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Toward a Cognitive Psychology of Syntax: Information Processing Contributions to Sentence Formulation

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It is widely acknowledged that characteristics of the general information processing system in which sentence formulation occurs may provide constraints on syntax in language use. This paper proposes one possible source of such constraints. Evidence is reviewed indicating that the syntax of sentences may to some degree reflect the transient processing demands of lexical retrieval, suggesting an interaction between syntactic and lexical processing. Specifically, the syntactic structure of utterances appears to be sensitive to the accessibility of lexical information, with phrases containing more accessible information occurring earlier in sentences. The existence of such an interaction argues that the utterance formulation system is not strictly hierarchical, as most current approaches to sentence production imply. A broad framework for models of production is outlined that incorporates these interactions within a limited-capacity processing system. This framework also permits a resolution of contradictions in the literature on pragmatic determinants of constituent order in adult language use.

People talk and write, in large part, to communicate various ideas. For ideas to be expressed in speech or writing, they must first be mapped onto language. This paper is concerned with what happens to ideas before they are actually spoken or written. In particular, it examines possible relationships between the syntactic structures of eventual utterances and the formulation processes that transform thought into speech. The aim is to explain how these processes are coordinated in the creation of utterances.

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The syntax of an utterance necessarily reflects something about the structures and processes that serve sentence formulation. To gain an appreciation for the significance of syntax in production, its role in production can be contrasted with its role in comprehension. Successful comprehension yields some representation of the underlying meaning of the sentence. Because of the large influence of our prior semantic and world knowledge on this recovery of meaning, many of the aspects of a sentence's surface form appear to play a relatively minor role in comprehension, in comparison with higher level semantic and knowledge integration processes. As a result many current theories of language comprehension are more concerned with these higher level processes than with syntactic parsing procedures (Lachman & Lachman, 1979). In sentence production, on the other hand, it is necessary to create a surface structure. This surface structure should of course convey a certain underlying

meaning, but to do so it requires the paraphernalia of the correct morphology, constituent structure and order, and clause structure and order, that is, the correct syntax. Thus, a theory of language production can no more ignore syntactic structure than a theory of language comprehension can ignore knowledge structure. Sentence production theories therefore have important implications for explanations of syntax and vice versa.

Exactly what the syntax of an utterance reveals about formulation processes depends, however, on the way in which the processes responsible for syntax are integrated with, related to, or shared by processes responsible for other aspects of sentence meaning or form. There are currently two different views of the relationship between syntactic processing and the other mechanisms of sentence production. One approach, strongly influenced by transformational grammar (e.g., Chomsky, 1965), regards syntax as originating within an autonomous syntactic component that maps the information to be conveyed by an utterance onto uniquely linguistic structures in an independent linguistic system (Fay, 1980a, 1980b; Foss & Fay, 1975; Garrett, 1975, 1976).¹ An important assumption of this viewpoint is that, in its fundamentals, syntax originates in certain strong linguistic universals, giving human language a component that is independent of more general cognitive abilities (Chomsky, 1972, 1975). An alternative to the autonomous syntax approach regards syntax as the product of various cognitive and communicative factors influencing the processing of the intended messages underlying sentences in different communicative contexts (Ertel, 1977, Note 1; Osgood, 1980; Schlesinger, 1977; Zubin, 1979). This approach is closely related to some of the assumptions of functional grammar (Bates & MacWhinney, in press; Givon, 1979; Halliday, 1970). One of the most important of these assumptions is that languages and their syntax take the form that they do because humans process information in particular ways within domains that language shares with other cognitive processes (E. V. Clark & H. H. Clark, 1978; Osgood & Bock, 1977; Slobin, 1979).

Although these approaches reflect very different views of the mechanisms of syntactic processing in sentence formulation, each has certain empirical and theoretical advantages. On the one hand, to the degree that the functional assumption is valid, explanations of syntax can be constrained as well as enriched by theories of the general cognitive processes that influence or support syntactic processing in sentence production. On the other hand, to the degree that the assumption of syntactic autonomy is valid, it will be profitable to investigate syntactic processing in language use as an isolable subsystem, to some extent independent of the influence of pragmatic and general information processing factors. Despite the differences between these approaches, there are reasons to believe that each may have some validity, though in different parts of the sentence formulation system. To gain the advantages of both, however, it is obviously necessary to determine their respective domains.

The analyses and evidence presented below are organized around three major claims that bear on the possibility of integrating various elements of the functional and autonomous syntax approaches to sentence production. First, a case will be presented for two syntactic processing modes affecting

¹ Garrett, for example, argues that

we should take seriously the view that most significant aspects of syntactic processing for sentences are done independently of their ultimate semantic consequence. Evidently there must be a means of insuring or determining that the forms resulting from such processing have the appropriate (i.e., speaker intended) semantic consequences. But that constraint in no way prejudices the possibility that syntactic form is processed autonomously both for sentence production and sentence comprehension, since semantic selection may be accomplished by means other than the importation of semantic variables into the domain of processing rules for establishing sentence form. (1976, p. 232)

Fay takes an even stronger position, proposing not only autonomous processing of syntactic form, but also "that speech production involves a direct realization of a transformational grammar. The transformational grammar to be realized is the so-called 'standard theory' of *Aspects of the Theory of Syntax* (Chomsky, 1965)" (1980a, p. 445).

adult language production, one which operates in a substantially automatic fashion, in parallel with the retrieval and assembly of semantic and phonological information, and a second which is more controlled. Second, the need for flexible trade-offs between the automatic activation and retrieval of information, and more controlled construction or deployment of syntactic plans will be proposed as an important part of an explanation for the existence and use of syntactic paraphrases (sentences which are semantically quite similar but syntactically different, e.g., datives such as "The secretary told Malcolm the joke" versus "The secretary told the joke to Malcolm," active/passive variants, and many others). Third, evidence will be presented indicating that lexical accessibility influences the syntactic structure of utterances, implicating a certain amount of data-driven processing in sentence formulation. The existence of such effects suggests that surface syntax is the product of interactive rather than strictly hierarchical processing. A framework capable of accounting for such interactions requires a syntactic system that coordinates linguistic information efficiently without sacrificing communicative precision.

The plan of the paper is as follows: The next section outlines the nonsyntactic components of a general sentence production system, drawing on several current proposals, and discusses certain broad processing constraints on sentence production models. The second section discusses possible contributions of different processing modes, and trade-offs between them, to the syntactic structure of sentences. The third section presents the relevant psycholinguistic evidence and converging findings from lexical processing that suggest a role for data-driven processing in determining syntax. The fourth section proposes a framework for sentence formulation that distributes hypothesized effects on syntactic processing among several information sources and couples certain processing assumptions with some of the standard representational assumptions of sentence production theories. The fifth section examines the implications of the resulting framework for certain conflicting claims about the functional correlates of the order of words and phrases in sentences.

Components of Sentence Production

The cognitive processes that support sentence production can be roughly subdivided into five "arenas" in which information is formulated, excluding, for the moment, a syntactic component. The five arenas include a referential arena, a semantic arena, a phonological arena, a phonetic arena, and a motor-assembly arena. The characteristics of the codes or representations that differentiate these arenas will be described in this section, along with certain general constraints on the relationship between these components and syntactic processing. Because the characteristics of referential, semantic, and phonological information are more central to the concerns of the paper, these three arenas will be emphasized.

The Referential Arena

The primary responsibility of the referential arena is the translation or coding of the nonlinguistic representation of thought into a format that can be used by the linguistic system. The characteristics of the nonlinguistic representational system are a matter of considerable dispute (J. R. Anderson, 1978; Fodor, 1975, 1978; Johnson-Laird, 1978; Kieras, 1978; Kosslyn, 1981; Kosslyn & Pomerantz, 1977; Pylyshyn, 1973, 1981; Rumelhart & Ortony, 1977), but there is at least a general consensus that some such system furnishes the ideational content of language (H. H. Clark & E. V. Clark, 1977; Fodor, Bever, & Garrett, 1974; Foss & Hakes, 1978; Osgood, 1971; Schlesinger, 1977). The nature of the relationship between these nonlinguistic ideas and their linguistic representation is, if anything, even more problematic than their form.

Though offering no definitive resolution of this conflict, Chafe (1977) nonetheless provides a useful overview of the types of processes that might precede such a translation. Chafe argues that nonverbal memories and knowledge come in interrelated "chunks" representing particular events. To talk about a certain chunk, its components must first be organized in terms of some already established pattern, a process which Chafe calls schematization. An example of such a pattern might be Lichtenstein and

Brewer's (1980) "Plan" schema for goal-directed events, which includes a specified or inferred goal of some actor, along with a sequence of subgoals that define actions required to achieve the primary goal. Thus, someone wishing to narrate an action sequence leading up to the mailing of a letter (the primary goal) might schematize the sequence as a series of subgoals (e.g., writing the letter, typing it, signing it, addressing the envelope, sealing and stamping the envelope, and going to the post office).

Schemas can be reiterated at several different levels, so that the components of one chunk may themselves permit or require schematization. For example, as part of his planning the narrator might schematize the events that comprise the signing of the letter, including finding a pen, removing its cap, and writing a signature. This process continues until the would-be speaker arrives at a level of detail that satisfies the communicative goals and constraints that are in force, and which is verbalizable in an utterance. At this point a process that Chafe calls *framing* ensues. Framing requires the selection of participants and their assignment to particular roles. For example, in the schematization of the letter-signing subgoal, the action of removing the pen from a drawer might be framed, with its participants and their roles including the narrator as the actor, the pen as the object of the action, and the drawer as the location.

Following Fillmore (1968, 1977), linguists and psychologists have argued for the existence of a limited number of conceptual predicate types with associated roles. Chafe's framing notion presupposes such predicate types, organized around similar event or action relations, and to some extent specified by the required roles played by the participants. For example, in actions such as breaking, opening, cooking, baking, and melting, the participant roles include those of the agent, the recipient of the action, and the instrument. The speaker, however, has certain options in the selection of participants to include in a frame. Very different utterances may result from a decision to talk about an event only in terms of the recipient of an action (e.g., "The display window was broken") rather than in terms of all three

(e.g., "A looter broke the display window with a baseball bat").

Though Chafe does not discuss them, there are a number of other characteristics of ideas, events, or situations that have implications for linguistic form, and which should therefore be translated in the referential arena. These include such things as speech act type (whether the speaker's intention is to assert, deny, question, command, etc.); *hierarchical relationships* between related ideas, events, or situations; information relevant to tense, truth value, modality, and other components of the auxiliary; and designations of topic or perspective (whether a certain event, for example, is identified as a "coming in" or "going in" will depend on the speaker's perspective or his assumptions about the listener's perspective; Kuno & Kaburaki, 1977; MacWhinney, 1977).

The *relational structure thus composed* in the referential arena can be neutrally described as a proposition or set of propositions that structure and segment nonlinguistic conceptual patterns. The components of and relations defined by these propositions are processed in the semantic arena.

