JOURNAL OF MEMORY AND LANGUAGE **35,** 724–755 (1996)
ARTICLE NO. 0038

# Is It Better to Give Than to Donate? Syntactic Flexibility in Language Production

VICTOR S. FERREIRA

*University of Illinois*

This article compares the predictions of two models of grammatical encoding in language production. The basis of one model is that alternative syntactic structures compete to determine which structure is eventually used. The second model is incremental: Utterances are gradually built up, and the structure emerges from the construction process itself. If grammatical encoding is competitive, syntactic choices should pose difficulties; if incremental, syntactic choices should ease the creation of speech. These predictions were tested in three experiments where speakers created utterances which sometimes required a syntactic decision. When constructing a sentence allowed a syntactic choice, speakers generally constructed that utterance with fewer errors and more quickly. This finding supports the notion that language production operates incrementally. 

Talking is easy. At least it seems to be. Language production research attempts to characterize the processes that allow production to proceed efficiently and effortlessly. Somewhat paradoxically, much early research in production focused on speech errors and other dysfluencies—events that belie this efficiency (e.g., Butterworth, 1980; Dell, 1986; Dell & Reich, 1981; Dell & O'Seaghdha, 1992; Fromkin, 1971; Garrett, 1975; Goldman-Eisler, 1968; Holmes, 1988; MacKay, 1970, 1972; Shattuck-Hufnagel, 1979; Stemberger, 1985). As we learn more about production, though, researchers have begun to use methods that are both more experimental in nature and designed to tap productive processes while they are in progress (e.g., Bock, 1986, 1987; Bock & Loebell, 1990; Bock, Loebell, & Morey, 1992; F. Ferreira, 1994; Levelt, 1989; Levelt et al., 1991; Meyer, 1991; Schriefers, Meyer, & Levelt, 1990). Here, I will report on three experiments which use a new online method. These experiments test two alternative conceptions of utterance generation and, more generally, provide insight into why production goes as smoothly as it does.

I wish to explore the aspect of language production that involves the choices that speakers make regarding the structure of the sentences they utter. The processes that underlie these choices fall within those that are responsible for *grammatical encoding* (Bock & Levelt, 1994; Levelt, 1989). Grammatical encoding processes take a *message*, which is a conceptual representation of the idea a speaker wishes to convey, and convert it into an abstract representation that encodes the hierarchical and positional relationships among the words eventually uttered. This abstract representation subsequently undergoes phonological encoding and eventually articulation, resulting in the sounds we hear as speech.

Sentences (1) and (2) below have similar meanings but different syntactic structures. Sentence (1) exhibits a *prepositional dative*

The research reported here contributed to the author's Master of Arts degree. Portions of this work were presented at the 66th Annual Meeting of the Midwestern Psychological Association. The research was supported by National Science Foundation Grant 93-19368 (Linguistics Program) to Gary S. Dell and National Institute of Health Grant R01-HD-21011 to Kathryn Bock. The author was supported by a National Science and Engineering Research Council (Canada) Postgraduate Scholarship. I thank committee members Kay Bock and Susan Garnsey, and my advisor Gary Dell, who provided constant feedback with this manuscript. Danielle Holthaus assisted with the reliability coding. I also thank Cooper Cutting and Fernanda Ferreira for helpful discussions, and Brian Butterworth and an anonymous reviewer for very helpful comments on this paper. Address reprint requests to the author at the Beckman Institute, University of Illinois, 405 N. Mathews, Urbana, IL 61801. E-mail: vic@uiuc.edu.

0749-596X/96 $18.00

sentence structure, where the verb is followed by a noun phrase and prepositional phrase; the noun of the noun phrase (''toys'') has a *theme* thematic role, and the noun in the prepositional phrase (''children'') has a *goal* role. Sentence (2) is a *double object* structure, in which the verb is followed by two noun phrases, the first of which contains a goal and the second contains a theme:

(1) Sheila gave the toys to the children.
(2) Sheila gave the children the toys.

Examples (1) and (2) show that the verb *give* is able to occur with both a prepositional dative and a double object syntactic structure. For this reason, verbs like *give* are called *alternator* or *dative shift* verbs. When a sentence includes an alternator verb, the grammatical encoding system needs to choose whether to use a prepositional dative or a double object structure.

Verbs like *give* show that the grammar of English exhibits *syntactic flexibility*—the possibility of employing more than one syntactic structure to express a particular message. Syntactic flexibility is very common in English. Nearly every transitive sentence in English can be said in either an active or a passive voice, and the sentences corresponding to these voices have distinct syntactic structures. The research described in this paper will investigate how syntactic flexibility affects the fluency with which speakers create sentences.

## Two Models of Language Production

I will discuss two mechanisms that the grammatical encoding system might employ to choose between the syntactic alternatives posed by, for example, alternator verbs. The first mechanism is *competitive,* where the alternative structures actively compete; the winner becomes the utterance's syntactic structure. The second mechanism is an *incremental* one; according to this approach, the language production apparatus constructs an utterance in a piecemeal fashion, and this process automatically chooses between syntactic structures. I will present these two mechanisms in the context of the choice between the two structures of alternator verbs, but these mechanisms are assumed to apply to other syntactic structure choices.[1]

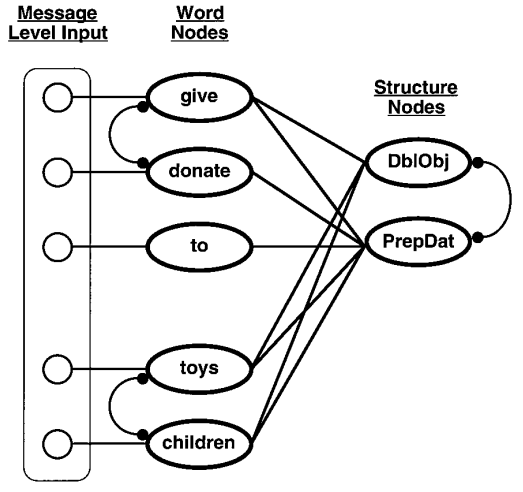


FIG. 1. Interactive activation architecture to competitively choose between alternator verb syntactic structures. (DblObj = Double Object; PrepDat = Prepositional Dative.)

### *The Competitive Model*

A competitive model of grammatical encoding claims that alternative syntactic plans actively compete to determine the produced syntactic structure. In general, a competitive model predicts that simultaneously active syntactic plans entail greater competition; thus syntactic flexibility should result in more difficult language production

An interactive activation architecture (McClelland & Rumelhart, 1981) that models the choice between the two alternator verb constructions is shown in Fig. 1 (see also Dell & O'Seaghdha, 1994). Activation spreads between

[1] The models discussed below assume that grammatical encoding is *lemma driven*—that the process of building a syntactic structure is guided by lexical information. Note, though, that the effects of flexibility—whether competitive or incremental—should occur even if grammatical encoding is not lemma driven. For example, in a model like Garrett's (1975), the mapping from the functional to the positional representation can occur in two ways with an alternator verb like *give,* and the eventual assignment to positional slots may occur either competitively or incrementally.

the nodes of the model through excitatory (straight line) and inhibitory (curved line terminated with dots) connections. Word (or lemma) nodes (e.g., ''give'' or ''toys'', corresponding to the words *give* and *toys* in a speaker's utterance) receive input from message level units, and pass activation to the syntactic structures in which those words occur. Syntactic structures are represented by the structure plan nodes, representing the likelihood of the corresponding structure being used in a sentence. (Note that the structure nodes may represent complex production processes that build, for example, X-bar sentence frames [e.g., MacDonald, Pearlmutter, & Seidenberg, 1994]. The activation of the node itself in the model is intended to abstractly represent the evidence these complex processes have accumulated.)

The model in Fig. 1 is set up to contrast alternator verbs, which participate in more than one syntactic structure, with *nonalternator* verbs such as *donate*, which participate in only one syntactic structure. Sentences (3) and (4) correspond to sentences (1) and (2). Whereas sentence (3) is a prepositional dative sentence and is grammatical, sentence (4) is a double object sentence and is not grammatical:

(3) Sheila donated the toys to the children.
(4) *Sheila donated the children the toys.

Because nonalternator verbs do not occur with double object structures, the same sentence with a nonalternator instead of an alternator verb has fewer structure options and less syntactic flexibility.

Most important in the model in Fig. 1 is the inhibitory connection between the ''DblObj'' and ''PrepDat'' structure nodes, since this connection implements the competitive aspect of the model. If the alternator verb ''give'' node is active, then activation will spread via the excitatory connections to both the prepositional dative and double object structure nodes. However, the inhibitory connection between the structure nodes forces activation in one node to suppress activation in the other. Thus, as both structure nodes' activation levels increase, the two nodes suppress one another, resulting in lower overall activation levels, and more difficulty in choosing a structure. Instead, if the ''donate'' node is active, only the prepositional dative structure node builds activation, less competition ensues, and a structure node is chosen more easily.

*Predictions of an implemented competitive model.* A simulation was constructed to explore the effects of syntactic flexibility in a competitive framework. The simulation was based on the model shown in Fig. 1 (see Appendix A for the details of the implementation). Predictions regarding syntactic flexibility were generated by clamping (fixing as ''on'') either the ''give'' or ''donate'' node, corresponding to an utterance containing either verb. (Message level input nodes for the verbs and preposition were not implemented.) Activation spreads at each time step through the excitatory and inhibitory connections. Message input for the noun arguments was introduced by clamping each of the message level nodes after a different random number of time steps. Processing halts when one of the structure nodes reaches threshold activation, and the time required for the threshold to be reached can be taken as an indication of the difficulty the model had in choosing to produce a particular utterance.

As Fig. 1 shows, the model includes a node labeled ''to.'' The purpose of this node is to model the four conditions of Experiment 1. To anticipate, Experiment 1 participants created sentences with alternator and nonalternator verbs, exploring production under flexible and nonflexible circumstances respectively. However, assessing syntactic flexibility by contrasting verb classes in this manner is problematic, since properties confounded with verb class could systematically influence the dependent measures. To avoid this confounding, the effects of flexibility were compared within as well as between verb classes. This was accomplished by forcing half of the critical utterances to contain a preposition; since simple double object utterances do not contain dative prepositions (see Example (2)), forcing an utterance to contain a preposition eliminates the possibility of using a double object

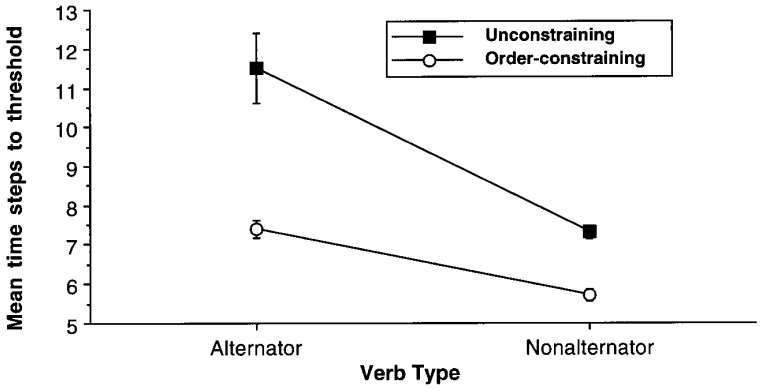


FIG. 2. Results of simulating competitive effects of verb type and preposition constraint.

structure. Thus, sentences containing alternator verbs like *give* are *not* syntactically flexible when forced to contain a preposition, since participants can only correctly use a prepositional dative sentence. Forcing a preposition into an utterance was simulated by clamping the ''to'' node shown in Fig. 1. The ''to'' node is excitatorily connected only to the prepositional dative structure node, so that clamping this node will influence the model towards settling on a prepositional dative structure.

Summarizing, four conditions were simulated by crossing the factors *verb type* and *preposition.* The *alternator* verb condition was simulated by clamping the ''give'' node, and the *nonalternator* verb condition was simulated by clamping the ''donate'' node. The preposition factor was simulated as *order-constraining* or *unconstraining* by either clamping or not clamping the ''to'' node respectively. The results of running simulations in the four conditions are shown in Fig. 2. Each data point corresponds to 10 runs of the model. Along the ordinate is the average number of time steps the model required to settle.

The model demonstrates how a competitive mechanism predicts an interaction between verb type and preposition constraint. Only the condition with simultaneously active structure nodes—when the alternator verb ''give'' node is clamped and a preposition is not forced—results in slower selection times. With nonalternator verbs, or when a forced preposition biases a prepositional dative structure, the model selects a structure node quickly.

The length of time the model requires to select a structure can be taken to reflect the overall difficulty of the structural decision, which could manifest in a behavioral task either as a greater likelihood of committing an error or as increased production latencies. Selection time is related to production error probability under the assumption that a production error is more likely to occur when the grammatical encoding system is in an unstable state. In general, the longer the model takes to select a structure, the more time the model is in a relatively less stable state. Thus, longer selection times should correspond to greater error probability. Selection time and production latency are related in a straightforward manner—a structure cannot be built until one is selected. Thus, longer selection times will result in longer production latencies.

