (which I will describe below). Thus, it is possible to use TAG and assume the Minimalist framework, a Lexical-Functional Grammar framework (Bresnan, 1982), or some other theoretical system for capturing syntactic analyses. It turns out that most computational linguists working with TAG have assumed a largely Principles and Parameters / Minimalist framework, and so the analyses I will examine will do so as well.

In the TAG approach, a grammar is a set of objects and a set of operations that manipulate those objects (Frank, 1992). The objects are termed *elementary trees*.

Elementary trees are primitive syntactic units consisting roughly of a lexical head and the argument(s) the head licenses. For example, the tree below is an elementary tree[1]:

```
2)  CP
     2
  C     IP
         2
   DP      I'
            2
       I       VP
                2
           V       DP
           |
          read
```

The verb *read* is the lexical head and it licenses two arguments—a subject and an object. Thus, elementary trees are prototypically clause-like. Indeed, they are often described as corresponding roughly to a simple clause (Kroch, 1987), and as being similar to Chomsky's (1955) original kernel sentences (Frank, 1992). The operations that manipulate elementary trees combine them in two different ways: by processes known as *substitution* and *adjoining*. Intuitively, substitution is similar to an appending operation: one elementary tree is attached to the bottom node of another elementary tree. The adjoining operation essentially inserts a special type of elementary tree inside another elementary tree.

[1] Throughout this chapter, I will be using the following syntactic conventions and abbreviations. First, I will assume the analysis of clauses presented in Chomsky (1986), according to which a clause is an Inflectional Phrase (abbreviated as IP), and a full clause including the node for a complementizer is a Complementizer Phrase (CP). I will not include clausal machinery involving tense or agreement, simply because those structures are not relevant to the discussion here. Finally, I will assume Abney's analysis of noun phrases as Determiner Phrases (DPs). Other abbreviations are fairly standard: NP for noun phrase, PP for prepositional phrase, and VP for verb phrase.

More precisely, an elementary tree consists of a simple semantic predicate plus positions for its arguments. Frank (1992) has formalized this definition as the Condition on Elementary Tree Minimality (CETM): Every elementary tree consists of the extended projection of a single lexical head. The tree below gives an example:

```
3)
 [VP]
   2
[V]   CP
       2
  C      IP
          2
   DP       I'
             2
        I       VP
                 2
            V        DP
            |         2
          read   [D]      [NP]
```

The nodes not in boxes are all part of the same elementary tree. Those nodes are allowed because of the notion *extended projection*. An extended projection of a head includes not just the nodes that the head obviously projects to (i.e., the VP node in the case of the lexical head V) but also its "functional projections"—nodes such as I(nflection) and its projections, C(omplementizer) and its projections, and depending on one's theory of clausal structure, A(greement), T(ense), and its projections (Chomsky, 1986; Pollock, 1989). The nodes in boxes are excluded from this elementary tree because their inclusion would not meet the CETM. The boxed VP and V nodes are excluded because the lexical head *read* does not license them; the boxed V takes the lower clause as its argument, not the other way around. The D and NP nodes at the bottom of the tree are excluded as well because the head *read* licenses the argument positions but does not license the internal content of those phrases. Thus, it should be clear at this point that inserting arguments into those argument positions will require some sort of grammatical operation (substitution, as it will turn out).

Elementary trees come in two basic types: auxiliary trees and initial trees. An example of an auxiliary tree is given in (4):

4)

```
   CP
    2
 C    IP
       2
  DP     I'
          2
      I      VP
              2
          V      CP
          |
        thinks
```

The important feature of this type of tree is that the root node (CP) is identical to one of the non-terminal nodes. This feature allows these trees to be recursive: The matrix clause takes a clause as complement to the verb. Of course, an auxiliary tree can be recursive on some other node—for example, the matching nodes might be NP, which would allow embedding of a noun phrase inside of another noun phrase. When I discuss the operation of adjoining below, the importance of this property will become clearer, above and beyond the obvious need for any grammar to provide a formalism to capture recursive embedding. Initial trees are simply all the elementary trees that are not auxiliaries. Initial trees do not by themselves permit recursion. An example of an initial tree is given in (2), which illustrates a transitive structure. (5) gives an example of an initial tree with an intransitive structure:

5)

```
     CP
      2
  C       IP
           2
   DP        I’
              2
        I         VP
                   |
                   V
                   |
                 slept
```

Thus, these different basic syntactic frames correspond to different elementary trees—a transitive frame (2), an intransitive frame (5), a clausal complement frame (4)—and what determines the form of the frame is the lexical head (verb in each of these cases). One can view these trees, then, as bits of phrase structure appropriate for different lexical heads given their different argument-taking properties.

Although, as stated above, the prototypical elementary tree is clausal (i.e., consists of a verb and its argument positions), clearly some tree types are required that are not. For example, as shown in (3), the actual content of a phrase such as the nominal argument of a verb is not specified in the tree that includes that verb, due to restrictions imposed by the CETM. Therefore, there must be elementary trees for such phrases, as shown in (6):

6)

```
    DP
    2
D       NP
```

The lexical head is the determiner, D.

Adjunct phrases are also elementary trees. An example is given in (7), a structure that would correspond to a phrase such as *after Tom left* in the sentence *Mary closed the blinds after Tom left*:

7)

```
    VP
     2
VP      PP
         2
     P       CP
```

The lexical head in this case is the preposition, P. Note that this structure projects beyond just the PP all the way to VP. The justification for this degree of projection would take us too far afield here, but is assumed by Frank (1992) based on the work of Grimshaw (1991). Of course, an elementary tree for a clause could never include an adjunct phrase, because adjunct phrases are defined as phrases not licensed by a head (in this case, the verb). Therefore, the inclusion of any adjunct in a sentence requires a syntactic operation that combines a clausal elementary tree with another elementary tree for the adjunct.

So far, we've seen that TAG assumes the existence of elementary trees as primitive syntactic objects. The other component of TAG is the operations that manipulate those trees: substitution and adjoining. Substitution is straightforward: One elementary tree is inserted at the bottom of another tree. The restriction on this operation is that the root node of the tree to be inserted must match the label on the node at the insertion site. For example, the tree in (6) is labeled DP at its root, so it can be inserted into the tree given in (2) by substitution, yielding (8):

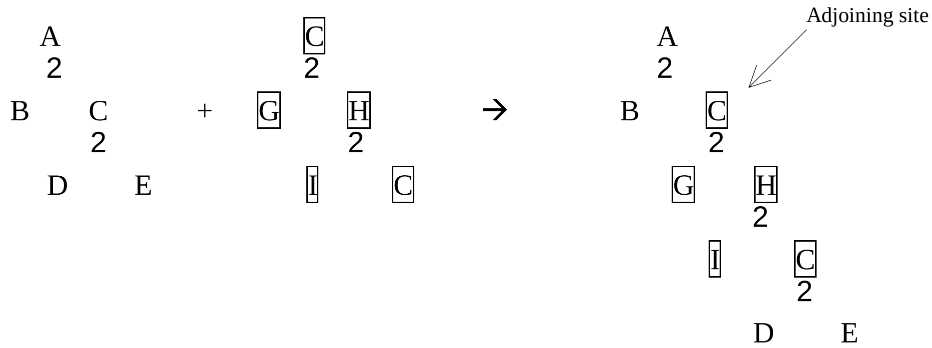
8)

CP
2
C IP
2
DP I’
2
I VP
2
V DP
2
$\boxed{\textit{D}}$ $\boxed{\textit{NP}}$

The nodes corresponding to the original (6) are surrounded by boxes. The term substitution highlights one feature of this operation: The DP node at the bottom of (2) is in some sense substituted with the root node from (6) (or vice versa). As stated above, substitution is used to insert arguments into argument positions, including clausal complements as well as DPs such as *the book*.

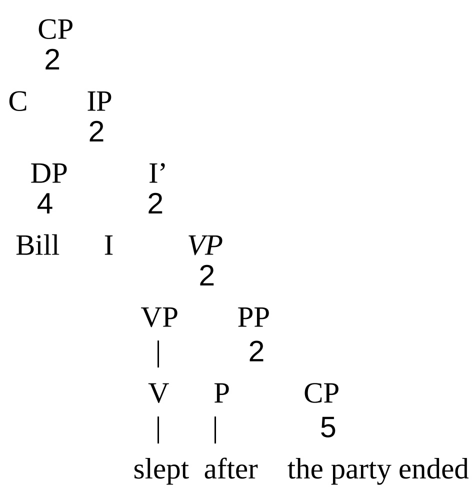
The second operation is adjoining, which allows one tree to be inserted inside another. In (9) this operation is shown schematically:

9)



Adjoining is important because it allows a number of different sorts of syntactic structure to be created. One type is a structure including an adjunct phrase. Recall that an adjunct phrase has the structure shown in (7). Let's assume an elementary intransitive clause such as (5). To create a sentence such as *Bill slept after the party ended*, these two elementary trees would be adjoined as follows:

10)



This structure now carries the critical information that the PP *after the party ended* is not an argument of the verb *slept*, because it is not sister to that head.

Adjoining is also the means for creating the so-called "raising" structure—sentences such as

11) Pat is likely to leave.