The Semantic Arena

The semantic arena is responsible for meshing the propositional relations and components formulated in the referential arena with lexical concepts. This process, which has been discussed by H. H. Clark and E. V. Clark (1977) and Chafe (1977), involves mapping the propositional components onto those linguistic categories that will serve to communicate the speaker's thought. In "A looter broke the display window with a baseball bat," for example, the categorization of the propositional information underlying the phrase *a looter* might instead have produced matches with lexical concepts for words such as *thief*, *hoodlum*, or *robber*. Selection of a particular concept will depend on both the existence of related lexical concepts in a speaker's vocabulary, as well as the amount of differentiation of related concepts within some semantic field (i.e., whether the speaker has separate and distinctive lexical concepts for different words in the language). When no single lexical con-

cept is adequate for a propositional component, Chafe (1977) suggests that modifying concepts (adjectives, adverbs) may be selected in conjunction with categorical concepts.

One of the most important determinants of lexical concept selection is the codability of a propositional component, that is, how readily it is matched to a unique lexical concept (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). Lexical categorization of a propositional component symbolizing some object or category of objects may be more rapid the better it matches the representation of the lexical concept (E. E. Smith, Balzano, & Walker, 1978).

Because typical instances of object categories are likely to be labeled in the same way by speakers of a particular language (Brown, 1976; Brown & Lenneberg, 1954), the communicative burden on the speaker may be reduced when a propositional component is highly codable. Evidence relevant to this has been provided by Chafe (1977), who compared the number of different descriptions given by a group of subjects for a certain common type of fruit with the number of descriptions given for a free-form piece of playground equipment. Both objects had appeared in a film the subjects had seen and were later asked to recall in writing. The fruit was described in only five different ways, with 90% of the writers calling it a banana. The piece of playground equipment received 20 different labels, with the highest degree of consensus for any label reaching only 19%. The mean number of modifiers used in communicating the idea of a banana was only .16, whereas expressions denoting the piece of playground equipment contained a mean of 2.12 modifiers. Work by Oldfield and Wingfield (1965; Wingfield, 1967, 1968) suggests that the difficulty in such cases is not necessarily in the nonlinguistic identification of the objects, but may instead occur in the selection of an appropriate basic-level lexical concept (H. H. Clark & E. V. Clark, 1977).

The Phonological, Phonetic, and Motor-Assembly Arenas

The phonological arena is responsible for the mapping of lexical concepts onto pho-

nological representations. This mapping process may be principally associative, because of the essentially arbitrary relationship between lexical concepts and their phonological representations. However, for derived and inflected forms of words (e.g., adjectives derived from nouns, such as *tinny* from *tin*, and the various inflections of nouns and verbs, such as *plural*, *past tense*, etc.), some controversy surrounds the issue of whether morphologically related forms have separate stored representations that can be accessed independently or are constructed by rule from a single abstract phonological representation (see MacKay, 1978, for discussion of these matters). Regardless of the answer to this question, it is necessary that phonological representations for novel inflections and derivations be computable under the guidance of relational procedures that embody the morphological system of the language. Such procedures are needed to account for the ability to appropriately inflect unknown or newly learned words: Even children know that the correct plural for the nonsense syllable *wug* is produced by adding */-z/* and not */-s/* (Berko, 1958).

An important property of the retrieval of phonological information is that it is not necessarily an *all-or-none* phenomenon. Brown and McNeill (1966) found that "tip-of-the-tongue" failures of lexical access were often accompanied by information about the first and last letters (their task required written responses) of the sought-for word, with first letters somewhat more likely to be recalled than last. Subjects were also generally accurate about the number of syllables in the word and the location of primary stress (see also Rubin, 1975).

Such observations, in company with the morphophonemic accommodation that commonly occurs in speech errors (e.g., a speaker who intends to say "an ounce of flour" says instead "a flounce of hour," accommodating the indefinite article to the phonetic environment of the errant utterance, rather than that of the intended utterance; Fromkin, 1971), suggest that the coding performed in the phonological arena is still relatively abstract in comparison with the phonetically specified representation that actually guides

motor program formation. This latter representation is constructed in what may be called a phonetic coding arena. For speech this code may define certain vocal-tract configurations (MacNeilage, 1970), whereas for handwriting or typing the specification may be in terms of visual-spatial relations. The motor program is constructed from the phonetic code in the motor assembly arena, which is responsible for the actual production of the utterance, including the compiling and running of the motor program.

Processing Constraints in Sentence Formulation

There are certain general constraints on the way formulation processes coordinate the components described above in creating utterances. A language's syntactic system is determined in part by the manner in which the processing system satisfies these constraints (Bates & MacWhinney, in press).

The most basic and obvious of these constraints is that, for communication to be successful, there must be a determinable relationship between the idea that a speaker wishes to convey and the form in which it is conveyed. The regularities that make the relationship determinable may be very roughly divided into two subtypes: communicative regularities and code regularities. Communicative regularities are those that in some way reflect the substance that a speaker intends to convey and his attitudes or communicative intentions with respect to that substance. These, then, are regularities whose origins may be traced directly to processing in the referential arena. Communicative regularities are most clearly evident in choices among lexical items, certain inflectional morphemes, and various basic sentence types. Thus, an English speaker who claims to have seen a cow is under most circumstances more likely to be credited with having seen a cow than an airplane; likewise, the word *cows* is interpreted to have a reliably different denotation than the word *cow*; and interrogative sentences often reflect the speaker's desire to obtain information, whereas declaratives tend to be used more

often when the speaker wishes to assert some information.

Code regularities also provide a basis for mapping determinability, though of a very different type. If a language were, for example, to require all sentences to begin with the production of a glottal stop and to end with a bilabial nasal, their presence in an utterance would only indicate where a particular sentence began and ended (assuming a competent and cooperative speaker). The "significance" of the regularity derives from the nature of the code employed; it is defined by its relationship to other elements of the code, rather than by the nature of the information transmitted by the code. Code regularities do not directly originate in processing in the referential arena but appear instead to represent constraints on the way in which surface structures may be assembled from the information recruited in other arenas.

A code regularity found in many languages is nominal gender-marking. All nouns in such languages must be marked as masculine, feminine, or neuter. For a few nouns this marking is communicative: The prototypical referent in these cases is masculine in the case of masculine marking, feminine in the case of feminine marking, and neuter in the case of neuter marking. But for the great majority of nouns in the language, the marking is purely a code convention, carrying with it only implications for related code conventions (such as the requirement that inflections on verbs agree with their subjects in gender). That these are code conventions is most clearly evident in languages that require pronouns to agree with their explicit or implicit lexical antecedents: If one asks for a certain eating utensil in German, using a pronoun (along the lines of "Would you give me that?"), it is necessary to use a different pronoun depending on whether the lexical antecedent the speaker has in mind is the German equivalent of *fork*, which is feminine, or the German equivalent of *utensil*, which is neuter. If the former one asks for *her*, if the latter, *it* (Maratsos, 1979).

For most syntactic structures and devices,

classification in terms of code and communicative regularities is highly ambiguous: a particular structure can often be argued to be either one. It is in their evaluation of syntactic devices on this dimension that autonomous and functional approaches diverge most clearly, with functionalist analyses stressing communicative regularities and autonomous analyses stressing code regularities (Bates & MacWhinney, in press). From a functionalist perspective, apparent code regularities like nominal gender-marking are vestiges of communicative regularities whose communicative motivation has disappeared. The conventions might then be regarded as prime candidates for linguistic extinction. Within an autonomous approach, though, nominal gender-marking is only a peripheral example of a very general category of devices that exist for no readily specifiable cognitive or communicative purpose but are instead the result of specifically linguistic functions or mechanisms.

The grammatical relation "subject of main verb" represents a more central example, within autonomous syntax, of a linguistic code regularity. These more central relations have been argued to be linguistic universals (Perlmutter & Postal, 1977). On a functional analysis, however, the subject relation is likely to be regarded as an artifact (Garcia, 1979), resulting from an insensitivity to differences in communicative functions that happen on occasion to be coded in superficially similar ways. According to this argument, instead of a single subject-of-main-verb category, there are actually a variety of communicative regularities like focus, topic, and locus of perspective, expressed in ways that to various degrees overlap one another, creating the superficial impression of a single code regularity.

Autonomous and functional views of syntax thus regard the mapping regularities found in languages somewhat differently. For functional approaches these regularities are predominantly communicative, with a few vestigial code regularities, whereas for autonomous approaches there are significant code regularities that derive from certain specifically linguistic functions. The question is to what extent the requirement of mapping

determinability that constrains the processing system is realized by communicatively based or by code-based coordinations of the formulation system.

These differences between autonomous and functional approaches in turn have important implications for the realization of the second major constraint on the coordination of the components of the sentence formulation system: Transient utterance formulation processes must operate within any limits imposed by the general information processing system (E. V. Clark & H. H. Clark, 1978; Slobin, 1977). Though little is known in any detail about the nature and contribution of this constraint either to the form of language in general or to speech production in particular, it is widely assumed that such performance limitations impose restrictions on language. The next section examines this constraint more closely.

Automaticity, Control, and Flexibility in Sentence Formulation

Evaluation of the role of processing demands in language structure and language use requires consideration of certain apparently general characteristics of information processing. Three interrelated issues are particularly relevant to such an evaluation. These include the development and maintenance of automaticity in processing, the characteristics of controlled processing, and the flexible balancing of automatic and controlled processing to achieve optimal use of available processing resources.

Modes of Processing

Automatic processing. Automatic processing is important in a broad range of cognitive tasks, including reading (LaBerge & Samuels, 1974), stimulus detection (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977), and the performance of planned actions (Norman, 1981; Reason, 1977, 1979). Although strict definition is difficult, possible characteristics of automaticity have been discussed extensively (e.g., Carr, 1979; Jonides, 1981; Palmer, Jonides, & Palmer, Note 2; Posner & Snyder, 1975a, 1975b; Regan,

1978, 1981). Some of the commonly cited correlates of automaticity include, first, that an automatic process should operate outside of awareness; second, that it may operate in the absence of intention; and third, that it should not interfere with other processes. This last feature implies, in terms of a limited-capacity processing analysis (Kahneman, 1973), that an automatic process is one that demands no capacity. If a task can be performed completely automatically, it should be possible to perform that task as well with a second task as alone.

There is growing awareness of the importance of processing automaticity in language use, particularly with respect to developmental issues (Case, 1978; G. M. Olson, 1973; Shatz, 1978). Various linguistic subskills, including controlled articulation and word production, seem likely to require significant investments of processing capacity in early speech. For production abilities to go much beyond single words, children may have to automatize such lower level speech skills. The growth of automaticity in these components of language performance would permit allocation of processing resources to less predictable demands of utterance formulation. With further development, automaticity in performance may extend to higher levels in the hierarchy of language abilities.