### *The Incremental Model*

Instead of employing competitive principles, the language production system might take advantage of the sequential nature of language production to resolve its choices. This type of mechanism is described by Bock (1982; see also deSmedt, 1990; Kempen, 1987; Kempen & Hoenkamp, 1987; Levelt, 1989). According to this account, syntactic flexibility and lexical accessibility interact to determine the form of utterances.

As an example of how incremental processing operates, assume that a speaker begins with a message that could underlie sentences (1) or (2), expressing that a person named Sheila gave toys to some children. Further assume that the structure for the fragment ''Sheila gave'' has thus far been built. After the verb *give,* there are two possible items that might go in the immediate postverbal position: *toys* or *children.* If *toys* is inserted first, then grammatical encoding can proceed by eventually constructing a prepositional dative sentence (''Sheila gave *the toys* to the children.''); if *children* is inserted first, then a double object structure would eventually be built (''Sheila gave *the children* the toys''). Thus, the grammatical encoder is faced with the problem of inserting one of two possible items into the immediate postverbal position, and the item that is inserted determines which structure is eventually built.

The incremental theory postulates that the item that is most active at the time the postverbal position is to be filled is selected and thus determines which syntactic structure eventually is constructed. Lexical representations have higher activations based on discourse factors (discourse themes), lexical factors (concrete or frequent items), or effects of prior processing (semantically primed or phonologically unprimed rather than primed items), among other things (for a review of these effects, see Bock, 1982; other effects are investigated in, for example, Bock & Warren, 1985; Bock, 1986, 1987; and McDonald, Bock, & Kelly, 1993). Thus, an incremental grammatical encoder would produce a prepositional dative utterance if *the toys* is more active than *the children,* and it would produce a double object utterance if *the children* is more active than *the toys.*

Figure 3 illustrates an interactive activation model that implements an incremental mechanism at one moment during sentence construction. There are three main differences between this incremental model and the competitive model in Fig. 1, each corresponding to theoretical differences. First, an incremental theory does not require competition among syntactic structure options. This is implemented in Fig. 3 by the fact that the structure nodes are not inhibitorily connected. Thus, both structure nodes can be highly active simultaneously. Second, incrementality implies that syntactic processing cannot occur on later phrases before earlier phrases. In Fig. 3, the structure nodes of the competitive model (e.g., ''Double Object'') have been replaced with single phrase nodes that represent only the immediate postverbal phrase in the corresponding argument structure (e.g., ''NP-goal''). Thus, the syntactic structure to be built at a particular moment is only the current phrase. Third, incremental theories usually claim that syntactic structures are slots that are *available* to be filled, rather than *active* plans that influence non-syntactic processing. This is represented in the model by the absence of connections between the structure nodes and the noun argument nodes. Thus, high activation levels in structure nodes represent only the availability of that structure, and do not influence the processing that occurs with the subsequent noun arguments.

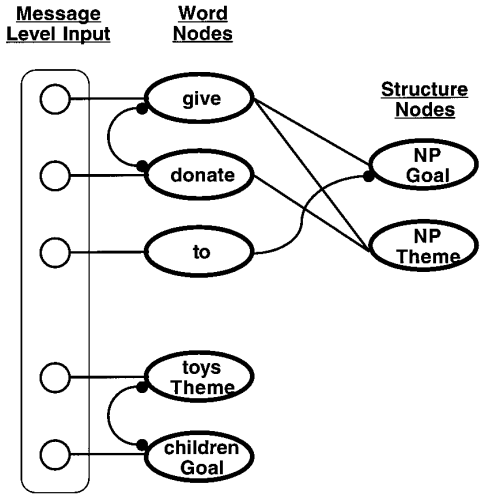


FIG. 3. Interactive activation architecture to choose between alternator verb syntactic structure within an incremental approach.

(There are also two less important differences between Figs. 1 and 3. First, the incremental model explicitly represents the binding of message level information [represented

here by thematic information] to word [e.g., ''toys-theme''] and structure [e.g., ''NP-goal''] nodes. All theories of language production are faced with this binding problem [Levelt, 1989], but representation of message level information is necessary here to implement the selectional restrictions described later. Second, the ''to'' node, which should force a prepositional dative [or NP-theme first] structure, affects processing by inhibiting the inappropriate ''NP-goal'' node rather than by exciting the appropriate ''NP-theme'' node. Thus, activation of the ''to'' node inhibits the ''NP-goal'' node, meaning only the ''NP-theme'' node will be available for selection. Since the incremental model has no competition, both structure nodes reach threshold quickly, and additional activation to an appropriate node is completely redundant. Other technical differences between the implementations are noted in Appendix A.)

*Predictions of an implemented incremental model.* The incremental model in Fig. 3 was implemented much like the competitive model in Fig. 1 (details in Appendix A), with one processing difference. Incremental theories claim that syntactic selection occurs when available slots are filled by the most highly active item, if appropriate. Selection occurred (and processing terminated) in the model when a structure node reached threshold *and* the appropriate thematic noun argument was the most highly active noun argument. Thus, the relative activation levels of the noun arguments crucially affect selection times. Recall that the noun arguments receive input from message level units, each of which are clamped beginning after a random number of time steps from the start of processing, and remain clamped for only five time steps. The results of running the model 20 times in each verb type and preposition constraint condition are shown in Fig. 4.

The results show that the incremental model makes different predictions than the competitive model concerning the effect of syntactic flexibility. The alternator/unconstraining condition—the flexible condition—results in the fastest selection times. Faster selection occurs with flexibility because only with flexibility are both structure nodes active; thus, the noun argument that happens to become active first can always be selected. In the nonflexible conditions, only the ''NP-theme'' structure node is active; thus the model can only select the ''toys-theme'' noun argument node. If the ''children-goal'' argument becomes active before the ''toys-theme'' argument, then the model must delay selection until the ''toys-theme'' node can overtake the ''children-goal'' node in activation. Overall, flexibility insulates an incremental grammatical encoding system from the effects of variable input, because the existence of alternative syntactic structures for a particular utterance permits grammatical encoding to accommodate a greater variety of lexical activation states.

### *The Bottom Line*

Competitive and incremental theories make opposite predictions about the effect of syntactic flexibility on production. Competitive theories claim that structural decisions are made by permitting simultaneously active candidate structures to compete with one another, thereby restricting one another's availability. Thus, the simultaneous activation of structure plans that occurs with syntactic flexibility requires competition to occur so that a structural decision can be made. Incremental theories predict easier production with syntactic flexibility for two reasons: First, structural decisions are not accomplished through competition, so that all possible structures are simultaneously and freely available to be filled. Second, strict incremental construction permits the most active lexical representation (rather than syntactic competition) to determine structural decisions. Without strict incrementality, the most active lexical representation could be inserted into any position in the sentence at any time, which would not restrict the syntactic options remaining as a consequence of that insertion. With syntactic flexibility, more structural options are available at each moment during production, and greater variability among lexical representations can be accommodated. Overall, any theory which

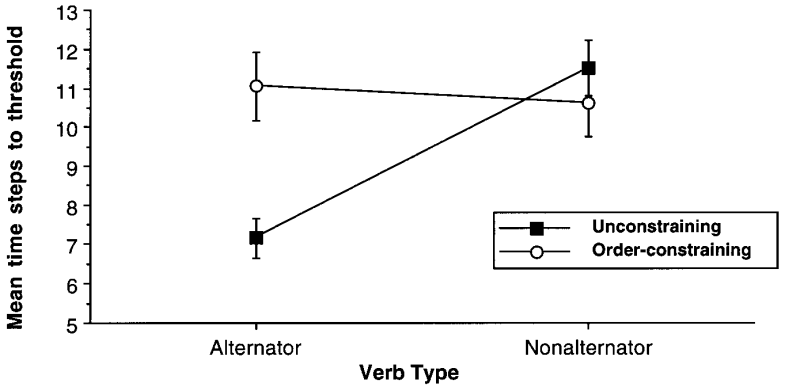


FIG. 4. Results of simulating incremental effects of verb type and preposition constraint.

claims that syntactic decisions are accomplished via competition predicts difficulty with syntactic flexibility, and any theory which claims that syntactic decisions occur as a consequence of strict incremental construction and variable lexical activations predicts ease with flexibility.

## TESTING THE MODELS OF GRAMMATICAL ENCODING

The three experiments presented here assess the effect of syntactic flexibility on the ease of language production. The tasks used in the three experiments have the same basic methodology: Speakers received the main meaning-carrying words of a sentence in a quasi-random order and were asked to create a sentence with those words. This task forces speakers to think about the meaning of the sentence to properly reorder the presented words, and add the function words to make the sentence grammatical.

In the experiments, the number of errors that speakers made and the production latency, or time required to begin the utterance after presentation of the to be included words, were measured. These latencies measure the time needed for speakers to plan their utterances prior to articulation. Note, though, that neither production model precludes grammatical encoding after a speaker has started to say the sentence, implying that difficulties in production might occur *during* as well as *prior to* articulation.

To the extent that planning difficulties occur during articulation, speakers' tendencies to commit errors should be relatively high. However, errors during normal production provide a coarse measure of difficulty, so a deadline on speakers' articulation time was imposed. The purpose of the deadline was twofold: First, the pressure to say the utterances quickly should increase the incidence of observed errors. Second, participants were told that a good strategy for completing their sentences prior to the deadline was to plan out their sentences before beginning to speak. If speakers plan their utterances prior to speaking, grammatical encoding should occur more during planning than otherwise. It is likely that the same processes underlie grammatical encoding before and during articulation (see Dell & Repka, 1992, and Wheeldon & Levelt, 1995, for evidence concerning the like nature of inner and articulated speech), so that if concurrent grammatical encoding is competitive or incremental, then pre-articulatory grammatical encoding should be of the same character. Thus, the tendency for the deadline to encourage a planning strategy should cause the time to plan—the production latency—to reflect the competitive or incremental nature of production.

More generally, tasks that study language production have two conflicting constraints: On the one hand, language production entails a certain amount of creativity, and the more such creativity is eliminated in a production

task, the further that task is removed from the interesting processes responsible for language production. On the other hand, allowing extensive creativity in a task permits much variability in speakers' productions, and thereby risks rendering the results of that task difficult to interpret. Investigations of naturally occurring speech error corpora offer the most naturalistic method of studying language production, but such analyses are methodologically unconstrained and are thereby open to questions of interpretation and sampling bias (Bock, 1995; Cutler, 1982). By determining the lexical content of speakers' utterances and imposing a deadline on articulation time, the experimental task used here succeeds in providing a sensitive, well controlled, but less natural experimental paradigm. Although this less natural experimental task may make generalization to all language production situations tentative, the experimental control should nevertheless permit the task to reveal interesting features of language production.

In Experiments 1 and 2, speakers were presented with alternator and nonalternator verbs. In Experiment 1, some trials forced prepositions into speakers' utterances, and Experiment 2 used pronouns as postverbal objects to sometimes restrict the syntactic flexibility that is normally present with alternator verbs. By comparing the flexible condition to the other three nonflexible conditions, these experiments will help to determine whether syntactic flexibility makes production easier or harder for speakers.

Experiment 3 used the passive/active alternation instead of the dative alternation used in Experiments 1 and 2. As in Experiment 2, a grammatical requirement of pronouns was used to constrain the syntactic flexibility normally present with the verbs used in the experiment. This third experiment provides additional evidence for the effects of syntactic flexibility with an entirely different set of materials.

## EXPERIMENT 1

Each trial in Experiment 1 proceeded as follows: Participants were first given two words. The first word was the personal pronoun ''I'', and the second was a verb in the past tense (e.g., ''I gave''). After the words disappeared, participants saw two or three more words, two of which were nouns, and the third, if it appeared, was a preposition (e.g., ''children/to/toys'' or ''children//toys''). These words appeared in a random order. Participants were instructed to create a sentence which began with ''I'', continued with the verb, and then finished using all the remaining words the participants saw. The length of time it took participants to prepare to produce the utterance was recorded, as was the actual utterance for later transcription and analysis.

Verb type was manipulated by presenting either an alternator verb or a nonalternator verb; for example, speakers would see a display such as ''I gave,'' including an alternator verb, or ''I donated,'' including a nonalternator verb. The preposition factor was manipulated by including a dative preposition in the display on half of the trials. Thus, when the preposition factor was order-constraining, speakers would see ''children/to/toys'', whereas when preposition was unconstraining, they would only see ''children//toys.'' Only when speakers receive an alternator verb and the preposition factor is unconstraining can either a prepositional dative sentence or double object sentence be uttered. Thus, syntactic flexibility exists only in this alternator/unconstraining condition. The competitive model predicts that the alternator/unconstraining condition should be more difficult than the other three conditions, whereas the incremental model predicts that the alternator/unconstraining condition should be easiest.