The description of how this works will reveal not only how raising structures are derived, but will also begin to address the important question of how and to what extent empty categories are used in TAG. A sentence such as (11) is made up of two elementary trees, as shown below:

12)

```
        IP                          I'
        2                           2
    DP      I'*                  I       AdjP
    4       1                    |          2
    Pat    I   VP                is     Adj      I'
           |    |                        |
          to    V                      likely
                |
              leave
```

Following convention, the adjoining site has been indicated with an asterisk. Notice that the tree headed by *leave* represents the information that *Pat* is the subject of leaving. Now the two structures are adjoined at the asterisked node, and the result is given in (13):

13)

```
        IP
        2
  DP         I'
   4          2
  Pat    I     AdjP
         |          2
        is   Adj       I'
               |         1
             likely   I    VP
                      |     |
                     to    V
                            |
                          leave
```

An intriguing effect of this operation, then, is that the raising structure can be represented without any sort of empty category. In theories of grammar that assume empty categories for this structure, the subject *Pat* would be co-indexed with the empty subject of the infinitive in order to maintain the thematic relationship between *Pat* and the action of leaving. In TAG, this representational tool is not necessary because the relationship is stated in the original elementary tree, and the operation of adjoining merely "stretches" the relationship. In the language of TAG, the "local structural relation between the subject and its associated clause has been stretched during the adjoining operation" (Frank & Kroch, 1995, p. 121). Thus, we see one important property of TAG: Fewer empty categories are used when a theory such as Principles and Parameters / Minimalism is translated into the meta-language of TAG.

In a similar vein, wh-movement also involves a more economic use of traces in TAG than in other syntactic theories. For example, a sentence such as

14) What do you believe Tom dropped

is created by adjoining the two elementary trees shown in (15).

15)

```
     CP                                           C'
     2                                            3
  DPi    C'*                                 C          IP
   |      2                                  |          3
what  C      IP                              do    DP         I'
             2                                     4          3
        DP       I'                                you    I         VP
        4        2                                                  3
      Tom   I       VP                                         V          C'
                    2                                          |
               V        DP                                   believe
               |        |
            dropped     ti
```

The result is (16):

16)

```
           CP
           3
      DPi         C'
       |          3
     what   C          IP
            |          3
            do    DP         I'
                  4          2
                 you    I        VP
                                 2
                             V        C'
                             |        2
                          believe  C      IP
                                          2
                                     DP       I'
                                     4        2
                                    Tom   I      VP
                                                 2
                                             V       DP
                                             |       |
                                          dropped    ti
```

The tree on the left in (15) is an initial tree, and the adjoining site is indicated with an asterisk. The tree on the right is an auxiliary tree (recursive on C’). The initial tree uses an empty category to represent the thematic relationship between the wh-word *what* and the verb *dropped*. Thus, TAG does not eschew the use of traces entirely. However, when the trees are adjoined, there is no need for the intermediate traces employed in theories like Principles and Parameters / Minimalism—just as in the case of raising structures, the local relation between the wh-word and the post-verbal position is stretched when the two trees are combined. As Frank and Kroch (1995) point out, then, any computational burden associated with unbounded wh-structures (e.g., *Who did Mary say that Tom knew that Susan drove …*) comes not from the need to perform multiple instances of wh-movement, but rather comes from the need to perform several adjoining operations. An implication of this idea is that the computational burden associated with a sentence such as *Who did Mary say that Tom knew that Susan likes* is predicted to be no greater than for a similar sentence without wh-movement such as *Mary said that Tom knew that Susan likes eel*.

In summary, the TAG approach assumes the existence of a set of primitive syntactic objects—elementary trees—which have interesting properties that might be useful for a theory of syntactic production. Elementary trees are retrieved as a single chunk. Within this chunk are represented all dependency relations. For example, the relation between a wh-phrase and its thematic position is stated within a single syntactic chunk. Another important type of relation is the one that exists between a head such as a verb and its associated arguments, and these connections are also all included in an elementary tree. In addition, elementary trees contain information about what sorts of further syntactic entities they may take, because required positions are explicitly represented. For example, a tree such as (2) states the need for a DP to occur in subject position and another in object position. An auxiliary tree such as (7) makes clear that it requires a VP to which it can adjoin. The operations of substitution and adjoining also may be interesting from the point of view of a psychological theory of syntactic production. One useful aspect of these operations is that they obviate the need for some empty categories—intermediate wh-traces and traces in raising structures, for example. Another intriguing possibility is that the two operations might differ in how easily they can be performed—substitution might be easier than adjoining because it requires less effort to simply attach a tree to the bottom of another tree than to actually insert a tree into the middle of another. These and similar ideas will be explored further as we discuss the psychological literature on syntactic production. I turn to this topic next.

IV. Production of syntax

How do speakers make syntactic decisions? Addressing this question forces us to consider the psychological mechanisms that underlie our ability to combine words to form communicatively appropriate sentences. The types of syntactic decisions I will consider here include the following: First, I'll discuss how speakers arrive at a particular syntactic form for a sentence. Second, I'll consider speakers' ability to make two different constituents within an utterance agree properly. A third important question concerns the domain over which syntactic planning takes place. Here, I'll review the literature demonstrating that the planning unit for syntax appears to be roughly clausal. The goal of this section will be not just to review the existing literature but also to indicate how the results can be understood from the perspective of TAG.

A. Speakers' Choice of Syntactic Form—Lexical Influences

Most languages allow speakers to convey the same propositional content in more than one syntactic way. For example, consider the proposition that a particular adult human male named Tom quoted a particular adult human female named Mary. This idea may be expressed as either

17)

a. Tom quoted Mary

b. Mary was quoted by Tom.

Syntactic analysis has revealed the existence of these different structures—the active in the case of (17a) and the passive in the case of (17b)—and has provided important descriptions of their properties. (Of course, other ways to convey this same idea exist beyond the two shown here—for example, *It was Tom who quoted Mary*—but corresponding to the state of the empirical literature, we will limit our discussion to just a few basic syntactic forms, including actives, passives, and dative structures.) The question for psycholinguists is, given these options, what factors influence the decision to choose of one of these structures during the on-line production of an utterance?

Bock and her colleagues have conducted a number of studies designed to address this question. To understand this work, it is important to begin with the way Bock reformulated the question to make it more amenable to a processing-based analysis: Instead of asking what factors determine the choice of syntactic form, Bock asked what factors influence the choice of entity to occupy the subject position of an utterance. This re-conceptualization of the problem is significant, because it changes the question from one that assumes a speaker has the communicative intention to select a particular syntactic structure to one that assumes the speaker makes a decision about just one constituent of that structure—the subject—with that decision then having consequences for the rest of the sentence's form. Linguists have long noted that the subject position of a sentence is privileged. For example, Keenan and Comrie (1977) argued for a hierarchy of grammatical positions, with subjects at the top, followed by direct objects and then indirect objects (Bock & Warren, 1985). Correspondingly, psychologists have found evidence that the first mentioned entity in a sentence is better remembered than entities in other sentential positions (Gernsbacher, 1988, 1995; for a review, see Gernsbacher, 1990), and that information shared between speaker and hearer tends to occur earlier than information that is new (Haviland & Clark, 1977). Thus, one might expect speakers to place known, available, and salient entities in subject position.

In numerous experiments, Bock has found evidence for just this tendency—concepts that are more prototypical, more concrete, more animate and generally more activated tend to be syntactically encoded so as to occupy earlier syntactic positions (Bock, 1986a, 1987a; Bock & Warren, 1985; Kelly, Bock, & Keil, 1986; for a review, see Bock, 1987b). We will use the term "available" to capture all these different characteristics. With a regular agent-patient verb such as *quote*, for instance, if the agent is more available than the patient, the agent will grab the subject position of the sentence and the overall form will then be active; if the patient is more available, then it will take the subject position and the overall form will be passive. I will describe just one of the important studies illustrating this tendency. Bock (1986a) investigated whether semantically primed words would tend to occur earlier in a sentence. Participants were shown pictures demonstrating transitive actions such as lightning striking a church, and their task was to describe the picture. Before the picture was presented, one component of the action or the other (*lightning* or *church*) was primed with either a semantically or a phonologically related word (for example, for *lightning*, the prime was either *thunder* or *frightening*; for *church*, the prime was either *worship* or *search*). Results showed that speakers preferred to place the semantically primed word in subject position. As a consequence, if the word *thunder* were presented as a prime before the picture was shown, speakers tended to say *lightning was striking the church*; if the word *worship* were given as the prime, speakers tended to produce *The church was struck by lightning*.

Interestingly, the effect of the phonological prime was different—in Bock (1986a), the prime had little effect, although there was a non-significant tendency for the phonologically primed entity to occur late in the sentence. Bock (1987) used a different sort of phonological prime (rather than priming with a word that rhymed, the prime began with the same initial phonemes as the target word) and found that the same tendency reached conventional levels of statistical reliability—the phonologically primed word reliably occurred towards the end of the sentence. She concluded from this study that the phonological prime made the concept less available, and this inhibition caused the word to occur late in the sentence. She argued further that this result challenged the notion that the syntactic production system is organized with information flowing only from higher to lower levels of processing. Instead, it appears that a source of information from later in the information processing sequence was able to influence a syntactic decision, a result that runs counter to certain views of information encapsulation (Fodor, 1983). A crucial assumption of Bock's account is that phonologically related words are connected by inhibitory links, as embodied in some connectionist models of the lexicon. However, a great deal of experimental evidence runs contrary to this assumption. For example, numerous studies have shown that the processing of a word is facilitated when it is preceded by one that is phonologically related (e.g., Collins & Ellis, 1992; Grainger & Ferrand, 1996; Hamburger & Slowiaczek, 1996; Radeau, Morais, & Segui, 1995; for a review see Lupker & Colombo, 1994). Therefore, it is not clear how viable Bock's account is. I will argue later in the paper for a different explanation of the same effect.