Although there is as yet little systematic evidence for changes in automaticity in the deployment of different language skills and linguistic units in speech, several observations point to the kinds of changes in demands for capacity that would come with the development of automaticity. Bloom, Miller, and Hood (1975), for example, found that children's utterances that contained well-learned words (words that had been in the child's active vocabulary for a relatively long time) tended to be longer than utterances containing newly learned words. Similarly, utterances that shared lexical information with a prior utterance were significantly longer than utterances that did not depend on prior utterances. Both findings point to the possibility that greater degrees of difficulty in formulating the lexical content of an utterance are associated with lesser degrees of syntactic or conceptual

complexity. An observation by Scollon (1976) exposes the likely operation, in another linguistic domain, of a corollary of the limited-capacity principle: The words of his single subject were phonologically less well formed in longer utterances than in shorter ones. Leonard and Schwartz (1978) reported that the single-word utterances of children who had progressed beyond the one-word stage generally occurred in the context of an abrupt shift of attention to a new element of the environment, suggesting that utterance length may also be reduced when attention is allocated to nonlinguistic processing.

Two factors that seem to be especially important in the development of automaticity are repeated practice and invariance in the relationship between task structure and performance requirements (Logan, 1979; Shiffrin & Schneider, 1977). Logan (1979), for example, found that repeated practice on a task with consistent mapping was associated with progressive reductions in the amount of interference from a concurrent task, eventually reaching a point where the two task performances were statistically independent of one another. A change in the mapping relationship, however, renewed the mutual interference between the tasks. This pattern of results suggests that mapping consistency fostered automatic processing, which was then disrupted by altering the mapping.

Though it is a long leap from such laboratory tasks to the task of language acquisition, there nonetheless appear to be natural occurrences of consistent mapping in children's language development. Overregularization, of course, is common in early speech and might be regarded as a way in which the child turns the learning of linguistic rules into as consistent a mapping task as possible. Another potential manifestation of consistent mapping is children's reliance on highly regular word orders (Braine, 1976). Even children acquiring languages in which the adult word order is quite variable show relatively stable preferences over periods of several months for particular word orders (Bates, 1976).

Language structure and mature language use also exhibit certain features that mesh with the consistent mapping prerequisite of

automatic processing. The clearest example is found in the phrase structure of language, where the inventory of basic phrase types (noun phrase, verb phrase, prepositional phrase, etc.) and their alternative realizations (discounting recursive applications) is very restrictive. In addition, at the sentence level there are syntactic conventions and constituent ordering biases, suggesting a preference for consistent mapping relationships: For example, it has often been noted that the bias in spoken English toward active sentence construction (Svartvik, 1966) is so pervasive that it is only in technical writing and psycholinguistic experiments that passives occur with any regularity. The fact that somewhat different biases exist in different languages (Greenberg, 1966) indicates that regularity itself may to some degree be more important than the exact form of the regularity. The advantages of automatic processing potentially conferred by the use of consistent mapping may thus exercise some degree of selective pressure over the evolution as well as the maintenance of certain regular syntactic patterns within particular languages.

Controlled processing. Controlled processing is strategic. It is therefore constrained in a number of ways that automatic processing is not, but it is at the same time less rigid in its application (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977).

The primary constraint on controlled processing is clearest in its potential to interfere with the performance of a second task. Automatic processing is regarded as capacity free, but controlled processing requires the allocation of processing resources. Thus, while automatic processing need not interfere with other ongoing processes, controlled processing necessarily intrudes on the ability to perform any other task that also requires a capacity investment. A well-worn example of this difference is the fact that conversations (and other things) suffer in heavy traffic: Routine driving can be handled largely automatically, so that a respectable polemic may be engaged in at the same time, but if the road becomes congested, extraneous creative activity must either cease or become substantially less creative. Controlled processing thus has a certain cost to

the limited-capacity system (Posner & Snyder, 1975a, 1975b).

The greater flexibility of a controlled process, relative to an automatic process, results from the requirement that it be deployed intentionally (Carr, 1979). Whereas an automatic process may be triggered by a specific set of conditions (Norman, 1981; Reason, 1979), a controlled process must be purposefully invoked, permitting its appropriateness or efficacy to be evaluated beforehand.

Many aspects of language use would seem to require controlled processing, minimally including decisions to talk and determinations of what to talk about. Beyond these obvious considerations there are a variety of choices that a speaker may make. Among these are certain syntactic choices. All languages appear to permit some freedom in the ordering of constituents in sentences or, more generally, in the syntactic expression of various closely related ideas. Thus, at least when considered in isolation, the sentences "What the football game interrupts is Howard" and "It is Howard that the football game interrupts," although syntactically different, are logically and conceptually very similar. In many cases, however, different syntactic options seem to be selected in production in response to different communicative demands (Bock, 1977; for reviews see Bates & MacWhinney, in press; MacWhinney, 1977). This selectivity permits a measure of communicative sensitivity and rhetorical flexibility: Whereas pairs of sentences like "Fred danced with Ginger" and "Fred and Ginger danced" may have identical truth value conditions, the two seem to have rather different informational foci. In the first the "spotlight" is on Fred alone, while in the second he shares it with Ginger.

The variety of options apparently available to the speaker or writer for tailoring an utterance or sentence to the communicative demands of a situation obviously gives language a great deal of flexibility. This flexibility may, however, be constrained in the same way that the flexibility offered by controlled processing is generally constrained: It is expensive in terms of processing resources.

Processing flexibility. Skilled perfor-

mance requires a blend of automatic and controlled processes (Broadbent, 1977; Norman, 1981; Reason, 1977, 1979; Shaffer, 1976; Shallice, 1972). In most tasks there will be invariant actions and activities that can, with practice, be carried out without the investment of processing resources, but there will also be task components with less predictable demands for attention to, selection from, or manipulation of various types or sources of information. Performance may therefore suffer by the absence of task-relevant processing in either mode.

If the routine aspects of a task are not automatized, performing them will require a capacity investment that draws resources away from those decision processes that might otherwise be involved in the evaluation of options; wise parents, as a result, teach children to ride two-wheeled bicycles on long, straight paths. If options are nonetheless evaluated in such situations, performance of the routine may be impaired; for example, beginning tennis players who are too concerned with shot placement often simply miss the ball. Obviously, proficiency requires that capacity be available to deal with changing information; the automatization of some components of an activity both speeds performance and frees resources for thinking.

Failure to employ controlled processing in the performance of a task can also have adverse consequences of various kinds. Some disruptions of automatic processing may be overcome by the deployment of a different routine or the use of a heuristic strategy; readers whose automatic word recognition skills fail may attempt to apply rules of spelling-to-sound translation to get a pronunciation, or evaluate the discourse context to get a meaning. If such supplementary strategies are not employed, task performance declines or may fail entirely. Neglecting relevant controlled processing when some deviation within an automated routine is required may also hurt performance (Norman, 1981; Reason, 1977, 1979). Norman (1981) offers as an example the familiar frustration of failing to deviate from the route home to carry out a planned errand. Persistence in the use of an automated routine can also obscure the possibility of a more efficient

task organization, comparable to the effects of set in problem solving.

Obviously, optimal performance requires careful allocation of the limited resources of the processing system: Routine activities must be automatized if resources are to be available for higher level processing, but at the same time they must not be so impervious to controlled processing that any resulting rigidity proves equally disruptive to performance. In general, it must be possible to maintain control of an activity while allowing certain components of it to be executed automatically.

The requirements of optimal allocation of processing resources and flexible use of automatic and controlled processes imply, for language production generally, the necessity for compromises between processing efficiency and the goals of communicative sensitivity or rhetorical expressiveness (Slobin, 1977). Syntax, as an important negotiator of this compromise, should thus provide for substantial automatization of the mapping from communicative intentions to speech, for options in carrying out this mapping, and for fluent coordination of controlled and automatic modes of processing in utterance formulation.

The Distribution of Processing Resources in Sentence Formulation

A flexible balance between automatic and controlled processing in utterance formulation may take a variety of forms, depending on what aspects of speech planning typically demand controlled processing. There are a number of observations that are relevant to this issue, though little direct evidence.

Intuition suggests that in planning to talk we generally attend to content decisions rather than to selecting words and syntax. This intuition is consistent, in a general way, with evidence that certain aspects of content selection are carried out by controlled processes. If processing in the referential arena tends to be controlled, we might expect that selection of some particular elements for expression would reduce the probability of selecting other elements. R. C. Anderson and Pichert (1978) have shown that subjects who read a story from a particular perspec-

tive and then recalled it, and subsequently recalled the same story again but from a different perspective, recalled significantly more information relevant to the second perspective during the second recall than during the first. This occurred despite instructions emphasizing recall of as much of the story as possible. This suggests that information that was in fact stored in memory when the story was read was not formulated for production during recall, possibly because the resources of the limited-capacity system were directed to information relevant to the perspective assigned for reading. The general effect of recalling "important" information from a passage at a significantly higher rate than less important information (e.g., Kintsch & Keenan, 1973) is another likely manifestation of the same effect.

In the context of an examination of the verbal report literature in problem solving, Ericsson and Simon (1980) divided verbalization processes into three levels on the basis of their probable demands for processing resources. Two of the three levels are straightforwardly identifiable with referential arena processing: Level 2 verbalizations were defined as translations from attended nonverbal information into a verbal form that is not especially tailored for communication to another person, whereas Level 3 verbalizations require, among other things, scanning and filtering processes that evaluate the communicative appropriateness (relative to some task) of various types of nonverbal information. (Level 1 verbalization processes simply expose information that is already in a verbal format.) Ericsson and Simon's review suggests that requiring Level 2 verbalizations from subjects, though slowing performance, does not alter the course of problem solving found in tasks that do not require verbalization. But if Level 3 verbalizations are required, problem solution strategies show qualitative changes. Without more detailed comparison of actual utterances, no inferences are possible about what types of planning are omitted in Level 2 verbalizations. However, Level 2 verbalizing (which might be regarded as "stream of thought" speech) appears to be automatically executable, so that its processing does not interfere with controlled problem-solving

processes. Level 3 verbalizations, on the other hand, which arise under conditions that may be more comparable in their demands to the usual circumstances of utterance formulation, seem to require control and, therefore, interfere with problem solving.

One of the few experiments that has explicitly examined processing requirements during sentence production suggests that construction of the propositional representation underlying an utterance regularly demands capacity. Ford and Holmes (1978) showed that reaction times to randomly occurring clicks heard during spontaneous sentence production were heightened significantly at the ends of deep clauses, which they equate with underlying propositions, whereas reaction times at the ends of surface structure clauses not corresponding to deep structure clauses did not differ from reaction times at the beginnings of the clauses. These results argue that content planning in spontaneous speech regularly requires controlled processing, while surface syntactic planning does not.