Note that whether syntactic flexibility exists in an experimental condition is effectively an empirical issue. That is, even if the verb is an alternator and the preposition is unconstraining, other factors may influence flexibility. For example, the overall meaning of the sentences to be created may be such that one form of a sentence is much more sensible than the other form. The degree of syntactic flexibility in each condition was evaluated in two ways: First, norms were collected in which participants rated the sensibility of the sentences from Experiments 1 and 2 in each of its forms. Second, the propor-

tion of each utterance type for each condition is reported; flexible conditions should have a greater balance than the nonflexible conditions in the number of utterances of each type spoken by participants.

*Method*

*Participants.* Forty-five students from the University of Illinois community participated. Of these, 43 students participated for partial credit in an introductory psychology class. The other two participants were volunteers. Five participants (all of whom participated for credit) were excluded from the analysis because fewer than 66% of their critical utterances were correct. All participants were native speakers of English.

*Factors.* The experiment included two factors, each with two levels. The first factor was *verb type* with levels *alternator* and *nonalternator,* and the second was *preposition,* with levels *order-constraining* and *unconstraining.* Both factors were within participants and within items in a counterbalanced design, detailed in the next section.

*Materials.* Alternator and nonalternator verbs were collected from various sources (Lombardi & Potter, 1992; Quirk, Greenbaum, Leech, & Svartvik, 1972). Twenty-four alternator–nonalternator verb pairs were selected, such that the two verbs in a pair were semantically similar. For each verb pair, two sentence frames were constructed, both of which could accept both verbs. Thus, there were 48 sentence frames, but 96 distinct sentences. All function words except the sentence initial ''I'' were removed from the sentence frame for presentation; the preposition of the prepositional dative form was included when that sentence was in the order-constraining condition. Thus, ''I gave/toys/children'' was presented in the unconstraining condition, whereas the order-constraining condition also included the preposition ''to.''

The resulting 48 sentence frames were put into four equal sized item groups. The item groups were rotated through the four experimental conditions by means of a four by four Latin square. Thus, each participant saw a particular item in only one condition, but saw all four conditions across the 48 items. The Latin square chosen ensured that participants saw each verb only once. See Appendix B for a list of all critical stimuli used in Experiment 1.

To add variability to the types of sentences participants were creating, 48 filler sentences were added to the experiment. Most of these sentences were intransitive verbs with prepositional phrase arguments (36 of the 48; e.g., *I drove/to/store*); some were verbs that accepted two noun phrases after the verb (the remaining 12; e.g., *I declared/underdog/winner*). Also, 20 practice sentences were created, none of which contained alternator or nonalternator verbs.

*Norms.* To evaluate the validity of the sentence frames, norms were collected. The 48 sentence frames were used to create 192 sentences: Each sentence frame appeared with both of its verbs (an alternator and a nonalternator), and it appeared as both a prepositional dative and a double object construction. The personal pronoun ''I'' was replaced by a unique two syllable common name for each sentence frame (e.g., *I gave the toys to the children* became *Sheila gave the toys to the children*). Four lists of the 48 sentence frames were constructed, where a particular sentence frame only appeared once per list. Each sentence frame in a list was randomly assigned to one of the four experimental conditions (alternator or nonalternator verb; prepositional dative or double object construction) with the constraint that each list contain 12 items in each condition, and each sentence frame appear in all four conditions. Each verb appeared exactly once per list.

Sixty-four additional participants rated the sensibility of the sentences on a scale from 1 to 7, where 1 was ''completely sensible'' and 7 was ''completely nonsensible.'' Table 1 presents a summary of the norms. The table shows that nonalternator verbs in double object constructions were judged as less sensible than the other three sentence types. (Analyses of variance with participants and items as random effects revealed all main effects and in-

TABLE 1

MEAN SENSIBILITY RATINGS AND STANDARD DEVIATIONS FOR ALTERNATOR AND NONALTERNATOR VERBS BY SYNTACTIC STRUCTURE

| | Syntactic structure | |
|---|---|---|
| Verb type | Prepositional dative | Double object |
| Alternator | 1.41 (0.315) | 2.46 (0.661) |
| Nonalternator | 1.58 (0.496) | 4.34 (0.891) |

*Note.* Ratings are on a 1 to 7 scale, where 1 is completely sensible and 7 is completely nonsensible. Standard deviations are in parentheses.

teractions to be highly reliable, all $F$s $> 100$.) These norms indicate that the choices of alternator and nonalternator verbs were generally valid (however, see the exception noted in the results section).

*Procedure.* In the main part of Experiment 1, individual participants sat in front of a Dell System 310 microcomputer with VGA monitor. A microphone connected to a Micro Experimental Laboratory (MEL) button box was directly in front of the participant, and the computer keyboard was next to the microphone. The experimenter sat next to the participant, and used the button box to code the participants' utterances. The experimental session was tape recorded for subsequent transcription.

The participant initiated each trial by pressing the space bar. This was followed by a 250 ms blank screen. A fixation point (a plus sign) then appeared in the center of the screen for 500 ms. The fixation point was immediately replaced by the subject and verb of the sentence to be uttered (e.g., ''I gave''). Participants were instructed to silently read the subject and verb. After 1500 ms, the subject and verb disappeared from the screen, and following a 250 ms blank screen, the two or three additional words appeared on the screen. If three words appeared, one was located at the vertical center of the screen, the second was two lines above and the third was two lines below the first. If only two words appeared, then they could appear in any two of these three positions. The relative position of the words was randomly determined.

Participants were instructed to create well formed utterances that contained every word that they had read on that trial. The utterance had to begin with the first two words that they had seen (e.g., ''I gave''), and then was to continue, incorporating the rest of the words they had seen (e.g., ''toys/children/to''). They were told they could add more words if they wished, and in fact, that they had to add ''things like *the* and *my.*'' Participants were instructed to create the sentence as quickly as they could without making mistakes or dysfluencies. The sentences were spoken into the microphone, triggering the voice key and thereby causing the software to record a production latency (the production latency was measured from the onset of the presentation of the postverbal words until the onset of the ''I'' of participants' utterances).

When the microphone registered a vocal response, the words disappeared from the screen and were immediately replaced by a timing bar. The bar progressively changed color from left to right (i.e., like a bar filling up), such that it took 1300 ms to change color completely. When the bar had changed color completely, a 250 Hz tone sounded for 250 ms. The experimenter then coded the utterance by pressing a button on the button box, and the next trial began.

Participants were encouraged to complete their utterance before the onset of the tone. They were told that the purpose of the timing bar was to encourage them to utter the sentence as smoothly and as quickly as possible. Participants were further instructed that the best way to attain this proficiency was to plan their utterance before speaking (since the timing bar did not begin to fill until they began to speak), but they were told that they should still begin to say their utterance as quickly as possible. Data were not excluded on the basis of performance relative to the timing bar.

The experimental session began with the 20 practice trials, followed by the 96 experimental trials. The entire experiment took approximately half an hour.

*Results*

*Scoring responses.* To evaluate the difficulty participants had when producing the sentences, their responses were categorized for their correctness. Participants' utterances were placed into one of three main categories: *correct utterances, errors,* and *deviations.* A correct utterance corresponded to the sentence frames reported in Appendix B, with minor exceptions (e.g., the use of a definite instead of an indefinite article). The remaining incorrect responses were subcategorized according to specific criteria. Some subcategories were considered errors, while others were deviations. An incorrect production was a deviation if the difference between the deviant utterance and a correct utterance could only logically occur in a particular experimental condition (examples are to follow). All other incorrect utterances were analyzed as errors. Thus, all errors could have occurred in any experimental condition and were nontrivially deviant from the sentence frames shown in Appendix B.

Error subcategories included the following: (1) A word substitution, where participants simply used a word other than the ones that appeared on the screen (e.g., *I built the equipment for the officer* instead of . . . *for the police*); (2) A category shift error, where participants took a presented word differently than intended (e.g., *I told the manager to excuse me* instead of *I told the manager an excuse*); (3) Inappropriate use or omission of a function word, such as *I sold computer to the engineer;* (4) A general dysfluency error, such as a stutter, a failure to complete the sentence, or a sound error or sound substitution; (5) A syntactic shift such as *I presented the boy with the game* instead of *I presented the game to the boy;* and finally, (6) A word movement error such as *I gave the priest to the gift.*

The deviation subcategories included the following: (1) Participants failed to produce the presented preposition; (2) In the unconstraining preposition condition, participants used a marginally sensible but inappropriate preposition (e.g., saying *I gave/donated the toys from the children* instead of . . . *to the children*); (3) Participants created a double object construction with a nonalternator verb. Also, any utterance where participants were excessively creative by adding adjectives or adjunct phrases was classified as a deviation.

The reliability of the classification of stimuli into error categories was checked by giving an independent rater 100 randomly chosen transcribed utterances from the experiment. For classification into subcategories, the original and checked categorizations differed on 4% of the sampled trials. However, when these subcategories were collapsed into the three main categories of correct, error, and deviation, the original and checked categorizations matched on the entire sample.

*Exclusions.* Two verbs (and therefore four item pairs) were excluded from the analysis for the following reasons: The pair *left/bequeathed* was excluded because the norms indicated this item to be inappropriate (the double object rating for *bequeathed* was better than the double object rating for *left*). The pair *handed/delivered* was excluded because of a programming error. Also, a total of 6.2% of the experimental trials were excluded because of experimental interruption or machine error (the proportion of excluded trials by condition varied from 5.0% to 8.6%).

As occurs with many production tasks, the error rates in this experiment were high relative to other reaction time tasks. The high error rates left three cells in the item analysis without any correct observations. The means for these empty cells were estimated using the row and column means, as in Winer (1971).

I will report three different sets of results. The first concerns the proportion of prepositional dative and double object utterances made by participants in each condition. These results can be used to evaluate whether participants exploited the syntactic flexibility available to them. The second set concerns the number of errors made in each condition, while the third set concerns the production latencies. These latter two results will be used to evaluate whether the language production system encountered more difficulty in the flexible (alternator/unconstraining) condition,

TABLE 2

NUMBER AND PERCENTAGE OF PREPOSITIONAL DATIVE AND DOUBLE OBJECT UTTERANCES AS A FUNCTION OF VERB TYPE AND PREPOSITION CONSTRAINT

| | Preposition | |
|---|---|---|
| Verb type | Order-constraining | Unconstraining |
| Alternator | | |
| Prepositional dative | 312 (70.9) | 229 (52.0) |
| Double object | 8 (1.8) | 120 (27.3) |
| Nonalternator | | |
| Prepositional dative | 309 (82.1) | 255 (58.0) |
| Double object | 2 (0.5) | 19 (4.3) |

*Note*. Percentages in parentheses. Total possible number of observations in each cell is 440.

as predicted by the competitive model, or in the nonflexible conditions, as predicted by the incremental model.

*Proportion of prepositional datives and double objects.* Overall, there was a strong tendency for participants to produce prepositional dative utterances. The numbers of utterances of a prepositional dative or double object type in each condition are shown in Table 2. It is important to note that participants produced 52.0% prepositional dative utterances and 27.3% double object utterances in the alternator/unconstraining condition. These values indicate that participants were indeed using the different structures available to them, but it is interesting that the proportions are not closer to even. This issue will be explored in the discussion.

*Production errors.* The numbers of errors in each condition are shown in Fig. 5. The figure shows that verb type and preposition constraint are interacting. Specifically, sentences with alternator verbs resulted in fewer errors than sentences with nonalternator verbs in the unconstraining condition, but not in the order-constraining condition.

Analyses of variance (ANOVAs) employing both participants ($F1$) and items ($F2$) as random effects were conducted on the production error totals. All reported reliable effects are at the .05 level unless reported otherwise. The main effects of verb type and preposition constraint were not reliable (verb type: $F1(1,39) = 0.50$, $MS_e = 1.006$; $F2(1,43) = 0.04$, $MS_e = 2.382$; preposition constraint: $F1(1,39) = 2.25$, $MS_e = 1.473$; $F2(1,43) = 1.26$, $MS_e = 1.796$). The interaction was highly reliable, $F1(1,39) = 13.08$, $MS_e = 1.147$; $F2(1,43) = 10.14$, $MS_e = 1.515$.

Both theories predict (in opposite directions) a difference between the flexible alternator/unconstraining cell and the three nonflexible cells, which in turn should not be different from one another. Planned comparisons were therefore conducted testing these predictions. As predicted by the incremental account, the alternator/unconstraining cell was reliably less error prone than the mean of the other three cells, $F1(1,39) = 11.98$; $F2(1,43) = 6.98$. Neither of the two remaining orthogonal contrasts were reliable.

*Production latencies.* The mean and standard deviation of each participant's correct utterances were calculated. Then, any latency greater than 2.5 standard deviations above that participant's mean was considered an outlier and was removed from the production latency analysis. Following this trim, the mean production latencies for each condition are shown in Fig. 5. The figure suggests that the alternator/unconstraining condition—the flexible condition—resulted in faster production latencies than the other three conditions.