In general, then, it appears that the availability of concepts influences syntactic form. A more available concept will tend to be subject, and the rest of the sentence's structure will be adjusted appropriately. Another way to think about this is as follows: The speaker wishes to convey some propositional content. For some reason, one of the several components of that proposition is most available—for example, the patient is highly available because it the topic of the discourse. The sentence production system begins working on this available piece right away, following the principle of incrementality. The grammatical encoder does the first thing it can do with an entity for a brand new utterance—it makes it a subject. The production system now has few options for encoding the rest of the utterance: The verb must occur after the subject and the object must occur after the verb; and because the patient is the subject, the overall structure must be set up as a passive.

Can this sequence of events be described more precisely using TAG? I suggest that it can. Again, imagine a proposition in which someone named Tom in the past quoted someone named Mary. This representation may be captured as in (18), using the standard notation assumed in theories such as that of Kintsch (1974; Kintsch & Van Dijk, 1978):

18) quote (Tom: agent, Mary: patient, PAST)

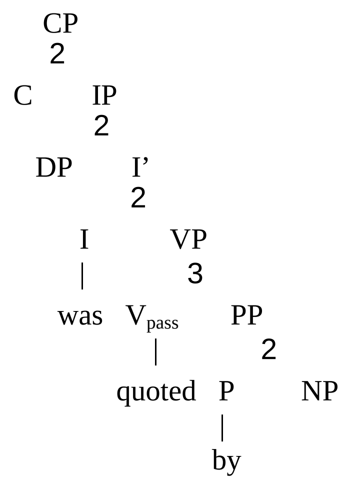
Now assume that the concept MARY is highly available. This concept can immediately be syntactically encoded. The nominal entity MARY is identified by the grammatical encoder as a determiner (see Levelt, 1989, for details concerning how this translation is effected), and a determiner is the lexical head of a determiner phrase. Thus, an elementary tree such as the one shown in (19) can be retrieved:

19)

```
      DP
      2
  D       NP
  |
Mary
```

The propositional structure given in (18) is now used to retrieve the appropriate clausal frame for the utterance. The concept QUOTE constrains the grammatical encoder to select an elementary tree headed by the verb *quote*, and the information that the patient *Mary* has already been grammatically encoded as subject requires that the passive form of the verb be selected. Thus, the elementary tree that would be retrieved is one that includes the passive verb *quoted* as the lexical head:

20)



Now the elementary tree (19) can be inserted into the elementary tree in (20) by the operation of substitution. The DP node at the bottom of (19) is the same as the label on the root node of (18), and so substitution is legal. Because the passive structure requires a PP after the verb (for the agentive by-phrase), the DP could have substituted into the DP node serving as object of the preposition *by*. However, the principle of incrementality insures that the substitution will occur at the earliest position possible—the subject position. The result now is the tree shown in (21):

21)

CP
2
C IP
2
DP I’
| 2
D I VP
| | 3
Mary was V_{pass} PP
| 2
quoted P DP
| 4
by Tom

The last step is to retrieve an elementary tree for the object of the preposition in (21). A DP tree headed by the lexical head *Tom* is selected and then inserted into (21) by substitution. The syntactic representation for this sentence is now complete. Of course, as soon as the first NP for the sentence becomes available—that is, as soon as the DP *Mary* is inserted into the elementary tree for the clause and consequently encoded as subject—the phonological encoder began working on converting this syntactic structure into a format suitable for the articulators. This assumption follows from the principle of incrementality, which as defined in the introduction to this paper states that different levels of processing can work on different pieces of an utterance at the same time. Thus, the phonological encoder can work on the early part of the clause while the syntactic encoder works on filling out what remains. As a result, once the syntactic representation for the sentence is done, its corresponding phonological representation is likely close to complete as well.

The view of syntactic production that has been outlined here has a number of interesting properties. First, because this model allows bits of syntactic structure to be retrieved complete with slots for functional elements, much of the work described in Levelt (1989) that is associated with creating slots for those elements is avoided. For example, Levelt describes a special procedure that fills in the slots for functional elements such as determiners. These special procedures are termed *functional procedures*, which contrast with what he terms *categorial procedures*—procedures that build syntactic structures based on activated lexical items. The model I am proposing does not require functional procedures because those functional elements are part of the elementary tree. Second, the model neatly captures a property Levelt refers to as resonance. In his model, the retrieval of a lexical head such as the verb *give* causes the information that an object should occur to be activated as well, and the NP slot is thus created. At the same time, once the lexical head of this object is known, it too builds an NP slot by projecting up from itself. As Levelt notes, then, there are two ways that a phrasal node may be created. A phrasal node such as DP after a verb could get made because the verb takes a DP, and so the verb predicts the existence of that DP slot; or, the DP slot could be built because the head of that DP "projects up" to its corresponding DP node. However, in the present model, both of these methods for creating phrasal nodes happen in parallel. Again, consider the case of a direct object slot after a verb. That DP slot would exist in a clause-sized elementary tree because the tree is retrieved on the basis of the verb, and that tree would include all the proper slots for arguments (by the CETM). At the same time, when the lexical head of that DP becomes available, it brings along its appropriate elementary tree. Then, the DP elementary tree is attached to the clausal elementary tree by substitution. Thus, the current model describes why these two ways of creating a phrasal node might occur, and also does not require the system to choose between them—both happen at the same time.

A final important property of this model of syntactic production is that it provides a critical role for the main verb of the sentence. Here, the model contrasts sharply with that of Levelt. According to Levelt, when an initial nominal element becomes activated, it projects not only to its N and NP nodes, but also to the sentence node. As a result, the grammatical encoder can create a subject tree (the nodes for the N, the NP, and the IP node dominating the NP) before the verb is even known. Indeed, the same process may occur with no more than a determiner—from the dominating D node the DP node can be built, and an IP node immediately above it. Furthermore, because sentence production is incremental, this unit consisting of just the subject may be phonologically encoded before the verb is made part of the syntactic representation. The model I have advocated here does not allow this degree of incrementality. There is no way for the NP or DP to encode the information that it is the subject of a sentence because of the CETM—the NP or DP node does not license the dominating IP node. Furthermore, there is no way for a nominal element to select for a particular verb at the same time, because again, a noun cannot take a verb as its argument. Thus, if a concept such as MARY becomes activated, a DP structure may be created, but no more—the creation of further syntactic structure must await the activation of the appropriate elementary tree headed by the verb.

This property, of course, can be viewed as either a strength or weakness of the model. Many researchers in language production such as Levelt and Bock have argued strongly for incrementality, and so it might seem a weakness that this model does not allow an initial DP or NP to be encoded grammatically as a subject until the verb for the sentence is known. However, whether this is indeed a weakness depends on what we know from empirical work on sentence production. It turns out that several studies provide evidence for the view described here. F. Ferreira (1994) found that whether a concept is encoded as a subject depends critically on the properties of the verb. Lindsley (1975) demonstrated that language production cannot begin until at least some information about the main verb of the utterance has been selected. Kempen and Huijbers (1983) drew conclusions similar to those of Lindsley. Finally, Meyer (1996) has obtained evidence that information about even the post-verbal arguments of simple utterances are retrieved prior to articulation. We will review each of these studies in turn.

F. Ferreira (1994) investigated the possibility that the choice of active or passive syntactic form would be influenced by the properties of the sentence's main verb. Consider a verb such as *like*: In an active sentence such as *Mary liked Tom*, the experiencer *Mary* occurs before the theme *Tom*. Many theories of sentence meaning (Kintsch, 1974; Jackendoff, 1972, 1987, 1990) assume that thematic roles are organized in an ordered list, with agents and experiencers at the top and patients and themes at the bottom. Thus, the active structure might be favored given a verb such as *like* because the active allows the thematic role higher in the hierarchy—the experiencer—to occur in the more prominent syntactic position—the subject. Now consider "theme-experiencer" verbs such as *frighten*. For these verbs, the active structure places the theme in subject position and the experiencer in object position, as in *The thunder frightened Tom*. Thus, the active structure demotes the more prominent thematic role. It might be expected, then, that the passive structure will be somewhat more preferred with theme-experiencer verbs than with normal verbs, because for the former the passive allows the more prominent thematic role to occur in the earlier syntactic position—the subject position. As evidence for this possibility, consider that the sentence *Tom was frightened by Mary* is much more natural than the sentence *Tom was liked by Mary*. This observation provides at least intuitive evidence that passive are better with theme-experiencer verbs than with normal verbs. In F. Ferreira (1994), I provided experimental evidence consistent with this intuition: Passives occurred on fewer than 5% of trials when the verb was normal, and this percentage did not differ depending on whether the two arguments of the verb were both animate or one animate and the other inanimate. In contrast, with theme-experiencer verbs, passives occurred on about 15% of trials when the two arguments of the verb were animate and about 30% when one was animate and the other inanimate.

In short, the decision whether to make a particular nominal concept a subject depends critically on the verb. Indeed, it is striking that with normal verbs, it made no difference whether a concept was animate or inanimate—speakers did not want to produce passives regardless of the animacy of the nominal concepts. But with theme-experiencer verbs, the animacy contrast exaggerated the tendency to create passives. This study demonstrates, then, that a nominal concept cannot by itself be encoded as the subject of a sentence. The concept may be encoded as a DP or an NP, but then that entire elementary tree can only be inserted into an elementary tree for a clause headed by a verb once the verb is accessed. The work done by the principle of incrementality is that it forces the DP to move into the earliest syntactic position possible—the subject position.