There are, however, other observations that suggest that if content planning requires too much attention, lower level performance suffers. Experiments by Goldman-Eisler (1968) and by Levin, Silverman, and Ford (1967) indicate that content difficulty leads to disfluency in production: Explanations of cartoons or depicted events produced greater speech disruption than descriptions. Deese (1978, 1980) provides a complementary observation: When the content, but not the form, of speech is planned in advance, the sentences produced tend to be more fluent (with fewer within-phrase disruptions) than in extemporaneous speaking. These data imply that lower level production processes may demand resources, but perhaps on a lower priority than content planning.

It is thus probable that content selection in the referential arena requires the participation of controlled processes that demand a substantial investment of limited-capacity resources. This conclusion is consistent with the proposal (see, for example, Broadbent, 1977; Keele, 1973; Lashley, 1951; Shaffer, 1976; Shallice, 1972) that the planning of both actions and speech requires the con-

trolled formulation of intentions, along with organization and initiation of the component action schemes necessary to fulfill those intentions. Although these assembly and initiation activities require resources, the component action schemes may operate automatically once they are initiated.

Because controlled processing draws heavily on resources, the amount of content planning that can be performed for a single utterance may, however, be strictly limited. Carr (1979) and Logan (1978) have suggested that capacity is required not only to organize and initiate component actions but also to maintain activation in the assemblage of automatized action schemes until they can be executed. Because the maintenance of activation requires capacity and the maintenance of a larger number of components requires correspondingly more capacity, the more components that are simultaneously required to perform a task, the slower or more error prone overall performance will be.

An important part of the content selection process may include evaluations of or decisions about potential referential information along dimensions defined by the syntactically relevant communicative or rhetorical categories envisioned within functional grammar. Such evaluations are necessary for the appropriate use of a variety of communicatively sensitive syntactic constructions (see Gazdar, 1980, for an overview of some of the types of pragmatic categorizations that might be required). However, the capacity requirements of controlled processing point to the possibility that the number or quality of the evaluations that can be carried out in a short interval may be severely limited. Such a limitation must obviously play a crucial role in a real-time process like speaking.

Consideration of the potential demands of pragmatic processing suggests the form of one possible compromise between controlled and automatic processing in utterance formulation. For occasions when processing resources are at a premium, the linguistic system may provide a set of default mappings that can be deployed with a minimum of controlled processing; these defaults would

represent requirements that must be met to ensure reasonably successful communication. As such, they would comprise a set of obligatory syntactic patterns or rules, potentially explaining the syntactic biases exhibited by languages. When there are fewer demands on processing resources, for example, when time pressure is reduced (as in much writing) or when fewer resources need be given over to content assembly (as when the substance, though not the form, of an utterance or discourse is planned in advance), the language provides a variety of syntactic devices to serve a range of more subtle communicative purposes. Consistent with such a view, Goldman-Eisler and Cohen (1970) have found that there is greater syntactic diversity in planned than in extemporaneous speech.

However, other empirical claims that follow from such a compromise stand in direct conflict with the arguments and evidence responsible for the general repudiation of the theory of derivational complexity (for reviews see Fodor et al., 1974; Foss & Hakes, 1978; Greene, 1972), which held that the processing complexity of a sentence was a function of the number of syntactic transformations that the sentence's deep structure had undergone. The idea that there are syntactic defaults and syntactic options, with the use of options adding time or difficulty to sentence processing, was in fact the basis of Miller's (1962) kernel-plus-tag proposal. The inconsistency of the relationship between the number of syntactic transformations in a sentence's derivation and various measures of its processing difficulty, along with theoretical uncertainty about the status and specification of deep structures and transformations, led to the rejection of these hypotheses as descriptions of sentence processing, particularly in comprehension tasks.

Although there have been considerably fewer examinations of the validity of transformational coding hypotheses in production than in comprehension, and certain evidence from speech errors is consistent with a transformational analysis of production (Fay, 1980a, 1980b; Foss & Fay, 1975), a number of problems with such hypotheses remain. First, theoretical uncertainty has, if any-

thing, increased with the proliferation of alternative syntactic descriptions in formal linguistics. Second, the great reduction in the use of transformational analyses in many influential linguistic models (Bresnan, 1978; Gazdar, 1981) potentially reduces the domain of application of coding hypotheses to a very small subset of cases. Third, there are a variety of syntactic options whose use seems unlikely always to require additional controlled processing. For example, as Fodor et al. (1974) argue with respect to comprehension, it is doubtful that it regularly requires more capacity to say "John picked Fred up" than "John picked up Fred." Although this may arguably be true on some occasions, a strict equation of syntactic defaults with relatively automatic processing and syntactic options with more controlled processing would require that one of these forms be consistently more complex than the other. Thus, this analysis would suggest that in such alternatives as "The shortstop threw the ball to the first baseman" versus "The shortstop threw the first baseman the ball" and "The barber gave a haircut to the hippie" versus "The barber gave the hippie a haircut," the first sentence in each pair (the untransformed versions) should be easier to produce or more likely to occur than the other. However, Bock and Brewer (1974) found, in a reconstructive recall task, that the first sentence in the first pair and the second sentence in the second were more likely to be recalled than the alternative forms, regardless of whether the participants in the experiment had actually heard these versions or their alternatives.

Thus, a division of syntactic procedures into sets of automatically processible defaults and sets of options that require controlled processing is, by itself, likely to be insufficient to explain syntactic processing in sentence formulation. There is, however, an alternative compromise between automatic and controlled processing that is consistent with characteristics of the use of the syntactic options afforded by language. This alternative suggests that syntactic options may serve very general processing functions in addition to communicative functions. Rather than existing solely for the purpose

of providing communicative flexibility, they may also provide flexibility and increase efficiency in processing.

The proposed compromise would allow certain syntactic options to be accessed automatically, not by message-level information in the referential arena, but by other components of the sentence formulation system operating in parallel with syntactic processes. Such constructions would still, however, be available for use under the guidance of controlled processes, allowing both for flexible balancing of processing resources and flexible deployment of linguistic resources.

Such a compromise might also yield substantial processing advantages in the formulation system. There is considerable evidence from speech errors that the language processing system is not well disciplined: Garrett (1975) shows convincingly that lexical information from different constituents in a planned utterance may be simultaneously activated in memory. Maintaining this information in an activated state requires capacity. At the same time the components that execute speech appear to deal serially with units roughly the size of phrase constituents (Grosjean, Grosjean, & Lane, 1979; Lindsley, 1975; for reviews see H. H. Clark & E. V. Clark, 1977; Foss & Hakes, 1978). Obviously, if words are retrieved before the constituent in which they are to appear is scheduled to be produced within a high-level syntactic plan, performance may be impaired by the resulting drain on processing resources. If, however, the formulation system has some flexibility in arranging constituents without distorting the communicative intention, it may be possible for constituents to be scheduled for production in a way that permits some accommodation of activated lexical information. To the extent that lexical interference is a regular processing hazard in the production of speech, it would be adaptive, and perhaps necessary, for languages to develop syntactic systems permitting alternative constituent orders. Languages, even rigid word order languages like English, provide options that may serve this purpose.

The next section assembles evidence that

suggests that interactions between syntactic and lexical processing do occur in sentence formulation.

Constituent and Word-Order Effects in Sentence Production, Recall, and Preference

Because of their emphasis on communicative regularity, functional approaches to syntax regard various characteristics of the processing of information within the referential arena as the primary determinants of the syntactic structure of sentences. Thus, explanations of the determinants of phrase order in sentences within this tradition, in both linguistics and psycholinguistics (Anisfeld & Klenbort, 1973; Bates & MacWhinney, in press; Ertel, 1977; Firbas, 1966; Halliday, 1967, 1970; MacWhinney, 1977; Zubin, 1979), emphasize effects of the retrievability or recoverability of a referent from the immediate discourse context (Chafe, 1970; Firbas, 1966; Halliday, 1967, 1970); of the speaker's perspective on the referential content as determined by intrinsic or idiosyncratic interest (Ertel, 1977; Kuno & Kaburaki, 1977; MacWhinney, 1977; Osgood & Bock, 1977); or of the speaker's focus of attention within the referential content (Zubin, 1979).²

This theoretical orientation toward referential effects on syntax is reflected in the empirical literature concerned with determinants of sentence structure, where a large number of experiments and discourse analyses have examined the syntactic effect of variables assumed to influence speaker interest in or attentional focus on particular referents. Because this literature has been reviewed in several different places in recent years (Anisfeld & Klenbort, 1973; Bates & MacWhinney, in press; MacWhinney, 1977; Osgood & Bock, 1977), a summary of these variables will suffice here. They include perceptual salience (H. H. Clark & Chase, 1974; Costermans & Hupet, 1977; Flores d'Arcais, 1975; Johnson-Laird, 1968a, 1968b), explicit or implicit attention-directing instructions (Olson & Filby, 1972; Tannenbaum & Williams, 1968), order of scanning elements in a to-be-described display (Olson & Filby, 1972; Turner & Rommet-

veit, 1967), vividness (Osgood & Bock, 1977), and speaker's sympathetic involvement (Ertel, 1977). Other experiments have manipulated assumed recoverability or retrievability of referents through discourse referent repetition (Maier, 1980; Perfetti & Goldman, 1975; Zubin, 1979) or prior mention in a question (Bock, 1977; Bock & Irwin, 1980, Experiment 1; Carroll, 1958). All of these experiments report at least some effect of the variables of interest on constituent order in tasks requiring sentence production, sentence recall, sentence preference, or implicit picture description.

The case for at least some referential effects on syntax thus appears to be reasonably strong. However, the evidence adds up to considerably less support than the sheer number of published experiments might suggest. In many of these investigations, several additional factors are confounded with the referential factor actually manipulated. For example, Tannenbaum and Williams (1968) showed subjects pictures of simple events that they were to describe. Attention was directed to either the agent or the patient of the action in the event by the prior presentation of a paragraph dealing with the category of objects to which the patient or agent belonged. For example, a picture of a train hitting a car might be preceded by either a

² Thus, Zubin (1979) argues that "the speaker 'decides' which of the several participants in an event is at the center of his interest . . . and then puts it in the nominative" (p. 475). Similarly, Kuno and Kaburaki (1977) suggest that "empathy is the speaker's identification, with varying degrees . . . , with a person who participates in the event that he describes in a sentence [p. 628] . . . empathy is a major factor interacting with syntax [pp. 628-629]." Ertel (1977), after defining a *cognitive unit* as the referent of a noun phrase, claims that

one of the basic mental operations underlying sentence construction is a certain manner of selection which may be called *nominal seizing*. The speaker seizes one and only one of the cognitive units that offer themselves as nominal candidates within the realm of what is going to be uttered. The cognitive unit that has been seized is the primary reference point of the sentential construction. (p. 146)

Chafe (1976) provides a taxonomy of the functions that noun phrases serve in sentences, including the function of marking discourse recoverability (givenness), and then notes that "strictly speaking, these are not statuses of nouns but of their referents" (p. 28).

paragraph about cars or one about trains. Subjects were instructed to produce either an active or passive sentence describing the picture, and the time necessary to complete the sentence was measured. The results of primary interest showed that when attention was directed to the patient, passive sentences took less time to complete than when attention was directed to the agent (because the patient is the surface subject of a passive sentence), while the reverse was true for active sentences. The referential focus-of-attention interpretation of these results is that the preamble caused subjects to attend more to the pictured element that had been the theme of the preamble than to other depicted elements. An equally plausible interpretation, however, is that production was facilitated because the preamble provided necessary lexical information—the phonological and/or semantic information required for the head noun of the surface subject constituent of the sentence.