ANOVAs employing both participants and items as random effects were conducted on the mean production latencies. The effect of preposition constraint was marginally reliable by items ($F1(1,39) = 1.99$, $MS_e = 14217.9$;

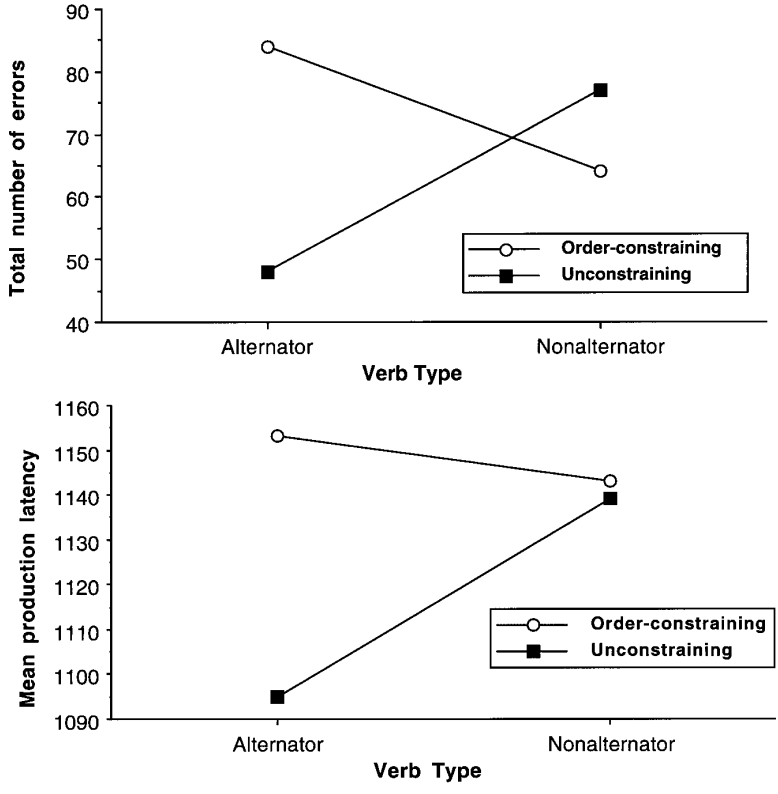


FIG. 5. Measured number of errors (top panel) and mean production latencies (bottom panel) as a function of verb type and preposition constraint in Experiment 1.

$F2(1,43) = 3.39$, $p < .08$, $MS_e = 15443.8$). The main effect of verb type and the interaction were not reliable (verb type: $F1(1,39) = 0.74$, $MS_e = 15121.2$; $F2(1,43) = 0.48$, $MS_e = 30593.5$; interaction: $F1(1,39) = 1.16$, $MS_e = 20250.5$; $F2(1,43) = 1.54$, $MS_e = 14582.7$).

As with the error analysis, the theories under consideration predict a production latency difference between the flexible alternator/unconstraining condition and the three nonflexible conditions. To test this contrast, planned comparisons were conducted. The alternator/unconstraining condition was marginally faster than the other three conditions ($F1(1,39) = 3.87$, $p < .07$; $F2(1,43) = 4.59$, $p < .04$). The other two orthogonal contrasts were not reliable. Thus, there is moderate support for the incremental account's prediction that the flexible condition should be faster than the other three conditions, which do not differ from one another.

*Discussion*

The pattern of errors in Experiment 1 provides strong support for the incremental theory. The incremental approach predicts relatively error free production under flexible circumstances, whereas the competitive approach predicts error prone production with flexibility. The fewest errors occurred in the flexible alternator/unconstraining condition, and the three nonflexible conditions did not have reliable differences among them. These results are exactly predicted by the incremental theory.

The pattern of production latencies also supports the incremental theory, albeit more equivocally. Recall that the competitive theory predicts that conditions in which syntactic flexibility exists should result in longer production latencies, whereas the incremental theory predicts that syntactically flexible conditions should result in shorter production la-

tencies. In fact, the results showed that production latencies were fastest in the flexible alternator/unconstraining condition, as predicted by the incremental theory. Note, though, that the statistical interaction of the two factors was not reliable; the planned comparison between the flexible condition and the nonflexible conditions, however, was marginally reliable by participants and reliable by items. Whereas these results only provide marginal support for the incremental theory, the results are completely incompatible with the predictions of the competitive theory.

Of methodological interest is the proportion of prepositional dative and double object utterances in the syntactically flexible alternator/unconstraining condition. Only in this condition can participants correctly create a double object construction, and indeed, 27% of participants' utterances were double objects. Thus, participants were exploiting the syntactic flexibility available to them. However, that participants have two choices available to them might lead one to expect a proportion of double object utterances closer to 50%.

The lower double object proportion of 27% might be explained by language-general or verb-specific preferences for prepositional dative structures over double objects. Other research (Bock & Brewer, 1974) indicated that whereas there exists verb-specific variability, double objects are generally preferred over prepositional datives for alternator verbs. At the very least, then, there is no reason to expect that the proportion of double objects is substantially less than half because of static structural preferences.

However, the low proportion of double objects might be linked to dynamic structural preferences. Research by Bock and colleagues (for example, Bock, Loebell, & Morey, 1992) has demonstrated the existence of *syntactic persistence*—when the language production system creates a sentence with a particular structure, the system is inclined to produce a sentence with that same structure in the future. Note that because of the design of this experiment, 75% of the critical sentences in an experimental session can be spoken only with a prepositional dative structure. It follows from this that most of the utterances spoken by a particular participant were prepositional datives (note, however, that the fillers will reduce the dominance of this proportion). So, if syntactic persistence operated in this experiment, it would depress the number of double object utterances seen, since double object utterances necessarily comprise the minority of critical utterances.

Overall, the results of Experiment 1 support the incremental theory of grammatical encoding. Experiment 2 tested the same flexibility conditions, but rather than force a presented preposition into participants' utterances, certain grammatical facts about the distribution of pronouns in sentences were used to manipulate flexibility.

## EXPERIMENT 2

Pronouns may occupy restricted positions in sentences. For example, sentences (5) and (6) are adapted from (1) and (2) respectively by replacing ''the toys'' with ''it'' in both cases:

(5) Sheila gave it to the child.
(6) ??Sheila gave the child it.

First, recall that sentences (1) and (2) with ''the toys'' were both grammatical. Sentence (5), adapted from (1), is also grammatical, but sentence (6), adapted from (2) is questionable at best.

Now note sentences (7) and (8), which are also adapted from (1) and (2), except that the pronoun ''him'' replaces the noun phrase ''the children'':

(7) Sheila gave the toy to him.
(8) Sheila gave him the toy.

Here, unlike in (5) and (6), the pronoun can appear with either structure. The appropriate generalization is that pronouns, for either grammatical or metrical reasons, must appear adjacent to either a verb or a preposition. So, in (5), (7), and (8), the pronoun appears adjacent to a verb [(5) and (8)] or a preposition

[(7)]. In (6), however, the pronoun appears adjacent to a noun, and the sentence is awkward, if not ungrammatical.

For the purposes of Experiment 2, then, the important fact is that when a pronoun like *it* substitutes for the theme of the sentence (e.g., ''toy''), the need for that pronoun to appear adjacent to a verb or preposition makes the use of the double object structure awkward or ungrammatical. Thus, an alternator verb is deprived of the syntactic flexibility it normally possesses if the sentence contains a pronominal theme such as *it.*

Experiment 2 used mostly the same alternator and nonalternator verbs and sentence frames as Experiment 1, except that either the order-constraining theme pronoun *it* or the unconstraining goal pronoun *him* replaced the corresponding full noun phrase. With nonalternator verbs, since double object structures are ungrammatical, the fact that the order-constraining pronoun *it* cannot be used with a double object sentence is irrelevant. With alternator verbs, however, use of the order-constraining pronoun *it* eliminates the syntactic flexibility that is otherwise present, such as when the unconstraining pronoun *him* is used instead. Thus, only the alternator/unconstraining condition is flexible; the other three conditions are not.

### *Method*

*Participants.* Fifty-three students participated for partial credit in an introductory psychology course. Five participants were excluded because fewer than 50% of their critical utterances were correct.[2] All participants were native speakers of English.

*Factors.* The experiment contained two factors, each with two levels: *verb type,* with levels *alternator* and *nonalternator,* and *pronoun,* with levels *order-constraining* and *unconstraining.* Both factors were within participants and within items in a counterbalanced design.

*Materials.* The sentence frames of Experiment 2 were adapted from the 48 sentence frames of Experiment 1. Four verb pairs were left out of Experiment 2 because of their relatively high error rates in Experiment 1. All remaining sentences were modified so that all postverbal arguments were singular; mostly, this merely involved changing the noun from plural to singular, but in a small number of cases, the particular wording made it necessary to create a new sentence. These 40 sentence frames were used to create 80 distinct sentences by replacing in one case the theme of the sentence with the order-constraining pronoun *it,* and in a second case replacing the goal of the sentence with the unconstraining pronoun *him.*[3] The 40 sentence frames were broken into four item groups, and rotated through a four by four Latin square, as in Experiment 1. (See Appendix B for a list of the stimuli.)

The 48 filler sentences from Experiment 1 were modified and included in Experiment 2. Most were modified by changing a postverbal full noun phrase to a pronoun, although some fillers included no pronoun in the sentence frame (except the sentence initial ''I''). The 20 practice sentences were also modified to include pronouns.

*Norms.* In order to verify the grammaticality (or lack thereof) of the pronoun sentences, the utterances were normed for sensibility. The 40 sentence frames were used to make 320 distinct sentences: Each sentence appeared with an alternator and a nonalternator verb, with the order-constraining pronoun *it* and the unconstraining pronoun *him,* and as a prepositional dative and as a double object. Eight lists of the 40 sentence frames were created, such that each sentence frame appeared once per list. Each sentence frame in a list was assigned to one of the eight conditions

[2] The exclusion criterion in Experiment 2 was less strict than in Experiment 1 because Experiment 2 productions were in general more error prone.

[3] Only the masculine pronoun was used in the critical utterances because the feminine pronoun ''her'' is ambiguous: ''Her'' can either be an accusative (as in *I gave the toy to her*) or a genitive (as in *I gave her toy to the boy*). This was compensated for by using mostly feminine pronouns in the fillers.

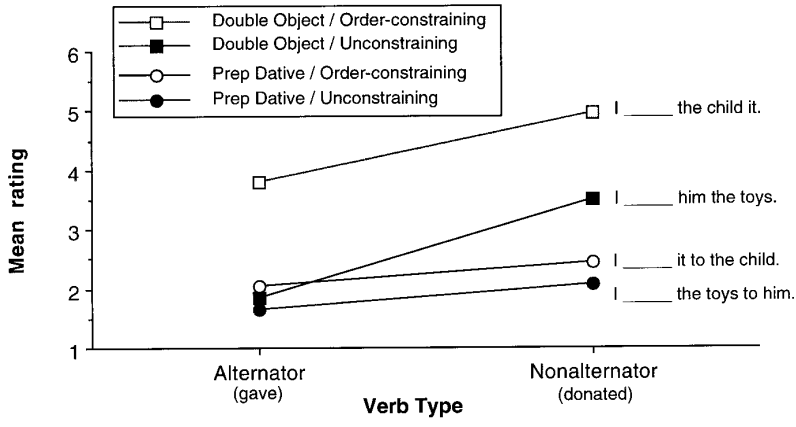


FIG. 6. Mean sensibility ratings for alternator and nonalternator verbs by syntactic structure and pronoun type. (Rating on a 1 to 7 scale, where 1 is completely sensible and 7 is completely nonsensible.)

such that each list contained five items in each condition, and each verb appeared once per list. Across the eight lists, each frame appeared in all eight conditions.

The rating instructions to participants were as in Experiment 1. Six new participants completed each list. Figure 6 illustrates the mean ratings. Any construction where a nonalternator verb appears as a double object should be ungrammatical; further, an alternator verb appearing in a double object structure with the order-constraining pronoun *it* should be ungrammatical, because the pronoun is appearing adjacent to neither a verb nor a preposition. The norms show that participants considered these three ungrammatical conditions to be more nonsensible than the other five conditions. (The three-way interaction was reliable by participants [$F(1,47) = 40.2$] but not by items [$F(1,39) = 2.8$]; however, a planned comparison of the three ungrammatical conditions to the five grammatical conditions was highly reliable [both $F$s $> 100$] by both participants and items.)

The norms support the claim that only when participants receive sentence frames with an alternator verb and with the unconstraining pronoun *him* can both a prepositional dative and double object sentence be uttered. In the other three conditions, only a prepositional dative sentence is possible. Thus, only the alternator/unconstraining condition possesses syntactic flexibility.

*Procedure.* The procedure in Experiment 2 was similar to that of Experiment 1. The differences between the two procedures are as follows:

After the 500 ms fixation and 250 ms blank screen, the postverbal arguments were presented first (e.g., ''toy/him''). Since there were always two postverbal arguments, one appeared on the line immediately above and the other immediately below the vertical center of the screen. The relative order of the two postverbal words was manipulated such that half of the critical utterances were presented with the theme above the goal, and the other half in the other order.