More specifically, assume that a concept such as TOM has become highly available, and imagine further that it is the experiencer of some action. This concept leads to retrieval of a DP elementary tree such as (19) (but with *Tom* as the head). This unit must now sit in a *syntactic buffer*—a structure proposed by Levelt (1989) for holding bits of syntactic structure that are waiting for units on which they are grammatically dependent. Now imagine that the concept corresponding to the main verb is activated, and that this verb is of the theme-experiencer variety—for example, the verb *frighten*. The propositional representation for the entire utterance shows that the experiencer has already been syntactically encoded. Given that entities higher on the thematic hierarchy like to occur in earlier syntactic positions, the passive form of the verb *frighten* is now likely to be activated so as to allow the experiencer to be the subject. An elementary tree for the passive structure will be retrieved, headed by *frighten*. Now the subject *Tom* is plugged into the tree by substitution, and the result is that the words *Tom was frightened* are grammatically encoded. This sequence may now be sent to the phonological encoder. At the same time, the remaining nominal concept is the basis for the retrieval of another DP, and that DP is inserted into the elementary tree headed by *frighten*. This tree includes the PP as well as the head *by* (those nodes are a part of the elementary tree because of the CETM), and so the DP is inserted, again by substitution. The rest of the sentence may now be phonologically encoded. The sequence of operations would not be much different given a normal verb such as *like*: If an experiencer became available first, a DP elementary tree would be retrieved, and then it would be substituted into an elementary tree headed by the normal verb. In this case the tree would be active, because that is the structure that permits the experiencer to occur in the subject position of the sentence.[2]

[2] Of course, this description assumes that important other factors are held constant—for instance, discourse. Clearly, the preferences that F. Ferreira (1994) uncovered can be overridden if a sufficient amount of context is provided.

As stated above, Lindsley (1975) conducted a study that supports this view that an initial sentence NP cannot be phonologically encoded until the main verb of the sentence is known. Lindsley asked participants to respond as quickly as possible to a simple picture showing a transitive action (e.g., one person touching another). They were to produce utterances consisting of just the actor, just the action, or a combination of the actor and action. Initiation times for the utterances consisting of the actor plus action were longer than for utterances consisting of just the actor, but no longer than for utterances consisting of just the action. In a second experiment, Lindsley asked the participants again to describe transitive events, but they were to use utterances consisting of either just the actor and action or the actor, action, and object. These two types of utterances took participants the same amount of time to initiate. From these results, it appears that speakers begin to phonologically encode their utterances before they have syntactically encoded the object of a transitive action but not before they know the verb. These results are consistent with the model I have described—the syntactic encoder can represent some NP as a subject only once it has retrieved the elementary tree for the entire clause (headed by the verb) and substituted that NP into the clausal structure. At the same time, the content of the post-verbal arguments is not relevant. Thus, the model assumes what we might term moderate incrementality: The production of the subject of a sentence depends on the particular verb but does not depend on the characteristics of the postverbal arguments.

Kempen and Huijbers (1983) conducted a study similar to Lindsley's, but they exploited an important and potentially useful property of Dutch: Utterances may take the form either of subject plus verb (as in English) or verb plus subject (which occurs rarely in English declaratives). The task of the speakers in their experiments was to describe simple displays of pictures with one utterance type or the other, and initiation times were recorded. A further manipulation involved changing the verb from one block of trials to another, in order to assess the effects of verb planning and retrieval on utterance preparation time. Kempen and Huijbers found that changing the verb increased latencies for both types of utterances, but more for the verb-subject than the subject-verb utterances. This pattern of results suggested an interpretation similar to the conclusion drawn by Lindsley: An utterance cannot be articulated until the subject as well as some aspects of the verb are computed. Kempen and Huijbers proposed that the verb's lemma (its semantic and syntactic features) must be retrieved, but articulation does not need to wait for information about the verb's phonological form. Again, it appears that only a moderate version of incrementality can be sustained: Speakers must have lemma information about the subject and its verb before beginning to speak. This empirically based conclusion is consistent with the model I have outlined here: Even if information about a DP is accessed early, that DP cannot be grammatically encoded as the subject of a sentence until the verb (and its elementary tree containing the subject slot) has been retrieved.

Meyer (1996) used a word distractor paradigm to examine how much information about the words of an utterance is accessed prior to articulation. In a couple of her experiments, speakers (of Dutch) produced simple utterances such as (the Dutch equivalents of) "the arrow is next to the bag". In addition, they were presented with a spoken distractor that was either semantically or phonologically related to either the first or second noun (arrow or bag). Meyer found that a semantic distractor for either noun increased initiation times, while a phonological distractor impaired performance only when it was related to the first noun. Meyer concluded that sentence production requires the retrieval of the semantic/syntactic information associated with most of the utterance, but only requires the retrieval of phonological information for the first word or phrase. Thus, Meyer's experiments provide evidence that grammatical encoding is even less incremental than the results reviewed above suggest: Speakers appear to encode information about both preverbal *and* post-verbal material. Of course, no conclusions about the verb can be drawn given that distractors for the verb were not presented. The paradigm likely made it impossible to present such distractors, because it would have been difficult for speakers to avoid using any other verb besides "is", which is semantically and phonologically rather impoverished. In addition, it is possible that the simple nature of the utterances as well as the argument structures associated with the verb *is* led speakers to grammatically encode as far as the post-verbal arguments in these experiments. Also, as Meyer argues, the circumstances of speaking might affect how carefully participants in experiments plan their utterances, and the conditions of her studies might have made participants careful (although it is important to note that participants were asked to begin to speak as quickly as possible). Still, the results of Meyer's experiments support the model of syntactic production based on TAG that I have described here, because they demonstrate that speakers need more than just the subject of a sentence before they can begin to produce their utterances.

Finally, Roelofs (1998) conducted seven experiments to test his model of language production. A critical assumption of this model is rightward incrementality--

serial, left-to-right encoding of utterances. The Dutch participants were required to produce verb-particle constructions such as *opzoeken* (to look up), and the stimuli in a trial set either shared the initial, particle component of the utterance (as in the immediately preceding example) or the later, verb component. The logic was that if the production system is rightward incremental, then times to initiate the utterances should be facilitated in the former condition but not the latter. This prediction was confirmed, and the pattern of results was taken to support the notion that speech production is indeed incremental. But while these results are clearly important and intriguing, they do not necessarily bear on the issues under discussion here. First, it is important to note that the experiments most likely do concern speech production rather than creative sentence production, because the participants were retrieving small utterances from memory rather than formulating them. Second, the main question that has been examined in this section is whether a sentence can be initiated before the speaker knows the main verb. The Roelofs experiments do not speak to this issue, because the utterances consisted of just a single verb.

B. Speaker's Choice of Syntactic Form—Syntactic Priming

Speakers have a tendency to repeat a particular syntactic form. For example, if they have just described a transitive action using a passive structure, then they are likely to describe a subsequent transitive event also using the passive form. This effect was demonstrated by Bock (1986b), who had speakers listen to a sentence with a certain form, repeat that same sentence, and then describe a picture. For example, participants would receive a sentence such as *The referee was punched by one of the fans* and then a picture showing lightning striking a church. She found that speakers were more likely to say *The church is bring struck by lightning* in this case than in a condition in which they were primed with *One of the fans punched the referee*. The same effect held for prepositional and double-object dative structures: Speakers were more likely to say (for example) *The man is reading the boy a story* if they had just heard *A rock star sold an undercover agent some cocaine*. Bock also found that the priming effect was not enhanced by the semantic similarities between the prime sentence and the concepts shown in the pictures. In a follow-up study, Bock and Loebell (1990) found that the priming effect was no greater when prime and targets shared the same thematic role structures than when they did not. From these results, Bock concluded that there is a stage of sentence production where just the structural form of an utterance is decided, and that in addition, the structures created during production are frequency sensitive.

Another implication of these results that has not been addressed in the literature on language production is that they challenge extreme forms of incremental production. The priming results imply that there is a point during production where the entire syntactic form of a sentence is available to be influenced by its prior presentation. If a syntactic structure for a sentence is simply built up in little bits that are immediately converted into phonological units, then it is not clear when a representation containing the entire sentence's global syntactic form would be available to be primed. Thus, it appears that the syntactic priming effect obligates us to assume a point in syntactic encoding where a large chunk of syntactic structure is simultaneously available. Again, a model of grammatical encoding that is based on TAG may provide an explanation. Recall that, according to this model, when the main verb of a sentence becomes available it brings with it an elementary tree consisting of all of that verb's extended projections—that is, the entire clausal structure. Thus, even without having the content of all the arguments of the verb known, the availability of a verb also makes available the entire clause's overall syntactic form—whether it is active or passive, a prepositional or double-object dative, and so on. Furthermore, the finding that syntactic priming is independent of lexical (Bock, 1989), thematic (Bock & Loebell, 1990), and general semantic content (Bock, 1986b; Bock, Loebell, & Morey, 1992) is expected on this model as well: Recall that the elementary tree headed by a verb may not include the internal content of any of the arguments included in that tree. Thus, the priming effect could not be affected by the above factors, because the type of tree available to be primed does not include any of that information. The only thing that may be primed is the number, configuration, and maximal projection labels of the verb's arguments, and Bock's studies demonstrate that this information is just what gets primed during sentence production.