This confounding of referential-attentional and lexical effects on constituent order is, in many domains, probably natural. For example, several of the theories of constituent ordering cited above assume that humans process information egocentrically and are, therefore, predisposed to attend to personally relevant stimuli. Among such personally relevant stimuli are other animate beings, particularly human animate beings. Thus, animate entities should tend to occur early in sentences more often than inanimate entities. This hypothesis has indeed been supported in many studies of the characteristics of sentences produced and recalled under a variety of conditions (H. H. Clark, 1965; H. H. Clark & Begun, 1971; Dewart, 1979; Harris, 1978). Although these experiments do not discriminate between a bias for animate subjects and a bias for verbs that happen to require animate subjects (Jarvella & Sinnott, 1972), there is a well-known universal preference for subject-object ordering in the basic constituent orders of the world's languages (Greenberg, 1966; Pullum, 1977). This preference is presumably correlated with agentivity/animate-ness in the subject and nonagentivity/inanimate-ness in the object. Although there are exceptions to subject-object ordering (Ullian, Note 3, cited

by E. V. Clark & H. H. Clark, 1978, estimated that 2% of all languages have object subject ordering), the universal strength of the trend argues that something other than random selection of basic orders is at work.

However, if the assumption of egocentric processing is true, languages are also likely to provide a much larger, more differentiated, and perhaps more accessible set of lexical concepts for animate referents. This is one of the clearest implications of cross-cultural research on the color-term system of languages (Brown, 1976): The colors that are universally salient by virtue of the nature of the perceptual system are also the one for which languages are most likely to provide color terminology (Berlin & Kay, 1969). Such colors are more readily named—faster as well as more univocally—than less “central” colors (Brown & Lenneberg, 1954; Heider & Olivier, 1972). Cultural differences in the importance of various referential domains are commonly reflected in richer semantic fields for those domains: thus the traditionally noted ability of Eskimo languages to readily code differences in types of snow (Whorf, 1956), of Southeast Asian languages to code differences in types of rice (E. V. Clark & H. H. Clark, 1978), and of Middle Eastern languages to code differences in types of aunts and uncles (Brown, 1958). Individual differences in expertise (that is, in knowledge) are similarly likely to be reflected in differences in the amount of differentiation within the semantic system used to code that knowledge linguistically (Rosch et al., 1976). In short, if a referent class or knowledge category is important, it is likely to be easy to code a particular member of that class with a basic-level term: highly codable referents thus map readily onto lexical concepts at a level of maximum communicative utility (Rosch et al., 1976).

A similar argument may be made about variants of the egocentric bias hypothesis. One such variant is related to Boucher and Osgood's (1969) Pollyanna hypothesis—the claim that people universally tend to “look on the bright side.” According to this variant, speakers should place affectively positive information earlier in sentences than affectively negative information (Ertel, 1977). However, Boucher and Osgood's ev-

idence for the Pollyanna hypothesis is lexical: In the languages they examine, there are more affectively positive than negative words, and the entropy value for positive concepts is higher than for negative concepts (i.e., positive words combine more readily with other words). The degree to which positive words precede negative words in a sentence, then, may be due not only to our tendency to look on the bright side, but also to our greater ability to say what we see there.

These arguments point to the somewhat paradoxical conclusion that if referential hypotheses are valid, they are probably too simple. Even if attentional factors were controlled, adult speakers might be likely to place a phrase or clause constituent containing more codable information before a constituent containing less codable information. Ease of lexicalization could result either from greater accessibility of lexical-semantic representations for certain types of concepts or propositions, or from greater accessibility of the phonological information associated with a lexical concept, or both.

Ordering effects have been found that do appear to be more readily explained by such lexical factors than by simple referential factors, and these will be reviewed in the remainder of this section. Before proceeding with this analysis, however, it is important to emphasize a limitation of the evidence to be cited. Much of these data come from studies employing reconstructive recall paradigms, where the subject's task is to recall sentences under conditions that either deemphasize or effectively rule out verbatim memory. There are obvious hazards in generalizing from recall, even reconstructive recall, to spontaneous production.

These hazards may not, however, be as severe as might initially be supposed. First, the commonly observed dissociation between memory for the meaning and for the syntactic form of sentences (J. R. Anderson, 1974; J. R. Anderson & Paulson, 1977; Sachs, 1967) argues against the assumption that syntactic information is stored or, if stored, readily retrieved. Recent evidence for precise storage of surface information in normal prose under natural listening conditions (Bates, Kintsch, Fletcher, & Giuliani, 1980; Bates, Masling, & Kintsch, 1978; Keenan,

MacWhinney, & Mayhew, 1977; Kintsch & Bates, 1977) indicates that the use of recognition, rather than recall, may overcome some of these accessibility limits, and that surface details may be more available for some types of speech than others: In particular, the form of jokes and interpersonally oriented conversational material seems to be very well retained. The experiments to be reviewed, however, employed narrative or descriptive prose that this same research (Keenan et al., 1977; Kintsch & Bates, 1977) has shown to be less memorable in its surface form.

Second, the syntactic structures employed in recalled sentences may be supplied more often by sentence production processes than by stored information about the sentence's original form, if that information is inaccessible. The types of syntactic changes that typically occur in recalled sentences argue that this is the case: These changes generally produce sentences with structures that are more in line with the syntactic biases of normal speech than the original, to-be-remembered sentences (Binet & Henri, 1894; Bock & Brewer, 1974; Doob, 1962; Levelt & Kempen, 1975; James, Thompson, & Baldwin, 1973). Such changes, moreover, occur somewhat independently of gist recall across certain syntactic variations in to-be-remembered material, so that the changes are not readily attributable to overall difficulty in recalling sentence content. For example, Bock and Brewer (1974) found that the rated naturalness of a particular syntactic form strongly influenced the likelihood of recalling sentences in that form, though it did not influence the overall probability of recalling (in the more natural version or an alternative, less natural form) the content of the sentences.

Third, the high level of correspondence between written recall of events originally experienced visually and written recall of the same events originally presented in prose form (Baggett, 1979; Lichtenstein & Brewer, 1980) suggests a significant degree of similarity between the conceptual representations that guide recall in both cases.

If this similarity extends down to the level of events described in and recalled as individual sentences, the reconstructive recall

paradigm may differ in relatively insignificant ways from normal conditions requiring descriptive or narrative speech. Because much spontaneous speech is under the guidance of conceptual representations of remembered events or ideas stored in memory, the mere circumstance that an experiment requires a memory performance does not imply that its results have no bearing on the process of producing sentences, and the substantial commonalities between recalled and naturally produced sentences argue that they may be quite relevant. In point of fact, limitations on the precision with which conceptual content can be specified in narration or picture-description tasks makes reconstructive recall of previously heard language one of the few methods currently available for testing certain hypotheses about the role of syntax in utterance formulation, while at the same time maintaining reasonable control over the substance the speaker intends to convey.

So, although recalling a sentence in an experiment is certainly different from producing it naturally, generalizations from one situation to the other have some warrant. With this proviso we can proceed to examine the literature relevant to the question of lexical effects on syntax.

Ordering Effects Attributable to Lexical-Semantic Factors

If accessibility of lexical-semantic representations, in addition to factors related to the cognitive processing of referential information, contributes to the ordering of constituents in sentences, such effects should be demonstrable in experiments where the requirements of mapping from a specific referential domain to a linguistic domain are reduced. Experiments on isolated sentence recall achieve some reduction of the contribution of referential factors to sentence production (though they obviously cannot completely eliminate them). A number of such experiments have been performed in which variables related to ease of lexical coding have been manipulated.

One variable with a strong claim to a relationship to ease of lexicalization is concreteness. Concrete objects and events are

certainly better coded (in the sense of Rosch et al., 1976) in the standard lexicons of the languages of the world than the apparently more open set of possible abstractions, perhaps because the domains of abstract categories lack the correlational structure that underlies the formation of basic-level concepts (Hampton, 1981). The general difficulty created by the need to talk about abstract versus concrete topics in sentence production has been demonstrated in a number of experiments (Maier, 1980; Reynolds & Paivio, 1968; Taylor, 1969), though in many of these experiments it is impossible to separate difficulties in deciding what to say (i.e., difficulties in composing the referential arena) from difficulties that arise in coding this content into lexical concepts. James et al. (1973), however, manipulated the imageability of the head nouns of the subject and object constituents in to-be-recalled active and passive sentences, and examined the effect of this manipulation on the syntactic structure of the sentences actually recalled. If the greater difficulty in retrieving a lexical-semantic code for an abstract than for a concrete concept is reflected in sentence structure, the more imageable noun in each sentence might be expected to occur in subject position in recall. The results confirmed this prediction: Sentences in which the subject was more imageable than the object were more likely to be correctly recalled than sentences in which the object was more imageable than the subject; sentences of this latter type were more likely to be transformed in recall (from active to passive or vice versa). Thus, familiar concrete information, whose lexical-semantic representation is likely to be more accessible than that of abstract information, tends to occur earlier in a sentence presented and recalled in isolation. Because such sentences carry no communicative burden and convey no specific referential information, it is reasonable to conclude that these effects are at least partially attributable to the retrievability of lexical-semantic representations, rather than to referential effects.

Lexical-semantic coding processes might also be facilitated by prior activation of the codes relevant for lexicalizing information for a sentence. This activation would be ex-

pected as a product of the prior processing of semantically related material (Collins & Loftus, 1975) and, to the degree that facilitated lexical-semantic coding affects syntax, should result in the earlier production in a sentence of material that is semantically related to previously processed material. Prentice (1966) examined recall of sentences in a paired-associate task in which active or passive sentences were paired (as the response term) with words that were primary associates of the head noun of either the subject or the object constituent of the sentence. Sentences were learned most rapidly when the stimulus word was associated with the head noun of the subject constituent of the sentence. In addition, the most frequent category of errors in the task consisted of order inversions in those conditions in which the stimulus word was associated with the surface object of the to-be-learned sentence.

Experiments concerned with the effects on syntax of characteristics of the lexical-semantic processing of information, though far from conclusive, thus indicate that ease of lexical-semantic coding may play a role in determining the sequence of constituents in sentences. To the extent that such effects can be successfully isolated from referential-level variables such as perspective and focus of attention, it is possible that both may contribute to the determination of constituent order.