The postverbal words remained on the screen for 1500 ms and were followed by a 1000 ms blank screen. Then, the personal pronoun ''I'' appeared with a verb in the past tense (e.g., ''I gave''). These words remained on the screen until the participant responded. In Experiment 2, the progress bar filled in 1500 ms rather than 1300 ms.

Participant instructions in Experiment 2 were identical to Experiment 1, except that participants were instructed to begin their utterances with the second two words they saw, beginning with ''I.''

The procedural modifications in Experi-

ment 2 were intended to reduce the effects of comprehension order.[4] The progress bar fill time was increased because some Experiment 1 participants reported having difficulty completing their utterances before the tone.

*Results*

*Scoring responses.* Responses were scored for correctness as in Experiment 1, with two changes: (1) The deviation category where participants ignored a presented preposition was unnecessary; (2) When participants created a double object sentence in the alternator/order-constraining condition (e.g., *I gave the child it*), it was categorized as ''Double Object It.'' This category is also a deviation, since these errors cannot occur in all conditions of the experiment.

The reliability of the coding was checked as in Experiment 1. For the subcategories, the original and checked classifications differed for 1% of the sample. Coding agreed for the entire sample when the subcategories were collapsed into the main categories of correct, error, and deviation.

*Exclusions.* One item pair was excluded from analysis because for one verb, errors left two cells without any correct utterances, precluding the possibility of estimating the mean latencies of those cells. Errors left two other cells empty on the item analysis which were estimated as in Experiment 1. In addition, 2.4% of all critical trials were excluded because of experimental intrusion or machine error; the percentage eliminated varied between 1.1% and 3.5% in the four conditions.

*Proportion of prepositional dative and double objects.* Both conditions in which the pronoun was order-constraining resulted in very few double object utterances (3.7% and 0.2% for alternator and nonalternator verb type conditions respectively). With alternator verbs and the unconstraining pronoun, the majority of responses were of a double object form (72.1%), though prepositional datives made up 21.3% of utterances. Interestingly, 14.3% of the utterances with nonalternator verbs and the unconstraining pronoun were double objects, although these are awkward or ungrammatical utterances. These proportions are shown in Table 3.

TABLE 3

NUMBER AND PERCENTAGE OF PREPOSITIONAL DATIVE AND DOUBLE OBJECT UTTERANCES AS A FUNCTION OF VERB TYPE AND PRONOUN ROLE

| | Pronoun | |
|---|---|---|
| Verb type | Order-constraining | Unconstraining |
| Alternator | | |
| Prepositional dative | 356 (81.6) | 94 (21.3) |
| Double object | 17 (3.7) | 308 (72.1) |
| Nonalternator | | |
| Prepositional dative | 347 (76.8) | 231 (51.5) |
| Double object | 1 (0.2) | 65 (14.3) |

*Note.* Percentages in parentheses. Total possible number of observations in each cell is 456.

It is important for the logic of the experiment that both utterance types be observed in the alternator/unconstraining condition, which is supposed to be the syntactically flexible condition. Indeed, both utterance types are well represented in this condition. It might also be argued, however, that both utterance types are well represented in the nonalternator/unconstraining condition; this point will be addressed in the discussion.

*Production errors.* The numbers of errors are shown in Fig. 7. The figure shows that participants' accuracy was most affected by verb type, with a small effect of pronoun role; no interaction is apparent in the figure.

ANOVAs confirm the above observations. There was a reliable effect of verb type by participants, $F1(1,47) = 7.67$, $MS_e = 0.695$; and by items, $F2(1,37) = 5.27$, $MS_e = 1.277$. There was no effect of pronoun ($F1(1,47) = 1.17$, $MS_e = 0.872$; $F2(1,37) = 0.72$, $MS_e =$

[4] In the end, comprehension order was unlikely to have exclusively caused the observed flexibility benefits. Post hoc analyses of order of presentation revealed that flexible conditions were always faster and more error free than nonflexible conditions. Easier production with flexibility appears to be more than just an experimental bias due to comprehension order.

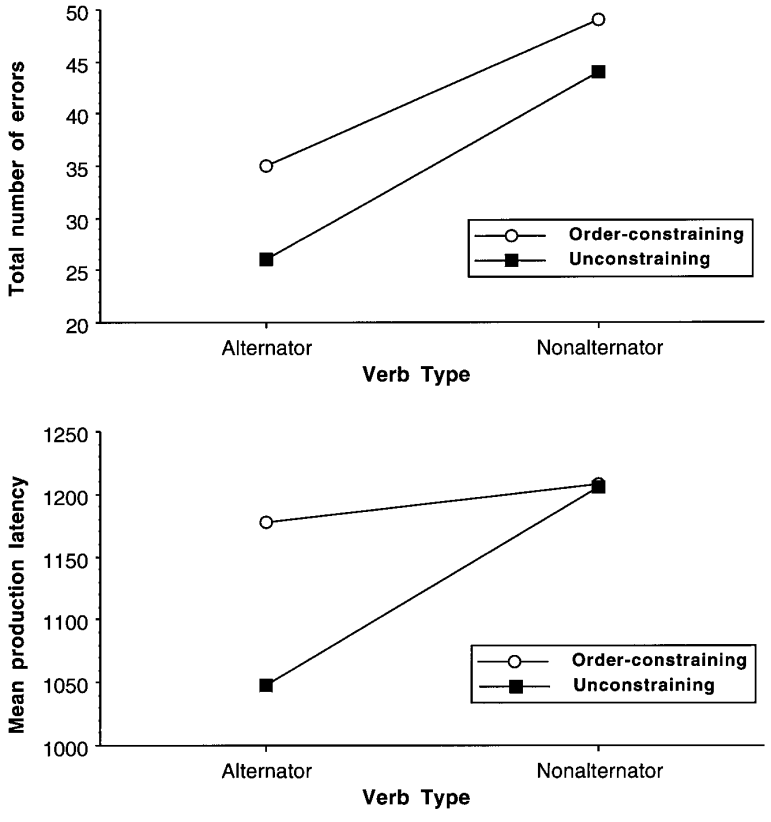


FIG. 7. Measured number of errors (top panel) and mean production latencies (bottom panel) as a function of verb type and pronoun in Experiment 2.

1.803) nor was the interaction reliable ($F1(1,47) = 0.10$, $MS_e = 0.849$, $F2(1,37) = 0.11$, $MS_e = 0.943$).

Both theories predict a difference between the flexible alternator/unconstraining condition and the other three conditions, so planned comparisons were carried out to test these predictions. The flexible condition was less error prone than the mean of the three nonflexible conditions, $F1(1,47) = 5.12$; $F2(1,37) = 5.84$. The other two orthogonal comparisons were not reliable (alternator/order-constraining vs both nonalternator conditions: $F1(1,47) = 2.17$; $F2(1,37) = 2.47$; nonalternator/order-constraining vs nonalternator/unconstraining: $F1(1,47) = 0.31$; $F2(1,37) = 0.35$). Note that although the flexible versus nonflexible comparison might primarily be due to the large main effect of verb type, the alternator/order-constraining versus both nonalternator conditions comparison was not carried through by the large main effect.

*Production latencies.* Outliers were excluded as in Experiment 1. The mean trimmed production latencies are shown in Fig. 7. The figure reveals an interaction such that the alternator/unconstraining condition (the flexible condition) has quicker production latencies than the other three conditions.

ANOVAs revealed that the main effect of verb type was reliable ($F1(1,47) = 9.40$, $MS_e = 36704$; $F2(1,37) = 6.93$, $MS_e = 39746$), as was the main effect of pronoun ($F1(1,47) = 10.37$, $MS_e = 32866$; $F2(1,37) = 4.22$, $MS_e = 45133$). The interaction was reliable by participants, $F1(1,47) = 10.34$, $MS_e = 12109$, but not by items, $F2(1,37) = 1.82$, $MS_e = 84558$.

Planned comparisons evaluated the difference between the flexible and the nonflexible conditions. The flexible, alternator/uncon-

straining condition was faster than the nonflexible conditions ($F1(1,47) = 64.40$; $F2(1,37) = 7.27$), and the other two comparisons evaluating differences among the nonflexible conditions were not reliable.

*Discussion*

The production latencies and, to a lesser extent, the production errors provide support for the incremental theory. The production latencies showed that participants could create sentences more quickly in the syntactically flexible alternator/unconstraining condition than in the three nonflexible conditions. The production error results require more care in interpretation. Strictly speaking, the flexible condition resulted in fewer errors than the other three conditions. However, there was a large main effect of verb type which may have caused the planned comparison of the alternator/unconstraining to the three nonflexible conditions to be reliable. Note, however, that if the production error results are taken to only reflect a main effect of verb type, that main effect contradicts the predictions of the competitive theory. That is, the competitive theory predicts that the alternator verb type condition should result in more errors than the nonalternator condition, which is opposite to the observed main effect.

A point of concern with the Experiment 2 results related to the somewhat high proportion of double object utterances with nonalternator verbs and the unconstraining pronoun ''him'' (e.g., *I donated him the toy*). Interestingly, this high proportion of ungrammatical utterances in this condition reveals how language production benefits because of syntactic flexibility.

Specifically, it may be that errors like *I donated him the toy* occur because of a strong tendency for pronouns to appear as early as possible in the sentence. (Note also that in the syntactically flexible alternator/unconstraining condition, 72% of participants' utterances were double objects such as *I gave him the toy*, rather than prepositional datives such as *I gave the toy to him*). Perhaps 14% of the utterances in the nonalternator/unconstraining condition were double objects not because participants considered utterances such as *I donated him the toy* grammatical, but because the pressure to place the pronoun immediately after the verb caused subjects to create an ungrammatical sentence.

Within the incremental theory, pronouns should possess intrinsically high activation levels because of their high frequency and phonological simplicity, and should thus emerge as early as possible in a sentence (Bock, 1982). If syntactic flexibility exists, then the number of word configurations a particular sentence may be expressed with is relatively large, and the probability that a pronoun can appear early in a sentence is greater. Without flexibility, grammatical encoding is more difficult, as evidenced by the longer production latencies and larger error proportions in the nonflexible conditions.

A second difficulty in Experiment 2 concerns the possible effect of verb frequency on speakers' productions. Overall, sentences with alternator verbs were produced reliably more quickly and with fewer errors than those with nonalternator verbs. It is possible that the higher frequency of the alternator verbs accounts for this main effect.

To investigate this possibility, the two sets of verbs were frequency matched (Francis & Kucera, 1982) by eliminating enough item pairs with the largest alternator verb frequency advantage (seven item pairs were removed), and item analyses were reconducted. With frequency matched verb groups, the main effect of verb type is no longer reliable ($F(1,30) = 1.38$ and $F(1,30) = 2.66$ for errors and latencies, respectively). With production errors, the interaction is still not reliable, but the flexible/nonflexible contrast remains ($F(1,30) = 4.31$). With the latencies, the interaction achieves reliability and the flexible/nonflexible contrast remains reliable ($F(1,30) = 4.45$ and $F(1,30) = 7.17$ respectively). Thus, frequency is perhaps explaining the main effect of verb type (possibly because the planning latency includes the reading time for the verb), but all reliable interactions and contrasts that exhibit

flexibility benefits remain reliable, even with frequency matched item sets.

There is a potential difficulty in interpreting the results of Experiment 1 and 2, however. If we assume that double object utterances are simply easier to say, then the syntactically flexible conditions may have faster production latencies and fewer errors because the flexible conditions are the only ones that include double object sentences. This possibility is supported by the fact that if the production latencies in the flexible conditions are broken down by utterance type, double object utterances are associated with faster production latencies than prepositional dative utterances. In Experiment 1, prepositional dative utterances in the alternator/unconstraining condition were accompanied by a 1109 ms production latency, while double objects occurred with a 1069 ms latency. In Experiment 2, prepositional datives in the alternator/unconstraining condition occurred with a 1177 ms latency, while double objects occurred with a 1009 ms latency.

One way to address this possibility is to have participants produce double object utterances under syntactically nonflexible circumstances, to see if they are produced with more difficulty. However, very few verbs in English permit only a double object structure (e.g., *I spared the reporter the details* vs *??I spared the details to the reporter*), so such a test would be difficult. Alternatively, if the effects of syntactic flexibility are observed with utterance types other than prepositional datives and double objects, then it is unlikely that the effects observed in Experiments 1 and 2 are due to the ease of producing double object constructions. Experiment 3 will exploit the active/passive alternation to investigate the effects of flexibility with different syntactic constructions.

## Experiment 3

Nearly every English sentence with a transitive verb can also be said with a passive structure. For example, the active sentence (9) can be said as a passive (10).

(9) The story confused John.
(10) John was confused by the story.

Each time a transitive sentence is uttered, a syntactic structure choice must be made.

Experiment 3 will investigate several aspects of transitive sentences like (9) and (10). First, transitive sentences contain two noun phrase arguments: the subject and the direct object. Flexibility is achieved in passive/active alternation by exchanging these subject and object noun phrases. However, if one noun phrase is a pronoun such as ''him,'' then the noun phrases cannot be exchanged without changing the form of the pronoun. That is, (9) can be said as (11) but not (12); to create a passive such as (12), the form of the pronoun needs to be changed to ''he.''