A TAG-based model of syntactic production, then, provides an account of Bock's syntactic priming effect: Elementary trees can be primed. This conclusion suggests that not just clausal trees (i.e., trees headed by verbs) may be primed but other structures may be as well. This prediction is difficult to test in English because English has such a rigid word order, particularly at the level of phrases. However, it might be possible to test this prediction in languages with freer word orders. For example, the prediction that elementary trees can be primed implies that the presentation of a sentence with an adjective before a noun could lead a speaker to produce another sentence with the adjective and noun in the same order. Again, a language like English allows only prenominal adjectives, but languages such as French or Portuguese allow adjectives to occur either before or after the noun (with some corresponding slight changes in meaning, but this is no different than for the active/passive alternation, for example). Cross-linguistic research should allow this intriguing prediction to be tested. One intriguing preliminary result comes from a recent study by Hartsuiker, Kolk, & Huiskamp (1999), which demonstrated that surface order in Dutch can be primed. Participants were presented either with “On the table is a ball” or “A ball is on the table”, and Hartsuiker et al. found that the same order tended to be used in a picture description task. Notice that this finding does not necessarily show that within-phrase ordering can be primed (instead, what is at issue is the order of two large constituents with respect to each other), but it is useful for providing evidence that priming can occur even when the variations do not differ in grammatical relations. In addition, it is precisely what one would expect based on the TAG model I have presented, because although both orders would be headed by *is*, each would have its own elementary tree.

Finally, Pickering and Branigan (1998) employed a novel paradigm for examining syntactic priming in production. Unfortunately, it relied on the creation of written rather than spoken utterances: Participants read a fragment of dative sentence which was to serve as a prime (or more than one, in some conditions), and their task was to complete it. For example, the participant might see *Mary gave the book*__, and the most natural completion would be a prepositional phrase. Then, the same participant received just a subject and dative verb, and his or her task was to complete the sentence. Priming occurs when the form of this latter sentence matches that of the prime(s). Pickering and Branigan observed that the priming effect was smaller but still present when the prime and target sentences employed different verbs. In addition, the amount of priming was the same regardless of whether the verb in the prime and target were of the same tense, aspect, or number. These results can be accommodated by the TAG model I have presented, as long as we introduce a further, critical concept in the approach. TAG assumes that elementary trees are organized into what are termed “families”. Families are clusters of related elementary trees. For instance, all elementary trees that are ditransitive and include a noun phrase and a prepositional phrase as postverbal arguments are part of the same family. Similarly, variations on the same basic tree headed by the same lemma (i.e., the differences associated with the same verb but in different tenses, and with different aspects) are also grouped together. Thus, one would expect that the priming effect is not just from trees that are identical to each other; instead, it makes sense that priming would occur across similar trees, and those similarity relations are captured by the notion of tree families.

C. Subject-Verb Agreement

Languages require different elements of a sentence to agree with one another. For example, in Portuguese, a phrase such as *O pequeno menino* (the small boy) requires agreement among all three words—all must be singular and masculine. English uses inflectional morphology to a much lesser extent than many other languages and so overt agreement is not as prevalent. Still, the number of a determiner and noun must agree (i.e., *those boys* versus **those boy*), and the form of some verbs and their subjects must agree also. For example, if a phrase such as *The boys* is the subject of the verb *to have* or *to be*, the head noun and the verb must agree in number. This process becomes especially interesting given that the head noun may be indefinitely separated from the verb with which it must concur. For example, consider a phrase such as *The boys that Mary and Tom saw at the circus*. The head noun is *boys*, but several other nouns occupy the subject NP too. Does the speaker ever get distracted by those nouns and produce a sequence such as *The boys that Mary and Tom saw at the circus is*...?

Bock has investigated this question in a number of experiments (Bock & Cutting, 1992; Bock & Eberhard, 1993; Bock & Miller, 1992). All employed the same paradigm: A spoken noun phrase such as *the keys to the cabinet* was presented to participants, and the participants' task was to repeat the phrase and complete the sentence. On many trials speakers produced a verb that requires overt agreement, and on some of those trials they made errors. Bock and Miller (1991) found that mistakes were rarely made, but those that did occur showed a particular pattern—errors were more frequent when the subject noun phrases contained a singular head noun and a plural distractor noun than when phrases contained a plural head noun and a singular distractor noun. Bock and Eberhard (1993) argued from this result that plurality is an explicitly marked feature while singularity is not. The overt plural feature on the distractor noun can become unbound from it and migrate up to the dominating NP (or DP) node. As a result, the speaker would produce an utterance with improper agreement between the subject and verb.

More relevant to the current discussion is the work of Bock and Cutting (1991), showing that agreement errors of this type are much less likely to occur if the head noun is separated from the verb by a clause rather than a prepositional phrase. Bock and Cutting contrasted agreement processes in phrases such as

(22)

a. The report of the destructive fires

b. The report that they controlled the fires.

The phrase in (22a) includes a prepositional phrase while the phrase in (22b) includes a relative clause. Recall from the discussion earlier that an elementary tree consists of a lexical head and all its extended projections. For (22a), the elementary tree for this DP would include the prepositional phrase, because the noun *report* takes the PP as its argument. In contrast, for (22b), the clause would not be included because it is merely a modifier of the head noun. Therefore, in (22a) the potentially interfering noun *fires* is part of the same elementary tree headed by the noun *report*; in contrast, in (22b), the potentially interfering noun *fires* is part of a different elementary tree (headed by *control*) which is inserted into the NP tree by the substitution operation.

Bock and Cutting (1992) found that agreement errors occurred more often given phrases such as (22a) compared with (22b). They argued that this result followed from the notion that clauses are in some sense independent planning units. The relative clause would be planned separately from the part of the phrase including the head, and so these two parts of the phrase would not be simultaneously present and so would not be available to interfere with one another. That is, even if the plural feature migrated from the final noun of the NP, it could not land on the head noun because the two are never co-present in memory. In contrast, the prepositional phrase and head noun would be simultaneously present and so the plural feature on the distractor noun *fires* could end up on the head noun. The approach I am advocating using TAG translates this account into an explanation invoking elementary trees. Because the phrase in (22a) is made up of one elementary tree headed by *report*, the head and local noun are part of the same structure and so are simultaneously available; but because the phrase in (22b) is made up of two elementary trees, one headed by *report* and the other by *control*, the two nouns are less likely to interact.

Not only does an account employing elementary trees provide an account of this result, it also leads to an interesting and highly testable prediction. The account depends critically on the notion that the noun *report* takes a prepositional phrase argument—that is, the PP is part of the elementary tree headed by *report* because it is an argument of *report*, and so its inclusion is required by the CETM. I would predict, then, that an experiment comparing agreement for NPs including PPs but differing in their argument/adjunct properties would show different results. Consider the phrases shown in (23):

(23)

a. The leader of the troops

b. The leader with the troops.

The model using elementary trees predicts that agreement errors will occur less often for (23b) than for (23a), because the phrase *with the troops* is not an argument of *leader* while the phrase *of the troops* is. This prediction does not follow from the account Bock and Cutting gave of their data, because their explanation relies entirely on the difference between PPs and clauses. Thus, I have outlined the basis for an experiment to distinguish between this proposal and the one given by Bock and Cutting, and I have shown that my explanation does not merely a translation of their terminology into the language of TAG.

D. Planning Units

The issue to be addressed in this section is, what is the unit of syntactic encoding? In other words, how much of the syntactic information of an utterance must be available in parallel before the utterance can be spoken? This question came up earlier in this chapter in the section addressing how the activation levels of lexical items influence a speaker's choice of syntactic form. There I argued that although an available nominal concept might have an affinity for the subject position of a sentence, that assignment actually occurs in two steps. First, the nominal concept is translated into a noun, which leads to retrieval of an elementary tree headed by the noun. Second, the NP is inserted into the subject position of an elementary tree headed by a verb (by the operation of substitution). I provided empirical evidence for this view based on my own work as well as the experiments of Lindsley (1975) and Kempen and Huijbers (1983), all of which demonstrate that a sentence is not produced until the verb's lemma is accessed. Thus, according to this research, the "planning unit" for an utterance includes at least the sentence's verb and whatever argument(s) precede it.

Other sources of evidence suggest that the planning unit is larger—perhaps the size of an entire simple clause. For example, Garrett (1975, 1976, 1980) argued from word exchange errors such as

(24) I left the briefcase in my cigar

that the syntactic structure of a sentence is planned over the domain of a verb together with its arguments. The evidence for this conclusion is that such errors involve words from different phrases (the arguments of the verb) but rarely from different clauses. And in several studies in which speakers talked freely about topics of interest to them, Ford and Holmes also found evidence for clause-sized planning units. Ford and Holmes (1978) asked participants to respond to tones as they spoke, and found that reaction times were longer for tones at the end of what they termed deep clauses (clauses consisting only of a verb and its arguments). Ford (1982) examined spontaneous speech for pauses longer than 200 ms and found that they preceded about 20% of deep clauses. She concluded that speakers plan an upcoming deep clause during the production of the last few syllables of the current clause; if that time is not sufficient for planning, then they hesitate. Because pause duration was unaffected by the number of upcoming deep clauses, Ford concluded that speakers planned no more than one deep clause. Holmes (1988) asked speakers to talk spontaneously on various topics and then asked another group of participants to read the utterances the former group produced. She found that pauses and hesitations occurred before complement and relative clauses in spontaneous but not read speech. This result provides further evidence for the conclusion that speakers plan in units roughly the size of a deep or simple clause: When speakers formulate their sentences they often pause not only at the start of a sentence but also before a clause that might be embedded inside that sentence. If participants are merely reading, then they pause much less often and almost never before embedded clauses.