Effects of Phonological Information

In the same way that certain lexical-semantic codes may be more readily retrieved than others, certain phonological codes may also be more accessible. One variable that appears likely to affect such operations is the complexity or the sheer amount of information in the phonological representation of the word. The finding of accurate recall of partial information about the phonological form of a word in "tip-of-the-tongue" experiments (Brown & McNeill, 1966; Rubin, 1975) implies that the phonological representations of words can be decomposed into units that may be independently retrieved. Thus, the fewer units a word contains, the less likely it should be that retrieval will be incomplete. Brown and McNeill do note that

monosyllabic words were less likely to induce tip-of-the-tongue states, though they do not report the size of this difference or whether the syllabic length of words in their sample was confounded with other variables, such as word frequency (Landauer & Streeter, 1973).

In sentence production, differences in retrievability between words differing in the amount of phonological information they contain might also be manifested in effects on the order of elements in sentences: Shorter words should precede longer words, other things being equal. *There is, in fact, a relatively strong sequencing constraint of this type.* Cooper and Ross (1975) performed an extensive analysis of frozen conjuncts (conjunctive, somewhat idiomatic expressions having invariant or nearly invariant order, such as "salt and pepper," "bread and butter," "hale and hearty," "men and women," "ladies and gentlemen") that provides evidence for this "less precedes more" syllable principle. Pinker and Birdsong (1979) examined this and several other phonologically conditioned ordering principles more systematically by collecting preference judgments of alternative orderings of nonsense words. The nonsense words were constructed on the basis of the phonological system of either French or English and were presented to both proficient speakers and beginning students of the language on which the words were based. Pinker and Birdsong found a strong preference for placing words with fewer syllables before words with more syllables in speakers of both languages at both levels of proficiency, pointing to the potential cross-language generality of the principle.

Retrieval of the phonological form of a word should also be facilitated by prior presentation of the word. A rather large number of experiments designed to demonstrate constituent ordering effects in sentence production, in addition to providing subjects with a particular referential or perceptual focus of attention, have also provided them with the lexical item to be used to refer to it. One study, though it does not separate phonological from semantic effects, nonetheless indicates that facilitating the retrieval of one of the content words of a sentence can affect the constituent order. Bock and Irwin (1980,

Experiment 2) examined the effect of providing a single content-word prompt on the recall of a sentence containing that word. The results showed that when subjects recalled a sentence in a different form from the one originally presented, the constituent containing the prompt word was more likely to be placed early than late in the recalled sentence. Thus, simply providing a word to be employed in a sentence seems to increase the likelihood that the phrase constituent containing the word will occur early.

Evidence for Multiple Sources of Syntactic Effects

The evidence reviewed above suggests the possibility of lexical (semantic and/or phonological) effects on syntax in sentence production. But such effects may be inseparable from referential effects and make no distinct contribution to syntax. It is thus necessary to show that multiple levels of processing may affect syntax independently.

A few sentence production experiments have employed designs that permit the effects of factors attributable to the processing of different types of information to be independently assessed. Bock and Irwin (1980, Experiment 1) varied, within sentences of several syntactic types, both the lexical similarity of referring expressions and the presence or absence of a referential antecedent for a target referring expression. The constituent order of recalled answers to questions was affected by both of these variables. For example, the sentence "The rancher sold the horse to the cowboy" could have been prompted for recall by any of four questions:

(a) A rancher had a horse that kept running away. What did the rancher do?

(b) A rancher had a stallion that kept running away. What did the rancher do?

(c) A rancher received an inquiry from a cowboy about something he needed for his act. What did the rancher do?

(d) A rancher received an inquiry from Roy Rogers about something he needed for his act. What did the rancher do?

Questions (a) and (b) provide a referential antecedent for the constituent *the horse*, and questions (c) and (d) provide an antecedent for *the cowboy*. The antecedents in (a) and

(c), however, are lexically identical to the target constituent, whereas those in (b) and (d) are different. The sentence was most likely to be correctly recalled following question (a), less likely following question (b), and least likely following questions (c) and (d). Conversely, the same sentence was most likely to be recalled as "The rancher sold the cowboy the horse" following question (c), less likely following question (d), and least likely following questions (a) and (b). In general, when a constituent in a sentence had a referential antecedent (i.e., was given information), it was likely to occur earlier in the produced sentence than when it had no referential antecedent (i.e., was new information), and this was even more likely when the antecedent was lexically identical.

Because lexically different expressions in this experiment were nonetheless semantically related, it is not clear whether the effects of providing a referential antecedent were due to referential or semantic processes, or both. However, the results imply that more than one level of processing can contribute to constituent order in sentences.

This conclusion is supported by other experiments. Perfetti and Goldman (1975) varied both the thematization of a referent (the number of occasions an entity was mentioned in a passage) and the word used to cue recall of the final sentence in the passage. The final sentence was presented in either the active or passive voice, and recall was prompted with the constituent representing either the agent or the recipient of the sentence. One of Perfetti and Goldman's analyses examined the factors influencing recall of passive sentences as actives. The probability of such a transformation was affected both by thematization and by prompting: Passives were most likely to be recalled as actives when the agent had been both thematized and presented as a prompt. Transformation was less likely when either of these conditions was absent.

Turner and Rommetveit (1968) found that accompanying the presentation of a to-be-recalled sentence with a picture of the agent or recipient of the action described by the sentence increased the probability of transforming the sentence so that the constituent representing the pictured referent

occurred in the surface subject position. In order to prompt recall, the same picture, a picture of the alternative participant, or a picture of the total event was shown. The probability of transforming the sentence (from active to passive or vice versa) was independently affected by the nature of the prompting picture, with constituents representing individually pictured referents more likely to occur initially. Though the precise interpretation of this effect depends on the way in which the prompt pictures were used by the 5- through 8-year-old children who participated in this experiment, it is probable that they named them. The prompt effect may thus be at least partially attributable to a lexical factor comparable to that found by Bock and Irwin (1980).

Because of the memory requirements of these tasks, alternative explanations are possible. For example, to the extent that referential and lexical factors interact with the sheer retrievability of some sentential representation in memory, it might be unnecessary to attribute the results to multiple production processes. Instead, they may simply reflect improved recall of sentences under conditions that decrease the amount of information that has to be retrieved. Such an explanation cannot be ruled out for the Perfetti and Goldman (1975) and Turner and Rommetveit (1968) results, because transformations were only a subset of the data examined in both experiments. However, it is less applicable to the Bock and Irwin (1980) study, where variables that interacted to affect constituent order did not similarly influence total sentence recall.

The Role of Lexical Accessibility

If the mechanisms responsible for the formulation of the syntax of a sentence are in fact responsive to the accessibility of lexical information, there should be convergences between the effects of the factors manipulated in the experiments concerned with constituent and word order that were reviewed above and the effects of the same factors in experiments concerned with the retrieval of individual words. Factors that facilitate early placement of a word or phrase in a sentence

should also facilitate the recall of single words.

These factors do converge to a striking degree. Potentially important lexical-semantic coding factors, such as concreteness, animateness, and positive evaluation, which are related to the early positioning of constituents in sentences, also appear to affect the probability of simply recalling a word from a list. Thus, the imageability of words, which is very highly associated with concreteness (Paivio, 1971; Paivio, Yuille, & Madigan, 1968), is positively correlated with the probability of their being recalled from a list (see Paivio, 1971, for a review). Animate words are also more likely to be recalled than inanimate words (Rohrman, 1970; Glanzer & Koppenaal, 1977); although this effect may not be independent of the effect of concreteness, the effect of animateness on constituent order also appears to be related to concreteness (cf., H. H. Clark & Begun, 1971; Harris, 1978). In the constituent order literature, the effects of positive evaluation and empathy have not been separated from the effects of factors with which they are generally confounded (e.g., frequency); an extensive word-recall literature suggests that empathy (e.g., Laird, 1923) and positive evaluation (e.g., Stagner, 1933) increase the probability of recall only when such confounding factors are not controlled (Klugman, 1956; Kott, 1955).

Even phonological factors may affect word list recall: Calhoun (1935) found that syllabically shorter words were more often recalled than longer words. In a more recent experiment designed to assess effects of imageability and morphological complexity on word recall, Kintsch (1972) found no correlation between length in letters and recall errors. However, a reanalysis of the data presented in Kintsch's paper shows that if length in syllables is used instead of length in letters, the correlation with recall errors is significant, $r(46) = .51, p < .01$. The same correlation is also significant for derived (morphologically complex) words alone, $r(23) = .53, p < .05$, though not for simple words alone, where the range of syllabic lengths is more restricted. Because these correlations collapse high- and low-frequency

words, frequency may again be the controlling variable, although Baddeley, Thomson, and Buchanan (1975) report effects of both syllabic length and duration on short-term memory recall tasks in which word frequency was controlled. Glanzer and Koppenaal (1977) found no effect of syllabic length on either immediate or delayed recall of a frequency-controlled list, but their procedure differed in an important respect from that employed by other experiments; subjects in Glanzer and Koppenaal's study read the words on each list aloud. In a very different type of task, Spoehr (1978) showed that the syllabic length of a tachistoscopically presented word containing a to-be-identified letter affected the probability of a correct letter identification when conditions favored phonological recoding, but not when they favored reliance on a visual code.

In parallel with the sentence recall findings of early positioning of constituents containing words that are semantically related to or repetitions of previously presented items, the word recall literature also provides considerable evidence for effects of semantic relatedness and lexical repetition. Repetition of a word within a list produces an increase in the likelihood of recalling it (Waugh, 1962), and semantic relationships among list words also increase the likelihood of their being recalled (Deese, 1959). These factors have been found to affect performance in chronometric word processing paradigms as well. In lexical decision and naming tasks, presentation of one lexical item reduces the time required for processing subsequently presented words that are identical (Forbach, Stanners, & Hochhaus, 1974; Scarborough, Cortese, & Scarborough, 1977; Warren, 1977), semantically related (Meyer & Schvaneveldt, 1971; Neely, 1976; Swinney, Onifer, Prather, & Hirshkowitz, 1979), or phonologically related (Hillinger, 1980; Meyer, Schvaneveldt, & Ruddy, 1974). In a series of experiments that embedded a lexical decision task within word-by-word reading (Aaronson & Scarborough, 1976), Davidson (1978) found that both semantic and phonological relatedness to a prior word facilitated lexical decisions relative to controls, and that when the target word was a repetition of the prior word, the amount of fa-

cilitation increased further. These results argue quite strongly for effects of the activation of semantic and phonological codes on the retrieval of individual words.