(11) The story confused him.
(12) *Him was confused by the story.

If participants are given sentences to create with pronouns like ''he'' and ''him,'' then both the passive and active structures are not simultaneously available, and syntactic flexibility does not exist. Instead, if participants create sentences with full noun phrases like ''John,'' or a case-invariant pronoun like ''you,'' then both structures are simultaneously available, and syntactic flexibility does exist.

Second, the frequency with which a structure is used in a language might modulate the effects of syntactic flexibility. The prepositional dative and double object alternative structures employed in Experiments 1 and 2 are not greatly imbalanced in their relative frequencies of use. In contrast, the passive structure occurs far less frequently than the active structure. If competitive or cooperative effects are restricted to syntactic alternatives of balanced frequencies, then the flexibility effects observed in Experiments 1 and 2 may not appear in Experiment 3.

To explore issues of relative frequency, two classes of verbs will be employed in Experiment 3: *theme-experiencer* verbs and *normal* verbs, after F. Ferreira (1994). Theme-experiencer verbs are like *confused* above, in that the active form of the sentence can contain an inanimate subject and an animate object (they are called theme-experiencer verbs because the active subject of one of these verbs is typi-

cally a theme, while the active object is an experiencer). Normal verbs are typical agent-theme verbs like *reject*, the active form of which takes an animate agent subject and (possibly) an inanimate theme object (as in *John rejected the story*). F. Ferreira showed that participants are more likely to create passive sentences with theme-experiencer verbs than with normal verbs. Thus, if the relative likelihood of producing a sentence in its alternative forms modulates syntactic flexibility effects, this should be seen by comparing performance on sentences with theme-experiencer verbs to those with normal verbs.

To summarize Experiment 3, syntactic flexibility was manipulated by presenting either the order-constraining subject pronoun ''he'' or the order-constraining object pronoun ''him,'' which can only be used in one sentence structure and thus results in syntactic nonflexibility, or with the unconstraining pronoun ''you'' or the unconstraining name ''John,'' which can be used in two sentence structures and thus results in syntactic flexibility. Other things equal, the competitive model predicts that sentences with the unconstraining arguments ''you'' and ''John'' should be more difficult to produce than sentences with the order-constraining arguments ''he'' and ''him,'' whereas the incremental model predicts the opposite. Both ''he'' and ''him'' are used so that syntactic nonflexibility is tested under conditions in which both actives alone and passives alone are expected. ''John'' is used in addition to ''you'' because if only ''you'' were used, any differences found between flexible and nonflexible conditions could be due to specific effects of using that particular pronoun. Next, the effect of availability of a sentence structure was explored by comparing sentences produced with theme-experiencer verbs to those produced with normal verbs. Passive sentence structures occur more frequently with theme-experiencer verbs than with normal verbs; if availability modulates the effect of syntactic flexibility, then the difference between the order-constraining and unconstraining argument conditions should differ for theme-experiencer and normal verbs. The two models do not make predictions regarding availability, so this aspect of Experiment 3 is exploratory.

### *Method*

*Participants.* Forty-nine students participated in Experiment 3 in exchange for partial credit in an introductory psychology course. One participant was excluded for having fewer than 50% correct critical utterances. All participants were native speakers of English.

*Factors.* Experiment 3 employed two factors, both of which were within participants and within items in a counterbalanced design. The *verb type* factor has levels *theme-experiencer* and *normal*, and the *argument* factor has levels *order-constraining subject* (''he''), *order-constraining object* (''him''), *unconstraining pronoun* (''you''), and *unconstraining name* (''John''). For both verb types, the two order-constraining levels of the argument factor are syntactically nonflexible, while the two unconstraining levels are syntactically flexible.

*Materials.* The stimuli for Experiment 3 were adapted from F. Ferreira (1994). These stimuli consist of 40 theme-experiencer/normal verb pairs. Each pair was used to create two sentence frames which each accepted both verbs of the pair. The verbs used require an animate agent argument, and the sentence frames contained an inanimate theme; this ensures that for each item, only one meaningful sentence could be created in the nonflexible conditions. Thus, a total of 80 sentence frames were adapted which could create 160 distinct sentences. The sentence frames are shown in Appendix C.

The 80 sentence frames were broken into eight equal-sized item groups. The item groups were assigned to conditions by means of an eight-by-eight Latin square. Each participant saw each item in only one condition and saw ten items in each of the eight conditions. Over eight participants, each item appeared in every condition.

Since there were twice as many critical stimuli in Experiment 3 as in Experiments 1 and 2, fillers were not used so that the experimental

session would not exceed its 30 minute time slot. Twenty-four practice stimuli were also created; roughly the same proportion of each noun argument type was employed in the practice stimuli. The practice stimuli were presented to participants in a fixed order, so that participants could be gradually encouraged to produce sentences with passive structures.

*Norms.* No norms were collected for Experiment 3, since the grammaticality judgments upon which flexibility was assessed were based on grammatical case. That is, unlike Experiments 1 and 2 where speakers' intuitions may differ regarding the grammaticality of *I donated him the toys* or *I gave the child it,* a sentence such as *Him was confused by the story* was considered categorically ungrammatical.

*Procedure.* The procedure of Experiment 3 was nearly identical to that of Experiment 1 with the following differences:

The fixation point was replaced by the verb to be used in its past tense form (e.g., ''confused''). The verb remained on the screen for 1500 ms and was followed by a 1000 ms blank screen. Then, the two noun arguments appeared on the screen, one on the line immediately above and the other on the line immediately below the vertical center of the screen. The relative position of the two words was manipulated such that half of the word pairs were presented with the animate argument (e.g., ''he,'' ''him,'' ''you,'' or ''John'') above the inanimate argument, and the other half in the reverse order. Participants were instructed to use all presented words in any order to make a sensible sentence. As in Experiment 2, the progress bar filled in 1500 ms.

## Results

*Scoring responses.* The correctness of participants' utterances was categorized as in Experiment 1, with the following differences: The deviation category where participants ignore the presented preposition is irrelevant to Experiment 3. Since dative verbs were not used, no double object related errors were scored. No word movement errors were recorded, because a word movement error is not detectable in the two unconstraining conditions, since the resulting utterance would be acceptable; in the two order-constraining conditions, the utterance was recorded as a case error, representing the fact that the participant attempted to use the inappropriate grammatical case. Note that a case error can only occur in two conditions of the experiment, and thus was considered a deviation in the analyses below.

The only other error category specific to Experiment 3 was labeled *wrong voice,* such as ''John confused the story.'' Since this error could occur in every condition, it was considered an error in the production error analysis.[5]

The reliability of the coding of stimuli into error categories was checked as in Experiment 1. Original and checked coding into subcategories differed for 8% of the sample; the coding differed by 4% when collapsed into the three main categories.

*Exclusions.* Across all eight conditions, 3.6% of utterances were excluded because of experimental interruption or machine error. The number excluded per condition varied between 2.3% and 5.8%.

Incorrect utterances were sufficiently frequent to leave 8 of 640 cells empty on the item production latency analysis. The mean production latencies were estimated for these cells as in Experiment 1.

*Proportion of actives and passives.* The proportions of active and passive utterances in each condition are shown in Table 4. In each of the order-constraining argument conditions, utterances were dominantly either active or passive; thus, participants mostly created only one type of utterance in each order-constraining condition, demonstrating that syntactic flexibility was not present. For the unconstraining argument conditions, however,

[5] An error such as ''John confused the story'' may appear to be a word movement error. For this experiment, however, such an analysis is inappropriate, since the corresponding error in the order-constraining conditions could not be a word movement error. That is, an error such as ''He shocked the story'' was not considered a strict word movement error, because the intended utterance in this case would be ''The story shocked he.''

TABLE 4

NUMBER AND PERCENTAGE OF ACTIVE AND PASSIVE UTTERANCES AS A FUNCTION OF VERB TYPE AND ARGUMENT NOUN

| | Argument | | | |
|---|---|---|---|---|
| Verb type | Order-constraining subject | Order-constraining object | Unconstraining pronoun | Unconstraining name |
| Theme-experiencer | | | | |
| Active | 12[a] (2.5) | 365 (76.0) | 167 (34.8) | 126 (26.3) |
| Passive | 295 (61.5) | 6[a] (1.3) | 190 (40.0) | 251 (52.3) |
| Normal | | | | |
| Active | 375 (78.1) | 11[a] (2.3) | 330 (68.8) | 384 (80.0) |
| Passive | 4[a] (0.8) | 198 (41.3) | 19 (4.0) | 6 (1.3) |

*Note.* Percentages in parentheses. Total possible number of observations in each cell is 480.

[a] These proportions are based on case errors (e.g., ''The story confused he''). Wrong voice errors (e.g., ''He confused the story'') are not included in these counts.

the variety of participants' utterances depended on verb type. For theme-experiencer verbs, participants created both active and passive utterances with these arguments, indicating the presence of syntactic flexibility. With normal verbs, however, participants nearly always produced active utterances, despite the fact that passive utterances are acceptable. Thus, with normal verbs, syntactic flexibility was not effectively present, even in the unconstraining argument conditions.

*Production errors.* The numbers of production errors in each condition are shown in Fig. 8. The figure shows that all four unconstraining argument conditions—the syntactically flexible conditions—result in few production errors. For the syntactically nonflexible order-constraining argument conditions, performance was error prone only when a passive utterance was necessary. That is, most production errors occurred in the theme-experiencer/order-constraining subject and the normal/order-constraining object conditions, which are the conditions that require participants' correct utterances to have a passive structure. The theme-experiencer/order-constraining object conditions and the normal/order-constraining subject conditions both resulted in as few errors as the syntactically flexible conditions.

ANOVAs performed on the error totals revealed no effect of verb type ($F1(1,47) = 0.001$, $MS_e = 1.774$; $F2(1,79) = 0.001$, $MS_e = 1.774$) and a reliable effect of noun argument ($F1(3,141) = 13.22$, $MS_e = 1.329$; $F2(3,237) = 16.86$, $MS_e = 0.626$). The interaction was highly reliable ($F1(3,141) = 23.87$, $MS_e = 1.553$; $F2(3,237) = 36.95$, $MS_e = 0.602$).

*Production latencies.* Outliers in Experiment 3 were determined as in Experiment 1. The trimmed mean latencies for each condition are shown in Fig. 8. The figure shows that sentences produced in the normal/order-constraining object condition resulted in slower production latencies than the other seven conditions, which in turn were roughly equivalent.

ANOVAs performed on the mean production latencies revealed no effect of verb type ($F1(1,47) = 0.86$, $MS_e = 31571$; $F2(1,79) = 0.45$, $MS_e = 96277$) but a reliable effect of noun argument ($F1(3,141) = 64.38$, $MS_e = 33141$; $F2(3,237) = 57.68$, $MS_e = 81506$). The interaction of noun argument and verb type was highly reliable ($F1(3,141) = 56.85$, $MS_e = 30856$; $F2(3,237) = 45.05$, $MS_e = 69848$).

### *Discussion*

The competitive model predicts that syntactic flexibility should result in more difficult

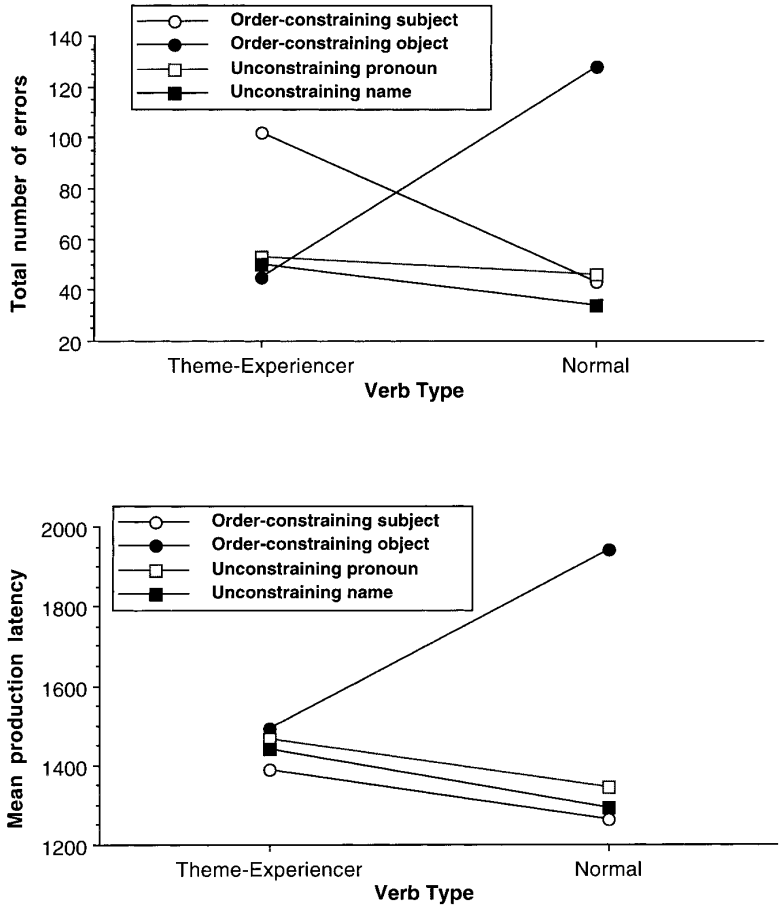


FIG. 8. Measured number of errors (top panel) and mean production latencies (bottom panel) as a function of verb type and argument type in Experiment 3.

language production, whereas the incremental model predicts easier language production with flexibility. The results of Experiment 3 showed that when syntactic flexibility affected performance, participants' productions under flexible conditions were accompanied by faster production latencies and fewer errors.