Thus, the experimental work conducted by F. Ferreira (1994), Lindsley (1975), and Kempen and Huijbers (1983) suggests that speakers syntactically encode their utterances up to about a clause's main verb. The research examining spontaneous speech (both speech errors and pauses) indicates that speakers syntactically encode an entire simple clause. Although both types of studies support the notion that the planning unit for an utterance is larger than a word or phrase, they differ somewhat in what the size of that unit actually is. Can the results be reconciled? One important difference between the two types of studies is that the ones providing evidence for the smaller unit all employed experimental tasks in which speakers received the raw ingredients for some part of their utterances (a picture or a few critical words) and then produced sentences as quickly as possible. In this sort of paradigm, each utterance might be viewed by the participant as a sort of performance, with a premium placed on reducing as much as possible the latency to initiate that performance. These circumstances might make the speakers less likely to take the time they normally would to plan their utterances. The non-experimental studies do not impose these sorts of constraints on the speakers. Data from speech errors are obtained simply by noting the botched utterances when they are produced, and the pause data came from speakers who were constrained by no more than a discussion topic. It is possible, then, that in the normal case people grammatically encode over the domain of a simple clause, but if they are rushed they truncate planning at the earliest possible point—once the verb for the utterance is known.

What are the implications of these conclusions for the TAG-based model of syntactic planning I have been advocating in this chapter? To begin, let us recall that the elementary tree is the fundamental unit of TAG, and that each elementary tree is centered around its lexical head. Although there are therefore many different types of elementary trees (corresponding to the different types of heads), it is reasonable to propose that the type headed by the verb is pivotal for syntactic production, because such trees provide a global skeleton for the utterance. (Indeed, section II describing the fundamentals of TAG points out that the clause is assumed to be the prototypical elementary tree.) The conclusion that speakers plan in units consisting of simple clauses can then be straightforwardly accounted for within the TAG framework: The critical syntactic chunk that must be retrieved for any utterance is the elementary tree headed by the verb. This entity provides the lexical head itself (intrinsically bound to the tree), the maximal projection labels for all the head's dependents, and any necessary traces. Retrieval of this unit takes some processing resources, and occasionally the time spent in articulation of a clause is not sufficient to allow retrieval of the elementary tree for the next. In those circumstances, a pause of some sort is required. A word exchange error such as (24) might occur when the clausal elementary tree is retrieved but the DP arguments of the verb are bound to the wrong argument positions. This view correctly predicts that verbs will not participate in word exchange errors, because they are an intrinsic part of the clause's skeleton and so can not be unbound from it. The actual content of the verb's arguments must be inserted into the tree, and so it is possible for the system to err by inserting the DP/NP elementary trees into the wrong argument positions. Finally, if the speaker is put into a situation in which he or she feels pressured to speak quickly (as in the standard experimental paradigm in which a stimulus is presented which the speaker must describe as quickly as possible), then planning will be limited to the smallest possible domain. The TAG approach to syntactic planning predicts that the smallest domain will have to include the verb, and so for English declarative sentences speakers may begin to speak once they know just the first NP and the main verb.

Not only does the TAG approach to syntactic production explain results already obtained, it also makes an intriguing prediction. Recall that in TAG, adjunct phrases are never part of an elementary tree for a clause. This restriction follows from the CETM, which specifies that an elementary tree may include only a head and its arguments. Thus, all adjunct phrases must be added by syntactic operations—operations to encode both their phrasal structure and their lexical content. One might expect, then, that adjuncts would be preceded by a pause more often than arguments. F. Ferreira (1988) compared pause durations before these two types of phrases and found support for this prediction. However, the speakers in these experiments did not produce the sentences spontaneously, and so the tendency to pause before adjuncts could be attributed to phonological or stylistic factors rather than to the need to plan. It is clear what needs to be done: Spontaneous speech should be examined to assess whether pauses occur more often before adjuncts than before arguments of comparable length and complexity.

V. Syntactic Production Based on TAG

In this section I will give an explicit description of how syntactic production takes place according to the TAG-based approach I have been advocating. In addition, I will contrast this model with one proposed by Levelt (1989), which is probably the most explicit and best-known in the area of language production. The critical representational assumption of the model I have proposed here is that syntactic structure is built up from primitive syntactic templates, each based on a single lexical item. A template is retrieved when its head is activated. The only primitive lexical content to the template is the head. All other material must be inserted by a syntactic operation, and so the other lexical items must be bound to their appropriate syntactic positions. It is reasonable to assume that this binding process requires resources, and that it can sometimes go awry (as in word exchange errors).

The production of an utterance begins with a message that is translated into a propositional representation—a formal representation of the utterance's meaning. The proposition specifies whether the utterance describes a state or an event; it is organized into a function-argument structure in which (usually) the main verb is the function and the rest of the proposition includes its arguments (including tense and aspect); it includes information about which argument is the topic (i.e., old information); and each nominal is specified in terms of definiteness, number, and thematic role. When a concept is activated, its corresponding lemma is activated as well. The lemma is translated into a syntactic head, and retrieval of that head brings along its associated elementary tree. The thematic role of any activated nominal concept that has been syntactically encoded determines which form of the verbal lemma becomes activated—active, passive, prepositional dative, double-object dative, and so on. Retrieval of the verb leads to retrieval of the syntactic skeleton for the whole clause. Any already constructed argument is inserted into the clause at the earliest possible point. This is the work the principle of incrementality does in this model—it ensures that the phrase is bound to the leftmost matching position (by substitution). At this point, the utterance could be sent to the phonological encoder and articulated. Meanwhile, any remaining arguments are grammatically encoded as well—the elementary trees based on each lexical item are retrieved and then inserted into the tree. If an adjunct phrase is part of the propositional representation (see Kintsch, 1974 and Jackendoff, 1990 for propositional notations that distinguish arguments from adjuncts) it is separately encoded and then inserted into the clausal elementary tree by the adjoining operation. The syntactic form is complete once each constituent of the propositional representation is grammatically encoded.

Let's take an example utterance: "The dog bit a flower". The propositional representation (expanded from the one shown in (18)) would look something like the following:

(25) event: BITE(def/1/agent/topic: DOG;

indef/1/patient: FLOWER;

past)

According to this proposition, the topic is a definite, single dog. An event of biting took place in the past. The topic of the utterance is the agent of the action (the dog), and the thing bitten was an indefinite single flower. This proposition contains three concepts that can be translated into lexical heads: BITE, DOG, and FLOWER. Assume that the concept corresponding to DOG is activated first (a plausible assumption given that it is the topic of the sentence). Activation of that concept causes retrieval of a lemma for DOG that is a single, definite noun. Retrieval of that lemma brings along its associated elementary tree, an NP (or DP—it makes no difference for our purposes). The agent thematic role in the proposition can be checked off as grammatically encoded. The NP is placed into the syntactic buffer, where it awaits the retrieval of a clausal elementary tree.

Assume next that the concept corresponding to the verb is activated. The lemma for BITE is therefore retrieved. Because the proposition specifies that the action happened in the past, a past tense version of the verb will be accessed. And because the proposition also indicates that the agent has been grammatically encoded, the verb will also be in its active form. Retrieval of the past, active form of the verb brings along an elementary tree including the verb and instantiating a past tense, active syntactic structure. This tree contains two NP slots, so the NP in the syntactic buffer can be retrieved and inserted into the clausal elementary tree. The principle of incrementality makes it likely that the phrase will go into the leftmost NP slot, and so the NP *The dog* will be grammatically encoded as subject. At this point, because the first entity of the sentence is now grammatically encoded, a piece of the utterance (consisting of the subject plus verb) can be sent along for phonological encoding. What remains from the proposition is the patient of the action. The concept corresponding to FLOWER leads to retrieval of a lemma for FLOWER that is indefinite and singular, and this lexical head brings along an indefinite NP structure. This NP is bound to the only remaining NP slot in the clausal elementary tree, and the grammatical encoding of the utterance is now complete.

Let's consider another example. This one will illustrate the advantages of assuming only a moderate degree of incrementality. Imagine that someone wants to express the idea that a particular trunk (of a car) was the location in which a particular singular male placed a body. The propositional representation would look something like the following:

(26) event: PUT (def/1/agent: MAN; def/1/theme: BODY; def/1/location/topic: TRUNK; past)

Because the trunk is the topic, it is likely to be available first. Its conceptual features lead to retrieval of a singular, definite, noun lemma, and that brings along a corresponding elementary tree for a singular, definite NP headed by *trunk*. The thematic role LOCATION can be checked off as grammatically encoded. The NP is placed in the syntactic buffer. Now assume that the lemma for the action of putting becomes available. Because a location was grammatically encoded first, two lemmas for the action of putting will be retrieved (and their corresponding elementary trees): Both are past tense, but one is active and one passive. It's possible that the active structure is more activated because it is used more frequently[3], but still two trees are available now in parallel. However, neither of the trees allows a location to be placed in subject position—the lexical semantics of the verb *put* are such that the argument corresponding to a location cannot be a subject. (*Put* contrasts with a verb such as *contain*, which does allow locations to be subjects, as in *The trunk contains the body*.) The system now has two options: One is to wait for another argument to be syntactically encoded. It will be either the agent or theme, both of which can occur in subject position. If the agent becomes available instead of the patient, it will move into the leftmost position (by incrementality) of the active syntactic

[3]As Bock (1986b) notes, one implication of syntactic priming is that the production of syntactic structure is frequency sensitive. The priming results show immediate and probably transient effects of frequency; however, it is likely that the overall frequency of use of some structure affects its accessibility during production.

structure; if the patient becomes available instead of the agent, it will move into the leftmost position of the passive syntactic structure. Whichever structure is not chosen will lose activation (either by passive decay or through a process of active inhibition; data sufficient to decide between these possibilities are not available) and the grammatical encoder will now have a single clausal elementary tree with the subject and verb slots filled.