There is thus very firm converging evidence for the claim that certain factors that influence the ordering of constituents in sentences are also generally important in single-word retrieval. Concreteness, animateness, a confound of frequency and other factors, syllable length, repetition, and semantic relatedness are all associated with facilitated recall of words from lists. Repetition, semantic relatedness, and phonological relatedness also reduce the time required to respond in various word processing tasks. These are the same factors that appear to result in the early positioning of constituents in sentences.

This evidence buttresses the claim that the syntactic structuring of an incipient sentence is sensitive to the accessibility of lexical information (whether lexical-semantic or phonological), in addition to referential information. A strong argument can be made, then, that factors that affect the coding or retrieval of the semantic or phonological components of the lexical information necessary for constructing a sentence can affect syntax, over and above the effects of the content to be conveyed.

Because lexicalization processes are in any case required in sentence formulation, it seems reasonable and obvious to assume that variables that generally affect access to words should affect sentence production in some way. Such an assumption underlies much of the literature on hesitations in speech (Boomer, 1965; Goldman-Eisler, 1968; Maclay & Osgood, 1959). It is a very small leap to the supposition (cf., Osgood, 1971) that, where possible, a syntactic alternative is employed so as to place lexical information that has already been formulated ahead of lexical information that has not yet been readied.

The importance of such a facility is underscored by evidence that lexical retrieval processes, once set in motion, may under some circumstances operate automatically, without significant or necessary intervention from controlled processes. This evidence points to the apparently unintentional re-

trieval of lexical information in varied production situations. There are three sources of such evidence. First, in experimental studies of induced speech errors (Baars, 1980; Motley, 1980), semantic priming manipulations increase the probability of semantically related errors. In this paradigm subjects expecting a memory test view tachistoscopically presented word pairs (e.g., *rack-seal*, *road-sale*, *real-sick*, *soul-rack*), some of which are followed by a cue to repeat aloud as quickly as possible the immediately preceding pair. If these target word-pairs have initial consonants in the opposite order of immediately preceding word-pairs, they reverse approximately 30% of the time (Motley, 1980), so that *soul-rack* in the list above might be repeated as "roll sack." If expressions semantically related to the target error are interspersed with the phonologically biasing items (e.g., *moist-pistol*, *damp-rifle*, *white-gown*, *will-go*, *get-one*), the error rate increases over conditions in which the semantically related items are replaced by neutral words. Subjects report being completely unaware of the semantic relationships between their errors and earlier list items (Motley & Baars, 1976).

Second, priming the sound and/or the meaning of a word appears to increase the probability that the word will later be employed to answer a question. Thus, Nisbett and Wilson (1977) found that subjects were significantly more likely to give *Tide* in response to a request for the name of a detergent if they had learned the word pair *ocean-moon* earlier in an experimental session. Kubovy (1977) simply asked subjects to "give a number" and found that the frequency of a particular numerical response could be increased by including a word referring to that number in the instructions, but with a different meaning. For example, in complying with a request to "give the first digit that comes to mind," 2.20% of 1770 people responded with "one," whereas 17.95% of 390 people responded with "one" when the request was changed to "give me the first one-digit number that comes to mind."

Third, evidence from natural errors (Boomer & Laver, 1968; Fromkin, 1971; Garrett, 1975) indicates that various types

of production interference are frequently traceable to characteristics of words to be produced later in a sentence, but generally within the current clause, and to characteristics of unintended but semantically related words. Though such evidence does not require that words be retrieved in parallel, their simultaneous availability implies this possibility.

Everyday experience and anecdotal observation also point to a potentially strong influence of automatic activation on lexical retrieval. Two commonplace occurrences are the unintentional parroting of an unusual word just used by someone else in a conversation and the unintentional repetition of the same phrase or content word in a stretch of writing or speaking. Some anecdotal evidence comes from the "trick" that begins by asking a person to say the word *cloak* ten times in rapid succession, and then asking immediately "What do you call the white of an egg?" The answer is invariably *yolk*. It appears, then, that factors which automatically activate various components of lexical information may affect the retrieval of words for use in utterances, and these factors include the accessibility or prior occurrence of identical and semantically or phonologically related words.

It is unlikely that all lexical retrievals benefit equally from automaticity. Automaticity and control may be usefully viewed as defining the ends of a continuum, suggesting that certain words and certain conditions should show more evidence of automatic processing than others. If the automaticity of lexical retrieval is related to the use of syntactic alternatives for the early placement of information, we would expect that those types of words and conditions that are most closely associated with automaticity in processing are again the same as those that tend to occur early in sentences. Evidence to this effect is available in the reading and word recognition literature.

A number of experiments have used the cost-benefit paradigm introduced by Posner and Snyder (1975a, 1975b) to assess the contribution of automatic and controlled processes to word recognition. These studies have shown automatic facilitation of performance on repeated (Irwin, Stanovich, &

Bock, Note 4) and semantically related words (Becker, 1980; Neely, 1976, 1977). High-frequency words would be expected to show more evidence of automatic processing than low-frequency words, and there is some evidence that this is true in the word recognition of beginning readers (Stanovich, Cunningham, & West, 1981; West & Stanovich, 1979). However, because frequency effects may be derived from recency effects (Dixon & Rothkopf, 1979; Scarborough et al., 1977), the automatic processing facilitation resulting from repetition would necessarily be more likely for frequent than infrequent words. Evidence that factors associated with lexical-semantic coding might also be associated with automatization has been found by Lupker (1979, Experiment 4), who obtained more interference from concrete than from abstract words in a Stroop picture-naming task.

Although word recognition may seem far removed from word retrieval in speaking, it is generally assumed that the two processes use the same store of lexical information. Evidence for reliable effects of the semantic and phonological characteristics of words on recognition processes (e.g., Meyer & Schvaneveldt, 1971; Shankweiler, Liberman, Marks, Fowler, & Fischer, 1979; Spoehr, 1978) suggests that the lexical systems that are important in production are also tapped by certain word recognition tasks. The evidence for automaticity, both in recognition and in the production of contextually primed words, is thus consistent with the hypothesized effects of lexical processing on syntax.

Implications

Words and syntax must be coordinated for serial output, but parallel retrieval of lexical information, coupled with different time courses of retrieval for different words, may produce mismatches between syntactic structure and lexical content that must be resolved before execution of an utterance is possible. The greater the discrepancy between the scope of the utterance planning unit and the size of the articulatory unit, the greater the need for accommodations between lexical and syntactic processing. Cur-

rent evidence (e.g., Ford & Holmes, 1978; Garrett, 1980) suggests that the planning unit is roughly clausal in scope, whereas the articulatory unit is roughly phrasal (e.g., Lindsley, 1975). The work just reviewed argues that certain syntactic features of utterances are influenced by characteristics of lexical retrieval, rather than being direct reflections of the communicative intention to be conveyed or of an underlying syntactic structure. Purely hierarchical formulation systems do not readily accommodate interactions between retrieval or assembly processes and surface syntax. However, sentence production, like other cognitive processes, appears to have both top-down and bottom-up components.

To the degree that certain syntactic details of an utterance arise not from representational features of linguistic or conceptual information but from characteristics of the system that processes that information, a psychologically valid theory of sentence formulation will necessarily have to incorporate a description of the principles that govern the interactions between representations and processing. The next section outlines a general framework for such a description.

A General Framework for Utterance Formulation

Overview of the System

The broad description of the utterance formulation system depicted in Figure 1 is principally concerned with characterizing both the informational interactions among processing arenas within the system and the processing interactions between these arenas and a limited-capacity working memory. In the figure the linkings of certain arenas to the working memory component represent the primary loci for the involvement of the limited-capacity system with utterance formulation. Arenas that typically require more working memory capacity (as suggested by evidence reviewed earlier) are connected to working memory via broader arrows in the figure. Thus, more capacity is allocated to referential processing than to either phonetic coding or output monitoring (represented by the link between working memory and ar-

tication in the figure). The broken arrow denotes the intermittent character of output monitoring and the perceptual source of the information monitored.

The absence of connections between working memory and syntactic and lexical processing in the figure has several implications. The major implication is that, for proficient speakers, the processing that occurs in these arenas during utterance formulation typically proceeds without the involvement of working memory. This should not be taken to mean that the information used in such processing is completely inaccessible to working memory, but only that these retrieval processes, at least in adult native speakers, do not consistently demand limited-capacity resources; that is, they are relatively automatic. A second implication is that our access to syntactic and lexical information during utterance formulation is generally indirect, mediated by referential

and phonetic representations. These representations, which instantiate the communicative intention and various linguistic resources for conveying it, are contained in working memory; intermediate processing results are not.

The third implication is a corollary of the second. The presence in working memory of both a phonetically coded and a referentially coded representation of an utterance may permit the development of direct associative connections between referential content and phonetic content. Although this is likely to be of limited use in production, such connections potentially provide a direct formulation route for a restricted set of utterances (e.g., rote memorizations and formulaic expressions like "How are you?"), so that certain referential representations may directly activate the phonetic codes that realize them.

A primary feature of the framework is

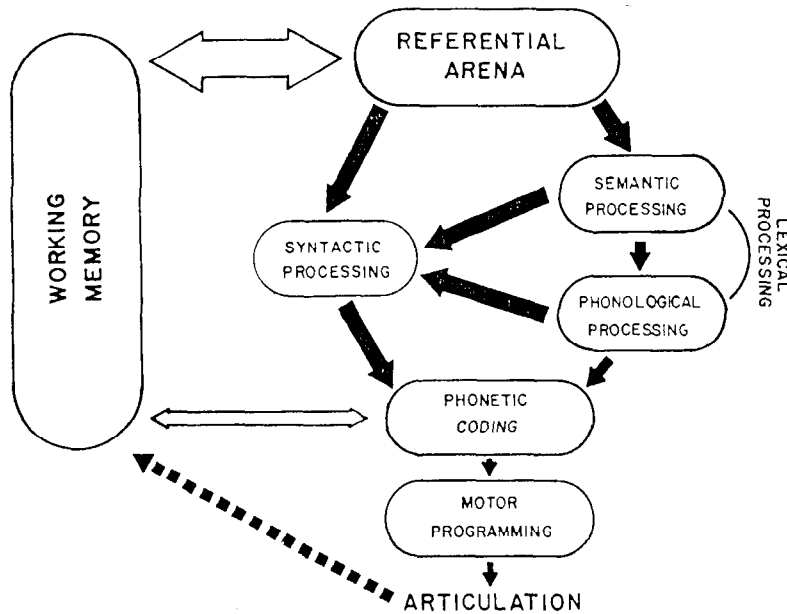


Figure 1. A processing model for the formulation of utterances. (Those components linked directly to working memory generally require working memory capacity during utterance formulation, with differences in the breadth of the arrows indicating typical differences in capacity investment. The components that are not linked to working memory are hypothesized to be capable of completely automatic operation. The broken arrow denotes output monitoring. Links between the syntactic and lexical systems represent hypothesized effects of lexical processing on syntactic processing. The phonetic coding arena is the locus of the operations that synthesize the syntactic and lexical information required for an utterance.)

that the referential arena branches to separate syntactic- and lexical-processing systems, permitting immediate referential effects on both syntactic and lexical processing. Such an arrangement also allows for two production modes, one a nonsyntactic lexical mode and the second a primarily syntactic mode, which seem to become dissociated in certain aphasias (Marshall, 1977). The syntactic and lexical processes operate in parallel and interact in specific ways. The connections in the figure between the syntactic processing component and the components of lexical processing represent avenues for effects of lexical processing on syntactic processing. The figure suggests that both semantic and phonological processing may automatically bias the formulation of syntactic structure, in line with evidence reviewed above, but it is important to keep certain limitations of that evidence in mind. First, whereas the evidence for some lexical effects on syntax is reasonably strong, the allocation of these effects to both the semantic and the phonological components should be regarded as tentative, pending more analytic empirical work. Second, the suggestion that these interactions may occur outside of working memory is no more than a hypothesis, but the most important one that follows from the claim that certain adjustments in syntactic structure are made automatically.