Experiment 3 revealed other important factors that affect language production. The production error analysis revealed that syntactic nonflexibility only resulted in more difficult production when participants needed to produce passive sentences. If participants could produce only active utterances, or if syntactic flexibility was present (even when a high proportion of passives were produced), then production was relatively error free. Similarly, the production latencies revealed that production was slowed only in a syntactically nonflexible condition where passives needed to be produced (the normal/order-constraining object condition). A second effect in the latencies, however, was that the other nonflexible condition where passives are necessary, the theme-experiencer/order-constraining subject condition, resulted in production latencies as short as the other fast conditions.

A result that may help explain these complex effects of flexibility concerns the lack of effect found among the unconstraining argument conditions. The quick production latencies and low error rates in the unconstraining argument theme-experiencer conditions are straightforward: Syntactic flexibility is pres-

ent, and participants exploited that flexibility (as evidenced by the roughly balanced utterance types in those conditions), so grammatical encoding is efficient, as described by the incremental model. The unconstraining argument normal verb conditions, however, are more complex. Despite the existence of syntactic flexibility, participants created active utterances almost exclusively. Thus, the two normal verb conditions are effectively nonflexible, yet production was still relatively quick and error free.

The results in the normal verb conditions point to the conclusion that the production of active sentences enjoys some advantage over the production of passives. Assume that grammatical encoding proceeds with some active promoting mechanism (e.g., by providing what would be the active grammatical subject with an activation boost, or because of different base activation levels of a syntactic production node [Bock, 1982]). The lack of difficulty in the flexible normal verb conditions then makes sense: Although speakers are not exploiting the flexibility that is available to them, the structure that is being used is an active one, and production is efficient. Further, with an active promoting mechanism, the nonflexible theme-experiencer/order-constraining object and the normal/order-constraining subject conditions should also be quick. Though these conditions are nonflexible, the utterance type that speakers must produce is the active structure, and difficulty due to syntactic nonflexibility should not be seen.

It remains to be explained why the theme-experiencer/order-constraining subject condition, which permits only passive structures to be produced and thus should be difficult for participants, results in a large number of errors but not slow production latencies. The lack of effect in the latencies might be explained by a strategic effect, related to the fact that these utterances must contain the argument ''he.'' On each trial, speakers first saw the verb of the sentence for 1500 ms, followed by a 1000 ms blank screen. It is likely that during this 2500 ms period, speakers were anticipating the utterance that they were to create upon presentation of the noun arguments. Further, every trial included one of four animate noun arguments (''he,'' ''him,'' ''you,'' or ''John''), and so a reasonable guess could be made about the argument to anticipate. The order-constraining subject argument ''he'' is good to anticipate with, since it is strongly associated with the beginning of sentences (and speakers are probably trying to anticipate the start of their sentences), and because it is the most frequent and phonologically simplest of the four possibilities.

A post hoc analysis of all errors and deviations provide some support for the notion that speakers are anticipating that they will say a sentence with the order-constraining subject pronoun ''he.'' Table 5 shows the number of error or deviation utterances where the utterance began with an incorrect noun argument, and where the presented noun argument was never included in the eventual sentence (i.e., removing from the analysis utterances where speakers were excessively creative rather than anticipatory, such as saying ''He shocked you with the story'' in the unconstraining pronoun ''you'' condition). Intrusions seem to only occur where the appropriate and intruding argument bear some visual resemblance (since ''he'' intrudes most often in the order-constraining object condition ''him,'' and the unconstraining name argument ''John'' never intrudes or is intruded upon). Most importantly, the table shows that the order-constraining subject noun ''he'' is the most commonly intruding argument, suggesting that speakers are often anticipating that their utterances will begin with ''he.''

## General Discussion

This research evaluated two alternative theories of grammatical encoding. One theory is based on competitive principles, and claims that syntactic flexibility and the simultaneous activation of structural plans that accompanies flexibility should cause instability in the grammatical encoding system, and thus should result in more difficult production. The second theory is based on incremental principles, and claims that syntactic flexibility permits well-formed grammatical encoding to proceed with a greater accommodation to varying lexical

TABLE 5

NUMBER OF ANTICIPATORY INTRUSIONS IN EACH NOUN ARGUMENT CONDITION

| | Noun argument condition | | | |
|---|---|---|---|---|
| Intruding argument | Order-constraining subject (''he'') | Order-constraining object (''him'') | Unconstraining pronoun (''you'') | Unconstraining name (''John'') |
| Order-constraining subject (''he'') | — | 33 | 11 | 0 |
| Unconstraining pronoun (''you'') | 6 | 2 | — | 0 |
| Unconstraining name (''John'') | 0 | 0 | 0 | — |

activations, and thus should make grammatical encoding more efficient.

Experiments 1 and 2 used alternator and nonalternator verbs to manipulate syntactic flexibility. Both experiments further manipulated the flexibility that alternator verbs possessed, but by different means. Experiment 1 forced participants to use a preposition in half of their utterances, eliminating the possibility of using a double object utterance. Experiment 2 had participants create sentences with pronouns, and flexibility was limited because any sentence including a theme pronoun *it* cannot be said as a double object. Experiment 1 participants made reliably fewer errors in the flexible condition than in the nonflexible conditions and a planned comparison showed that the flexible condition had reliably faster production latencies than the nonflexible conditions. Experiment 2 participants were reliably faster in the flexible condition than in the nonflexible conditions, but the error results were difficult to interpret because of a large main effect of verb type. Overall, every reliable result from Experiments 1 and 2 conformed to the predictions of the incremental model and contradicted the predictions of the competitive model.

In Experiment 3, participants created passive and active utterances under conditions of manipulated flexibility. Case-marked pronouns were used to restrict the variety of utterances participants could create. The effect of syntactic flexibility appeared only when participants created passive sentences such that the presence of flexibility made production more efficient, supporting the incremental model over the competitive model. In addition, the results suggest that active sentence structures are promoted by the grammatical encoding system. Quick latencies in one nonflexible condition requiring passive utterances were explained by a strategic effect, whereby participants anticipated that their utterance would begin with the pronoun ''he,'' reducing the chances of finding any effect of planning in measured latency.

One issue remains to be explored. Experiments 1 and 2 showed that the flexible conditions occurred with faster production latencies than the nonflexible conditions. However, only the flexible conditions included double object utterances, and it turned out that the double object utterance production latencies were faster than the prepositional dative latencies. In Experiment 1, this difference has no real implication for the overall conclusions; the prepositional dative mean latency in the flexible condition was still 30 ms faster than any nonflexible condition, so the main conclusion that flexibility results in faster production latencies still holds. In Experiment 2, however, the mean production latency for prepositional datives in the flexible condition was nearly identical to the latency in the nonflexible alternator condition. That is, utterances such as ''I gave the toy to him,'' which were produced in a flexible condition, occurred with the same production latency as an utterance

such as ''I gave it to the child,'' which were produced in a nonflexible condition.

However, an important difference between the two utterances concerns the position of the pronoun in each sentence. In ''I gave the toy to him,'' the pronoun occurs at the end of the sentence, while in ''I gave it to the child,'' the pronoun occurs immediately after the verb. It has been noted that pronouns possess many properties that would give their language production representations intrinsically high activation levels (e.g., pronouns are high frequency and are phonologically simple), so that pronouns should emerge early in a sentence (a claim supported by the dominance of double objects like ''I gave him the toys'' over prepositional datives like ''I gave the toys to him'' in the alternator/unconstraining condition). Assuming that pronouns possess intrinsically high activation levels, incremental theories claim that with respect to pronoun placement, an utterance such as ''I gave the toy to him'' occurs as a result of less optimal production than an utterance such as ''I gave it to the child'' (Bock, 1982). The latter construction with the earlier placement of ''it'' *should* be produced faster than the former construction with the later placement of ''him,'' but the two constructions were produced with the same latency.

From this perspective, the production of utterances with the order-constraining argument ''it'' are being slowed down, relative to the utterances with the unconstraining pronoun ''him.'' What may be slowing the production of these utterances is the lack of syntactic flexibility in the order-constraining condition. Although there is a general preference for pronouns to appear early in a sentence, each trial occurs under different circumstances that might make a prepositional dative or a double object sentence easier to produce on that trial. With the unconstraining argument ''him,'' the easiest to produce utterance on each trial can be produced. With the order-constraining argument ''it,'' a double object sentence cannot be produced (''I gave the child it''), even if it would be easiest to produce on that trial. Thus, across all trials, utterances with the order-constraining ''it'' are being produced more slowly than they would be if they were being produced under syntactically flexible circumstances.

Overall, then, it is unlikely that the production advantage in the flexible conditions is an artifact due to producing specific types of syntactic constructions. Such an explanation fails to account for the latency difference that occurs among prepositional dative utterances in Experiment 1, the latency differences in Experiment 3 (which did not use datives at all), and the error total differences in all experiments. Within an incremental approach, the lack of latency differences among prepositional dative utterances in Experiment 2 can perhaps be explained by preferences for pronoun placement.

Although the results of these experiments show beneficial effects of flexibility under different constraining conditions and with different types of structures, it must be acknowledged that the production task used is a marked departure from natural production. Although true production effects such as structural persistence and argument structure preferences were evident in the results, the tight control over planning (visually presenting the words to be used) and production (time pressure during articulation) makes generalization to natural situations tentative. The conclusions of these experiments would thus be strengthened by evidence from more natural language production situations. Such a combination of controlled artificial experiments with more natural, less controlled observations has been the key to progress in production theory (Levelt, 1989).

Nevertheless, the results of these experiments provide some insight as to why language production proceeds as smoothly as it does. At face value, syntactic flexibility seems to complicate language by providing possibly redundant means for expressing a particular idea. However, the results show that speakers produced sentences more easily under conditions of syntactic flexibility, suggesting that flexibility does not complicate language production. Rather, having more ways to express a message permits the speaker to choose a sentence that accommodates variation in the

way that a message evolves. This allows the speakers of a language to more easily and accurately communicate with one another.

## APPENDIX A

### *Implementation of the Interactive Activation Models*

The models depicted in Figs. 1 and 3 were implemented as interactive activation models. The models operate by clamping the activation of one or more of the units, and then permitting activation to spread through the connections of the model. The verb and preposition nodes were always clamped at the beginning of each simulation, and remained clamped until processing was terminated. The message level units for each noun argument were clamped between 5 and 14 time steps into the simulation, determined randomly from a uniform distribution with the restriction that both message level units could not be clamped starting at the same time step. These message level units remained clamped for five time steps. Activations were updated synchronously (i.e., the calculated activation of a unit did not affect the activation of other units until all the units in the model had been updated). Weight values remained constant throughout a simulation.

Since the problem space of the model is limited, the effect of other factors (e.g., other verbs, other syntactic structures, or other levels of processing) was simulated by adding noise to the models. Small, random variation was given to the initial weights. Beyond this initial quasi-randomness, there was no other randomness in the model; in particular, no noise was added to the model computations online.

For the competitive model (Fig. 1), activation was allowed to spread until either one of the two structure nodes (i.e., the prepositional dative or the double object node) reached a threshold activation of 1.0. For the incremental model (Fig. 3), processing halted when a noun argument node was *selected.* Only the most active noun argument node could be selected, and only if the structure node with the same thematic label (i.e., an appropriate slot) had an activation of 1.0.

Activation spread by means of a linear activation function bounded by 0 and 1. Thus, the activation of a unit at time $t$ was simply:

$$\text{act}_i(t) = d \times \text{act}_i(t-1) + \sum_j w_{ij} \times \text{act}_j(t-1)$$

where $\text{act}_i(t)$ is the activation of the unit about to be calculated, $d$ is a decay rate, $\text{act}_i(t-1)$ is the activation of the same unit on the previous time step, $w_{ij}$ is the weight to unit $i$ from unit $j$, and finally, $\text{act}_j(t-1)$ is the activation of the sending unit $j$ on the previous time step.