Notice that if the system did not wait for the verb but instead immediately made nominal entities into subjects, it would attempt to create an utterance like “The trunk was put the body by the man”, or something along those lines. Because the grammatical encoder waited for the verb, it received in time the information that the location argument could not be the subject of the utterance. Thus, the model I have presented here does not allow the system to create sentences violating the fundamental rules of the language. And as Bock (1982) and Levelt (1989) have argued, any adequate theory of language production must explain how speakers produce sentences conforming to the language’s syntactic constraints, as an overwhelming percentage of utterances are grammatically appropriate.

Another important characteristic of the model I have proposed here is that it assumes that syntactic encoding is not necessarily a serial process—instead, all syntactic structures compatible with a given lemma are activated at one time. As more information becomes available, competing lemmas drop out until only one structure is left by the time grammatical encoding is complete. Normally, activation of a nominal lemma together with a particular verb will uniquely determine a clausal elementary tree. However, the above paragraph outlined one circumstance in which clausal trees could be activated in parallel. Another circumstance is one in which two nominal lemmas are equally available. In this case, the speaker might be disfluent at the beginning of the utterance, as the production system tries to choose between them (for example, by waiting for some other lemma to become available that forces the choice between the structures).

Is there evidence relevant to the question whether more than one syntactic tree is activated in parallel? At this point, only one study has been conducted to explore this question, and it appears to support a serial view of syntactic production. V. Ferreira (1996) presented speakers with a sequence consisting of a nominative pronoun plus a verb, and then nouns that were to be used for the remainder of the utterance. The main manipulation was whether the verb permitted more than one arrangement of the postverbal nominal arguments—that is, either the verb was a dative such as *give* or a non-alternator verb such as *donate*. Participants were asked to produce sentences as quickly as possible using all the words they were provided on a computer monitor. V. Ferreira found that participants produced utterances faster and with fewer errors when they were given an alternator verb.[4] He argued that the results were inconsistent with a model in which multiple syntactic structures for a verb are activated and compete. This conclusion is based on the assumption that competition takes time to resolve and should be reflected in longer and more error-prone responses. On this view, initiation times should have been longer in the alternator verb condition, because the alternator verbs would activate two syntactic structures, and resolution of the competition between them should have taken

[4] A few other manipulations of syntactic choice were used by V. Ferreira (1996). For example, he varied whether one of the nouns presented after the subject plus verb combination was marked as accusative. The logic is that the inclusion of the case-marked pronoun removes any syntactic flexibility afforded by the verb. As the results for all his flexibility manipulations were similar, I will focus just on the data from dative and non-alternator verbs.

time. Instead, the alternator condition was faster than the condition in which only one syntactic structure could be grammatically produced. V. Ferreira argued that these results support an incremental model of production: Speakers opportunistically select syntactic structures based on the activation states of lexical items, and so syntactic flexibility is helpful to the production system because choices allow it to quickly adjust to a particular lexical item's activation state.

On the face of it, this study appears to provide evidence against the model I have argued for here. Fortunately, it does not. The present model can account for the fact that activated words tend to occur early in sentences. The assumption of moderate incrementality states that an activated NP will sit in the syntactic buffer until a verb becomes available, but then it will move into the first syntactic position provided by the verb's elementary tree—the subject position. Thus, this model allows the activation states of lexical items to determine syntactic form quickly, as does the model V. Ferreira assumes. Indeed, the V. Ferreira study allows us to clarify some important properties of the present model. I assume that multiple syntactic structures will be available only when lexical activation states are not sufficient to uniquely specify a single structure. Under most typical speaking circumstances, lexical items will become available at different points and to different degrees, and so syntactic structures will be dynamically pruned away until only a single one remains. Thus, the results obtained by V. Ferreira support the general model I have described here—a model that allows both moderate incrementality and the activation of multiple syntactic structures. Availability of lexical items influences syntactic positioning, which then leads to the immediate deactivation of syntactic forms not consistent with that positioning.

The TAG-based model can account for the effects of the various priming manipulations that have been used in experiments on language production—semantic, syntactic, and phonological. First, a semantic prime mimics the effect of some concept being a topic. Normally, the thing that is under discussion—the topic—will be the most available concept, and so it will be grammatically encoded first and will end up as the subject of the sentence (because of moderate incrementality). A semantic prime is simply an artificial way of making some concept active, as it would be if it were a topic. Second, a syntactic prime affects syntactic form because it affects which clausal elementary tree for a particular verb gets selected. Again, because most experiments do not provide any reason for making any particular concept a topic, speakers can do one of several things. Speakers may select randomly; they may use a heuristic such as making the leftmost entity in the picture the first constituent of a sentence; or they may default to the most frequent structure (typically an active clause). A syntactic prime minimizes the chances that the speaker will choose any of these strategies, because it provides some activation for one of the competing syntactic forms. So if a participant in an experiment has just encountered a passive sentence and then has to describe a transitive action depicted on a computer monitor, he or she might produce the passive because it is activated by the prior retrieval of a passive. (Indeed, although the priming effect is statistically reliable, it is quite a small effect, suggesting that the other strategies described here are quite compelling.)

What about the phonological prime? Here I will make good on the promise I made earlier in the paper to reinterpret Bock's (1986a, 1987a) finding that phonological primes under some conditions cause the primed word to occur late in a sentence. According to some interpretations of this effect (e.g., Bock, 1987a), this finding challenges modularity, because a source of information from late in the information processing sequence is able to affect syntactic form (which presumably is decided earlier). Bock's explanation of the effect of phonological primes is predicated on the notion that the links between phonologically related words are inhibitory rather than excitatory; and because the word is inhibited, it is not available to be encoded as an early constituent of the sentence. Therefore, there must be some feedback in the system, because the ultimate syntactic form of a sentence is responsive to the phonological states of one of the words.

However, the result could be taken to indicate that the system is not incremental, rather than that it is not modular. If the system were incremental in the extreme, then a phonologically primed word should occur early in a sentence—after all, it is highly available, and so if it were articulated the production system could get on with encoding the rest of the utterance. Instead, it appears that the language production system does not want to produce a word in the absence of any other information about the utterance. After all, the system does not know whether a determiner is required, whether the phrase is definite or indefinite, and of course it does not yet have the elementary clausal structure of the utterance (because the main verb is not yet known). Under these circumstances, the language production system might actively inhibit the word in order to prevent it from being produced, and that inhibitory state might cause the word to be the last one grammatically encoded. Under this view, the inhibition of the phonologically primed word is not attributed to passive spreading activation in a network in which phonologically related words are connected by inhibitory links (and indeed there is some evidence that phonological primes facilitate processing of the related word; Costa & Sebastian-Galles, 1998; Zwitserlood, 1996); instead, the word is actively squelched by the language production system.

Implicit in the model I have outlined here are some critical attentional mechanisms. Attention plays a role in binding non-clausal elementary trees into the clausal elementary tree. Attention is used to monitor which thematic roles in the proposition have been grammatically encoded and which remain. And now we see that attention inhibits a word that becomes available for articulation too early. Clearly, an important next step in exploring whether this TAG-based model of production is viable is to specify explicitly what these attentional mechanisms are, how they work, and how they are related to the sorts of mechanisms about which a great deal is known in other areas of cognitive science (e.g., visual attention).

How does the model I have proposed here contrast with another well-known model of grammatical encoding, the one proposed by Levelt (1989)? Levelt's model assumes the existence of a propositional representation, and assumes that the activation levels of concepts that make up that proposition (as those activation states unfold in real time) determine the order in which lemmas are retrieved. The syntactic structure for a lemma is created as soon as a lemma becomes available, and the maximum amount of structure is created at that point. Levelt's model is lexically based—syntactic structure is projected from the lemmas themselves. Therefore, lemmas are inherently bound to their syntactic homes. Syntactic pieces are sent to the phonological encoder as soon as they are available, in accordance with the principle of incrementality. Therefore, rarely is the entire syntactic form for an utterance or its constituent lemmas available in working memory.

The model I have proposed here also assumes that an utterance is generated from a propositional representation. Concepts making up the proposition become differentially activated, but one important determinant of activation levels is whether one concept is marked as topic. If one is, it will be the most available concept and so will have a strong affinity for the subject position of the utterance. The verbal concept determines which verb lemma becomes available (active, passive, dative, and so on), and so which elementary tree(s) is(are) retrieved. All possible elementary trees compatible with a verbal lemma are accessed, with their activation levels depending on their frequency of use. As grammatical encoding unfolds, ultimately only one clausal elementary tree remains activated, and it determines the ultimate form of the sentence. Elementary trees for syntactic entities other than clauses must be inserted into the clausal tree, and the order of their insertion is determined by availability. Binding phrases to their appropriate clausal positions presumably takes resources, and errors may occur (if, for example, not enough resources are allocated to the task). All of the syntactic structure for a simple clause is simultaneously present; and even if an utterance is phonologically encoded at the earliest point possible (once the subject plus verb are available), the overall syntactic nodes for the verb’s arguments will still be simultaneously present in working memory.

References

Bock, J.K. (1982). Toward a cognitive psychology of syntax: Information processing contributions to sentence formulation. *Psychological Review*, *89*, 1-47.

Bock, J.K. (1986a). Meaning, sound, and syntax: Lexical priming in sentence production. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *12*, 575-586.

Bock, J.K. (1986b). Syntactic persistence in language production. *Cognitive Psychology*, *18*, 355-387.

Bock, J.K. (1987a). An effect of the accessibility of word forms on sentence structure. *Journal of Memory and Language*, *26*, 119-137.

Bock, J.K. (1987b). Coordinating words and syntax in speech plans. In A. Ellis (Ed.), *Progress in the psychology of language* (pp.337-390). Hillsdale, NJ: Erlbaum.