The following parameters were used for the models: Clamped units were assigned an activation of 1.0, and unclamped units were initialized to 0.0. All connections were symmetric and bidirectional, except for the inhibitory connection from the ''to'' node to the ''NP-goal'' node in the incremental model. The decay rate for both models was 0.8. For the competitive model, excitatory weights were initialized to 0.2, inhibitory weights between word units were initialized to $-0.5$, the inhibitory weight between the structure nodes was initialized to $-1.0$, and the weight from the ''to'' to the ''PrepDat'' node was initialized to 0.05. For the incremental model, excitatory weights were initialized to 0.4, and inhibitory weights were initialized to $-0.2$. All weights had random noise added, selected from a normal distribution with a mean of 0 and a standard deviation of 0.01.

Analyses were conducted on simulated ''participants.'' That is, a simulation was run in all four conditions with a particular set of random weights. However, to simulate item differences, the randomly determined time step at which message level input is introduced varied within a ''participant.'' Statistical analyses were then conducted with two-way repeated measures ANOVAs with ''participant'' as the random factor.

## APPENDIX B

### *Stimuli Used in Experiments 1 and 2*

Each sentence contains a verb pair *alternator verb/nonalternator verb.* To create the double object structure, reverse the theme and

goal arguments and delete the dative preposition (e.g., *I gave/donated the toys to the children* becomes *I gave/donated the children the toys*). The *Theme Argument* and *Goal Argument* columns represent the nonpronominal themes and goals used in Experiment 2. ''N/A'' indicates a stimulus used in Experiment 1 but not in Experiment 2.

| | Sentence | Nonpronominal theme argument | Nonpronominal goal argument |
|---|---|---|---|
| 1 | I gave/donated the toys to the children. | toy | child |
| 2 | I showed/displayed the painting to the visitor. | painting | visitor |
| 3 | I sent/transmitted the message to the spy. | message | spy |
| 4 | I bought/purchased the plant for the secretary. | plant | secretary |
| 5 | I told/mentioned the excuse to the manager. | rumor | manager |
| 6 | I brought/carried the groceries to the family. | package | butler |
| 7 | I read/described the rules to the team. | rules | player |
| 8 | I mailed/addressed the letter to the company. | letter | company |
| 9 | I offered/suggested the solution to the executive. | solution | executive |
| 10 | I built/constructed the equipment for the police. | equipment | police |
| 11 | I taught/explained the lesson to the students. | lesson | student |
| 12 | I lent/presented the game to the boy. | cup | boy |
| 13 | I wrote/jotted the note to the neighbor. | note | neighbor |
| 14 | I served/provided the drink to the guests. | drink | guest |
| 15 | I sold/peddled the computer to the engineer. | computer | engineer |
| 16 | I fixed/heated the dinner for my daughter. | dinner | son |
| 17 | I got/obtained the tickets for my friends. | N/A | N/A |
| 18 | I reserved/kept the seat for my roommate. | N/A | N/A |
| 19 | I baked/warmed the muffins for my teacher. | muffin | chef |
| 20 | I assigned/distributed the questions to the class. | N/A | N/A |
| 21 | I loaned/trusted the skates to my nephew. | bike | nephew |
| 22 | I handed/delivered the evidence to the lawyer. | evidence | lawyer |
| 23 | I left/bequeathed the money to the widow. | N/A | N/A |
| 24 | I prescribed/applied the medication to the patient. | medication | patient |
| 25 | I gave/donated the gift to the priest. | gift | priest |
| 26 | I showed/displayed the artwork to the crowd. | artwork | critic |
| 27 | I sent/transmitted my location to the navigator. | location | navigator |
| 28 | I bought/purchased the antique for my spouse. | antique | spouse |
| 29 | I told/mentioned the story to the editor. | story | editor |
| 30 | I brought/carried the dog to the vet. | dog | vet |
| 31 | I read/described the script to the actor. | script | actor |
| 32 | I mailed/addressed the complaint to the senator. | complaint | senator |
| 33 | I offered/suggested the novel to the customer. | novel | customer |
| 34 | I built/constructed the model for the client. | model | client |
| 35 | I taught/explained the plan to the group. | plan | soldier |
| 36 | I lent/presented the jacket to the golfer. | jacket | golfer |
| 37 | I wrote/jotted the memo to the accountant. | memo | accountant |
| 38 | I served/provided the snacks to the worker. | snack | worker |
| 39 | I sold/peddled the trinkets to the tourists. | trinket | tourist |
| 40 | I fixed/heated the soup for the crew. | soup | traveller |
| 41 | I got/obtained the license for the hunter. | N/A | N/A |
| 42 | I reserved/kept the book for the critic. | N/A | N/A |
| 43 | I baked/warmed the bread for my mother. | bread | waiter |
| 44 | I assigned/distributed the reading to the section. | N/A | N/A |
| 45 | I loaned/trusted the necklace to the attendant. | necklace | attendant |
| 46 | I handed/delivered the pizza to the freshman. | pizza | freshman |
| 47 | I left/bequeathed the mansion to my son. | N/A | N/A |
| 48 | I prescribed/applied the lotion to the lifeguard. | lotion | lifeguard |

## Appendix C

### *Stimuli Used in Experiment 3*

The expected sentence for Stimulus 1, Theme 1 is as follows (the blank was filled based on the noun argument factor):

| | |
|---|---|
| Theme-Experiencer/Active: | The conflict angered ____. |
| Theme-Experiencer/Passive: | ____ was/were angered by the conflict. |
| Normal/Active: | ____ protested the conflict. |
| Normal/Passive: | The conflict was protested by ____. |

A second set of sentences was created by using Theme 2. All stimuli in Experiment 3 followed this pattern.

| | Th-Exp verb | Normal verb | Theme 1 | Theme 2 |
|---|---|---|---|---|
| 1 | angered | protested | conflict | proposal |
| 2 | alarmed | suppressed | news | screams |
| 3 | aggravated | bellowed | insult | command |
| 4 | relaxed | requested | massage | cigarette |
| 5 | confused | rejected | affair | story |
| 6 | soothed | enjoyed | lullaby | sunlight |
| 7 | tempted | decorated | sundae | invitation |
| 8 | troubled | examined | evidence | assignment |
| 9 | frightened | watched | lightning | bomb |
| 10 | entertained | applauded | jokes | performance |
| 11 | irritated | recommended | hairstyle | manuscript |
| 12 | terrified | dreaded | thunder | earthquake |
| 13 | disturbed | prevented | theft | accident |
| 14 | haunted | scrutinized | image | movie |
| 15 | worried | ordered | layoffs | attacks |
| 16 | shocked | loathed | slayings | carnage |
| 17 | pleased | wrapped | gift | chocolates |
| 18 | alerted | sounded | sirens | horn |
| 19 | scared | explored | cave | forest |
| 20 | distracted | ignored | television | conversation |
| 21 | guided | consulted | map | script |
| 22 | bored | xeroxed | textbook | article |
| 23 | enticed | devoured | cheesecake | brownie |
| 24 | encouraged | appreciated | praise | comments |
| 25 | stunned | mourned | tragedy | death |
| 26 | impressed | ensured | profits | victory |
| 27 | demoralized | disregarded | defeat | setback |
| 28 | excited | misplaced | prize | treasure |
| 29 | appalled | detested | crime | ritual |
| 30 | thrilled | feared | fireworks | adventure |
| 31 | annoyed | despised | delay | roadwork |
| 32 | amused | purchased | toy | Nintendo |
| 33 | enraged | noticed | profanity | graffiti |
| 34 | challenged | solved | puzzle | problem |
| 35 | captivated | criticized | mystery | artwork |

| | Th-Exp Verb | Normal verb | Theme 1 | Theme 2 |
|---|---|---|---|---|
| 36 | disgraced | fabricated | scandal | editorial |
| 37 | intrigued | analyzed | phenomenon | illusion |
| 38 | embarrassed | avoided | blunder | mistake |
| 39 | disgusted | refused | anchovies | caviar |
| 40 | offended | repeated | rumors | speech |

## 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. (1986). Meaning, sound, and syntax: Lexical priming in sentence production. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* **23,** 575–586.

BOCK, J. K. (1987). An effect of the accessibility of word forms on sentence structures. *Journal of Memory and Language,* **26,** 119–137.

BOCK, J. K. (in press). Language production: Methods and methodologies. *Psychonomic Bulletin & Review.*

BOCK, J. K., & BREWER, W. F. (1974). Reconstructive recall in sentences with alternative surface structures. *Journal of Experimental Psychology,* **103,** 837–843.

BOCK, J. K., & LEVELT, W. J. M. (1994). Language production: Grammatical encoding. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics.* New York: Academic Press.

BOCK, J. K., & LOEBELL, H. (1990). Framing sentences. *Cognition,* **35,** 1–39.

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., & WARREN, R. K. (1985). Conceptual accessibility and syntactic structure in sentence formulation. *Cognition,* **21,** 47–67.

BUTTERWORTH, B. (1980). Evidence from pauses in speech. In B. Butterworth (Ed.), *Language production* (Vol. 1, pp. 155–176). London: Academic Press.

CUTLER, A. (1982). The reliability of speech error data. In A. Cutler (Ed.) *Slips of the tongue in language production* (pp. 7–28). Berlin: Mouton.

DELL, G. S. (1986). A spreading-activation theory of retrieval in sentence production. *Psychological Review,* **93,** 283–321.

DELL, G. S., & O'SEAGHDHA, P. G. (1992). Stages of lexical access in language production. *Cognition,* **42,** 287–314.

DELL, G. S., & O'SEAGHDHA, P. G. (1994). Inhibition in interactive activation models of linguistic selection and sequencing. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory Processes in Attention, Memory and Language* (pp. 409–453). San Diego: Academic Press.

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.

DELL, G. S., & REPKA, R. J. (1992). Errors in inner speech. In B. J. Baars (Ed.), *Experimental Slips and Human Error: Exploring the Architecture of Volition* (pp. 237–262). New York: Plenum Press.

DESMEDT, K. J. M. J. (1990). *Incremental sentence generation.* Ph.D. dissertation, Katholieke Universiteit Nijmegen.

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

FRANCIS, W. N., & KUCERA, H. (1982). *Frequency analysis of English usage: Lexicon and grammar.* Boston: Houghton–Mifflin.

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* (Vol. 9, pp. 133–177). New York: Academic Press.

GOLDMAN-EISLER, F. (1968). *Psycholinguistics: Experiments in spontaneous speech.* New York: Academic Press.

HOLMES, V. M. (1988). Hesitations in sentence planning. *Language and Cognitive Processes,* **3,** 323–361.

KEMPEN, G. (1987). A framework for incremental syntactic tree formation. *Proceedings of the tenth international joint conference on artificial intelligence.* Los Altos: Morgan Kaufmann.

KEMPEN, G., & HOENKAMP, E. (1987). An incremental procedural grammar for sentence formulation. *Cognitive Science,* **11,** 201–258.

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.

LOMBARDI, L., & POTTER, M. C. (1992). The regeneration of syntax in short term memory. *Journal of Memory and Language,* **31,** 713–733.

MACDONALD, M. C., PEARLMUTTER, N. J., & SEIDENBERG, M. S. (1994). The lexical nature of syntactic ambiguity resolution. *Psychological Review,* **101,** 676–703.

MACKAY, D. G. (1970). Spoonerisms: The structure of

errors in the serial order of speech. *Neuropsychologia,* **8,** 323–350.

MACKAY, D. G. (1972). The structure of words and syllables: Evidence from errors in speech. *Cognitive Psychology,* **3,** 210–227.

MCCLELLAND, J. L., & RUMELHART, D. E. (1981). An interactive activation model of context effects in letter perception: Part I. An account of basic findings. *Psychological Review,* **88,** 375–407.

MCDONALD, J. L. BOCK, J. K., & KELLY, M. H. (1993). Word and world order: Semantic, phonological, and metrical determinants of serial position. *Cognitive Psychology,* **25,** 188–230.

MEYER, A. S. (1991). The time course of phonological encoding in language production: Phonological encoding inside a syllable. *Journal of Memory and Language,* **30,** 69–89.

QUIRK, R., GREENBAUM, S., LEECH, G., & SVARTVIK, J. (1972). *A grammar of contemporary English.* New York: Seminar Press.

SCHRIEFERS, H., MEYER, A. S., & LEVELT, W. J. M. (1990). Exploring the time course of lexical access in language production: Picture–word interference studies. *Journal of Memory and Language,* **29,** 86–102.

SHATTUCK-HUFNAGEL, S. (1979). Speech errors as evidence for a serial order mechanism in sentence production. In W. E. Cooper & E. C. T. Walker (Eds.), *Sentence processing: Psycholinguistic studies presented to Merrill Garrett.* Hillsdale, NJ: Lawrence Erlbaum.

STEMBERGER, J. P. (1985). An interactive activation model of language production. In A. W. Ellis (Ed.), *Progress in the psychology of language: Vol. 1.* Hillsdale, NJ: Lawrence Erlbaum.

WHEELDON, L. R., & LEVELT, W. J. M. (1995). Monitoring the time course of phonological encoding. *Journal of Memory and Language,* **34,** 311–334.

WINER, B. J. (1971). *Statistical principles in experimental design.* New York: McGraw–Hill.

(Received November 3, 1994)
(Revision received July 28, 1995)