Bock, J.K. (1989). Closed-class immanence in sentence production. *Cognition*, *31*, 163-186.

Bock, J.K. (1995). Sentence production: From mind to mouth. In J.L. Miller & P.D. Eimas (Eds.), *Speech, language, and communication: Handbook of perception and cognition*, Vol. II, 2nd ed. (pp. 181-216). San Diego: Academic Press.

Bock, J.K., & Cutting, J.C. (1992). Regulating mental energy: Performance units in language production. *Journal of Memory and Language*, *31*, 99-127.

Bock, J.K., & Eberhard, K.M. (1993). Meaning, sound, and syntax in English number agreement. *Language and Cognitive Processes*, *8*, 57-99.

Bock, J.K., & Levelt, W.J.M. (1995). Language production: Grammatical encoding. In M. Gernsbacher (Ed.), *Handbook of Psycholinguistics* (pp. 945-984). New York: Academic Press.

Bock, J.K., & Loebell, H. (1990). Framing sentences. *Cognition*, *35*, 1-40.

Bock, J.K., Loebell, H., & Morey, R. (1992). From conceptual roles to structural relations: Bridging the syntactic cleft. *Psychological Review*, *99*, 150-171.

Bock, J.K., & Miller, C.A. (1991). Broken agreement. *Cognitive Psychology*, *23*, 45-93.

Bock, J.K., & Warren, R.K. (1985). Conceptual accessibility and syntactic structure in sentence formulation. *Cognition*, *21*, 47-67.

Bresnan, J. (1982). *The mental representation of grammatical relations*. Cambridge, MA: MIT Press.

Carreiras, M., Gernsbacher, M. A., & Villa, V. (1995). The advantage of first mention in Spanish. *Psychonomic Bulletin & Review 2*, 124-129.

Chomsky, N. (1955). *The logical structure of linguistic theory*. Indiana University Linguistics Club, Bloomington, IN.

Chomsky, N. (1981). *Lectures on government and binding*. Dordrecht, the Netherlands: Foris.

Chomsky, N. (1986). *Barriers*. Cambridge, MA: MIT Press.

Chomsky, N. (1991). Some notes on economy of representation and derivation. In R. Freidin (Ed.), *Principles and parameters in comparative grammar*. Cambridge, MA: MIT Press.

Chomsky, N. (1992). A minimalist program for linguistic theory. *MIT Occasional Papers in Linguistics*, *1*.

Chomsky, N. (1995). *The minimalist program*. Cambridge, MA: MIT Press.

Collins, Alan F. & Ellis, A. W. (1992). Phonological priming of lexical retrieval in speech production. *British Journal of Psychology, 83*, 375-388.

Costa, A., & Sebastian-Galles, N. (1998). Abstract phonological structure in language production: Evidence from Spanish. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *24*, 886-903.

Dell, G.S., & O'Seaghdha, P.G. (1991). Mediated and convergent lexical priming in language production: A comment on Levelt et al. (1991). *Psychological Review*, *98*, 604-614.

Dell, G.S., & Reich, P.A. (1981). Stages in sentence production: An analysis of speech error data. *Journal of Verbal Learning and Verbal Behavior*, *20*, 611-629.

Ferreira, F. (1994). Choice of passive voice is affected by verb type and animacy. *Journal of Memory and Language*, *33*, 715-736.

Ferreira, F. (1988). *Planning and timing in sentence production: The syntax-to-phonology conversion*. Ph.D. thesis, University of Massachusetts, Amherst.

Ferreira, V.S. (1996). Is it better to give than to donate? Syntactic flexibility in language production. *Journal of Memory & Language*, *35*, 724-755.

Fodor, J.A. (1983). *The modularity of mind*. Cambridge, MA: MIT Press.

Ford, M. (1982). Sentence planning units: Implications for the speaker's representation of meaningful relations underlying sentences. In J. Bresnan (Ed.), *The mental representation of grammatical relations*. Cambridge, MA: MIT Press.

Ford, M., & Holmes, V.M. (1978). Planning units and syntax in sentence production. *Cognition*, *6*, 35-53.

Frank, R. (1992). *Syntactic locality and tree adjoining grammar: grammatical, acquisition, and processing perspectives*. Ph.D. thesis, University of Pennsylvania.

Fromkin, V.A. (1971). The non-anomalous nature of anomalous utterances. *Language*, *47*, 27-52.

Garrett, M.F. (1975). The analysis of sentence production. In G.H. Bower (Ed.), *The psychology of learning and motivation*, *9*, 133-177. New York: Academic Press.

Garrett, M.F. (1976). Syntactic processes in sentence production. In R.J. Wales & E. Walker (Eds.), *New approaches to language mechanisms* (pp. 231-256). Amsterdam: North-Holland.

Garrett, M.F. (1980). Levels of processing in sentence production. In B. Butterworth (Ed.), *Language production. Vol.1: Speech and talk* (pp. 177-220). New York: Academic Press.

Gernsbacher, M.A. (1990). *Language comprehension as structure building*. Hillsdale, N.J.: L. Erlbaum.

Gernsbacher, M. A., & Hargreaves, D. J. (1988). Accessing sentence participants: The advantage of first mention. *Journal of Memory & Language*, *27*, 699-717.

Grainger, J., & Ferrand, L. (1996). Masked orthographic and phonological priming in visual word recognition and naming: Cross-task comparisons. *Journal of Memory & Language*, *35*, 623-647.

Grimshaw, J. (1991). Extended projection. Manuscript, Rutgers University.

Hamburger, M., & Slowiaczek, L. (1996). Phonological priming reflects lexical competition. *Psychonomic Bulletin & Review*, *3*, 520-525.

Hartsuiker, R.J., Kolk, H.H.J., & Huiskamp, P. (1999). Priming word order in sentence production. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 52A*, 129-147.

Haviland, S. E., & Clark, H. H. (1974). What's new? Acquiring new information as a process in comprehension. *Journal of Verbal Learning & Verbal Behavior*, *13*, 512-521.

Holmes, V.M. (1988). Hesitations and sentence planning. *Language and Cognitive Processes*, *3*, 323-361.

Jackendoff, R.S. (1972). *Semantic interpretation in generative grammar*. Cambridge, MA: MIT Press.

Jackendoff, R.S. (1987). The status of thematic relations in linguistic theory. *Linguistic Inquiry*, *18*, 369-412.

Jackendoff, R.S. (1990). *Semantic structures*. Cambridge, MA: MIT Press.

Joshi, A.K. (1985). How much context-sensitivity is required to provide reasonable structural descriptions: tree adjoining grammars. In D. Dowty, L. Kartunnen, and A. Zwicky (Eds.), *Natural Language Parsing: Psychological, Computational, and Theoretical Perspectives*. Cambridge: Cambridge University Press.

Joshi, A.K., Levy, L., & Takahashi, M. (1975). Tree adjunct grammars. *Journal of the Computer and System Sciences*, *10*, 136-163.

Keenan, E.L., & Comrie, B. (1977). Noun phrase accessibility and universal grammar. *Linguistic Inquiry*, *8*, 63-99.

Kelly, M.H., Bock, J.K., & Keil, F.C. (1986). Prototypicality in a linguistic context: Effects on sentence structure. *Journal of Memory and Language, 25*, 59-74.

Kempen, G., & Huijbers, P. (1983). The lexicalization process in sentence production and naming: Indirect election of words. *Cognition*, *14*, 185-209.

Kintsch, W. (1974). *The representation of meaning in memory*. Hillsdale, NJ: Erlbaum.

Kintsch, W., & van Dijk, T.A. (1978). Towards a model of text comprehension. *Psychological Review, 85*, 363-394.

Kroch, A. (1987). Unbounded dependencies and subjacency in a tree adjoining grammar. In A. Manaster-Ramer (Ed.), *Mathematics of Language*. Amsterdam: John Benjamins.

Kroch, A., & Joshi, A.K. (1985). The linguistic relevance of tree adjoining grammar. Technical Report MS-CS-85-16, Department of Computer and Information Sciences, University of Pennsylvania.

Levelt, W.J.M (1989). Speaking: From intention to articulation. Cambridge, MA: MIT Press.

Levelt, W.J.M., Schriefers, H., Vorberg, D., Meyer, A.S., Pechmann, T., & Havinga, J. (1991). The time course of lexical access in speech production: A study of picture naming. *Psychological Review*, *98*, 122-142.

Lindsley, J.R. (1975). Producing simple utterances: How far ahead do we plan? *Cognitive Psychology*, *7*, 1-19.

Lupker, S. J., & Colombo, L. (1994). Inhibitory effects in form priming: Evaluating a phonological competition explanation. *Journal of Experimental Psychology: Human Perception & Performance*, *20*, 437-451.

Meyer, A.S. (1996). Lexical access in phrase and sentence production: Results from picture-word interference experiments. *Journal of Memory & Language*, *35*, 477-496.

Pollock, J.-Y. (1993). Verb movement, universal grammar, and the structure of IP. *Linguistic Inquiry*, *20*, 365-424.

Radeau, Monique, Morais, J., & Segui, J. (1995). Phonological priming between monosyllabic spoken words. *Journal of Experimental Psychology: Human Perception & Performance*, *21*, 1297-1311.

Roelofs, A. (1998). Rightward incrementality in encoding simple phrasal forms in speech production: Verb-participle combinations. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *24*, 904-921.

Stemberger, J. P. (1985). Bound morpheme loss errors in normal and agrammatic speech: One mechanism or two? *Brain and Language*, *25*, 246-256.

Zwitserslood, P. (1996). Form priming. *Language and Cognitive Processes*, *11*, 589-596.