The surface syntactic structure is composed in the phonetic coding arena on the basis of activated syntactic and lexical information. There are two important sets of processes in this composition. The first is the combining of lexical and syntactic representations. The syntactic component provides a structural frame for each constituent, and lexical processing provides phonologically specified words for filling out the frame. The cross matching required for their coordination is achieved, in part, via information about the syntactic privileges of occurrence of words permanently stored with them in the lexicon (Bresnan, 1978) and variable role information temporarily bound to activated lexical and syntactic representations during the formulation process. These mechanisms will be further examined below. The second

set consists of the phonetic coding processes themselves, which elaborate and adjust the phonological representations. Many of these adjustments (e.g., the selection of the appropriate form for an indefinite article) require serial-order information in order to be completed, and so must follow the processes responsible for the positioning of words. The general organization of phonetic coding has been extensively discussed in the speech error literature (Boomer & Laver, 1968; Fromkin, 1971; Shattuck-Hufnagel, 1979; Shattuck-Hufnagel & Klatt, 1979) and will not be considered in detail here. It is worthwhile noting, however, that linking working memory to the arena in which this processing occurs permits an account of the convergences between certain speech error regularities and various verbal short-term-memory phenomena (Ellis, 1980a, 1980b).

When phonetic coding is completed, the coded material is transmitted to motor programming. Evidence noted earlier indicates that this transmission occurs roughly phrase by phrase, but this is obviously not a necessary condition, as the utterance of incomplete phrases (Maclay & Osgood, 1959) shows. Such variation is, however, consistent with the hypothesized involvement of working memory in the process, which admits flexible control of the flow of information from phonetic coding to motor programming.

This processing system may be realized in terms of sets of productions for language generation (J. R. Anderson, 1976, 1980; Newell, 1980). Its syntactic processing component may also be implemented as an augmented transition network (J. R. Anderson, 1975; Kaplan, 1975; Wanner & Maratsos, 1978). Although either of these formalisms is sufficient to represent the real-time syntactic processing of sentences, including sentences with discontinuous or unbounded dependencies, the explicit processing assumptions and uniform vocabulary of production systems offer certain advantages in the present context. In particular, the production systems of J. R. Anderson (1976) and Newell (1980) incorporate activation processes, interactive use of a limited-capacity working memory, and the distinction

between automatic and controlled processing, all of which are important in the proposed framework.

Operation of the System: Formulation Processes

To show how such a system may operate, I will describe the major factors assumed to influence processing interactions within the system in terms of the general conditions necessary for the execution of productions, the principal actions of different types of productions, and various activation processes that affect the probability that a production will execute. This description is schematized in Figure 2. The description avoids detailed characterizations of the representational structures involved in utterance formulation and of the operations permitted by production systems (for this see J. R. Anderson, 1976) in favor of more general specification of types of information represented and types of processing interactions. I will then

work through the formulation of a simple example utterance.

Utterance formulation begins with the generation of a communicative intention in the referential arena. A broad outline of this processing was traced earlier in terms proposed by Chafe (1977); here only the information that serves as the immediate input to the syntactic and lexical systems will be considered, along with certain aspects of its utilization by those systems. This information is coded in what will be called an *interfacing representation* to signify its cognitive-to-linguistic translating function. Interfacing representations will be assumed to be structured units that enter the formulation system under the control of working memory (cf., Förd & Holmes, 1978). Only one such representation is processed within the formulation system (through phonetic coding) at a time, but the subcomponents of each representation are processed in parallel, at least in certain parts of the system.

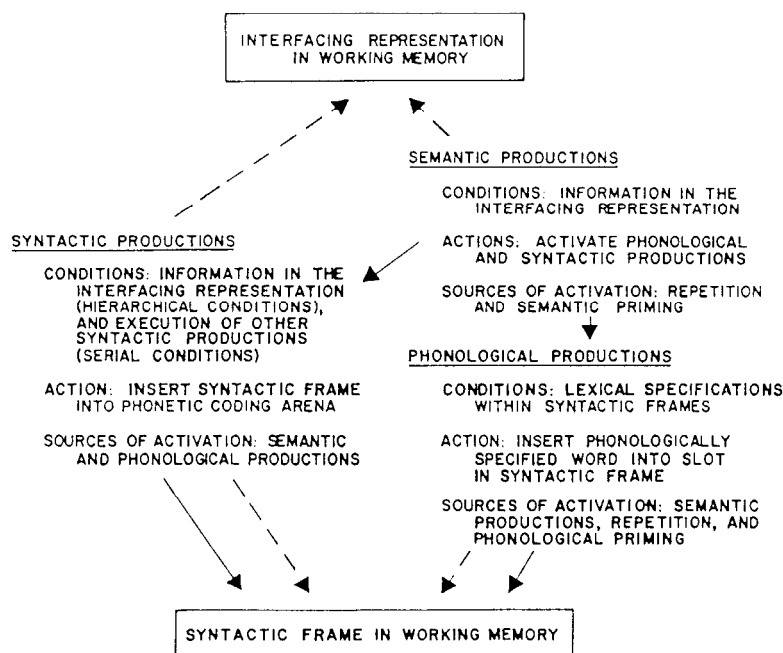


Figure 2. Outline of processing interactions in sentence formulation. (Unbroken arrows indicate direction of actions of productions, and broken arrows show sources of the information that satisfies conditions on productions.)

The interfacing representation may be thought of as performing the work of the semantic mechanisms within Montague grammar (Montague, 1974; Partee, 1975), although it also carries out the representational functions necessary for the selection of appropriate lexical concepts. It codes speech act intention, event or predicate type, and a variety of abstract features of events or predicates (including transitivity, modality, and dependency). Transitivity includes the values of transitive, bitransitive, and intransitive; modality includes the information relevant to (among other things) tense, negation, truth value, and perspective; and dependency indicates qualifying relationships within or between interfacing representations (e.g., subordination, complementation), and the nature of the relationship (e.g., qualification or elaboration of time or location of occurrence). These types of information can be classified as predominantly relational and will primarily satisfy certain conditions for syntactic processing.

In addition to relational information, the interfacing representation codes individuating information. This consists of nonlinguistic conceptual representations of selected identifications or identifying features of intended referents. An intended referent can be a conceptual category, a specific or non-specific member of a category, or a quantified subset of category members, in short, anything we are capable of talking about. Obviously, categories and their members may be abstract. Identifications of intended referents are also assumed to be specified according to their roles within the event or idea. The various role specifications comprise the values of variables that will be referred to as relational role variables, and the role specification of a component of the interfacing representation will be referred to as the binding of that component by a role. For present purposes the familiar role variables of case relations (Fillmore, 1968) will be employed, but others are possible.

The interfacing representation serves as the input to sets of productions in the syntactic and lexical processing components. Three general features of productions and production systems are particularly impor-

tant in the present context. First, productions represent knowledge in terms of condition-action rules. A particular set of conditions must be satisfied before a production may execute its action. Second, conditions on productions are represented in working memory; such information thus draws on limited resources. Third, productions may automatically activate associated information, so that the execution of a certain production may cause activation to spread to other productions. An activated production may be thought of as being more sensitive to its conditions than one that is not activated, so that its action is executed faster if its conditions are met.

The information coded by the interfacing representation thus must satisfy conditions on syntactic and lexical productions in order for utterance formulation to proceed. The sets of productions required to realize each interfacing representation will be assumed to constitute the rough equivalent of a clause, with the caveat that certain complement clauses and other types of so-called functionally incomplete clauses (Tanenhaus & Carroll, 1975) may not be independent planning units, but may instead be specified by the syntax as subcomponents of other clauses (see the treatment of derived nodes by Gazdar, 1981, for suggestions about how this might be achieved).

Different syntactic productions respond to different relations within the interfacing representation and are bound by the relation or role that satisfies their conditions. For example, subject noun phrases may have a topic condition and a disjunctive set of role conditions including agent, recipient, instrument, and so forth. The subcomponent of the interfacing representation that satisfies these conditions binds the production to one of its allowable roles.

Other productions respond to different sets of conditions. In simple cases a certain speech act intention may satisfy the conditions for a certain production or set of productions. So, for example, an intention to make an assertion, to issue an order, or to question the truth value of something would satisfy conditions on productions for, respectively, declarative, imperative, or yes-no

interrogative sentences. The presence in the interfacing representation of various dependencies requiring realization by a complex clause (e.g., complements, *wh*- questions, etc.) may also trigger selection of productions for specialized constituent structures. Other productions may respond to any dependency relationship existing between a current interfacing representation and a prior or subsequent one (subordination, conjunction, domination, etc.). Certain productions, in particular those that realize the auxiliary and main verb, are sensitive to transitivity and modality information, which includes perspective. Transitivity specifies whether a sentence will contain an indirect and/or a direct object, or neither, and perspective determines, among other things, selection of an active or passive verb frame. Time, location, and manner information may be coded by productions for the realization of adverb or prepositional phrases.

The representation of information in the syntactic component is assumed to follow lines suggested by Gazdar (1981, Note 5, Note 6; Gazdar, Pullum, & Sag, Note 7), who lays out arguments and formalisms for a context-free grammar of English. The rules in this grammar are considerably more complex than those of the context-free phrase structure rules that form the base component in transformational grammars, because they generate surface structures directly, without the intermediate step of transformations. But because no movement rules are employed in this approach, there need be no complex adjustments in early portions of sentences resulting from the movement of material from late portions of a sentence, or vice versa. Such a feature makes context-free grammars much more compatible with on-line processing models than transformational grammars, but at the expense of a formal representation of syntactic relatedness among various sentence types. Of course, whether people's grammars will turn out to be similar to context-free grammars in crucial respects is another question.

The syntactic rules in Gazdar's constituent structure grammar contain semantic information about the lexical items they admit. This feature may be readily translated into relationships between lexical concepts

and syntactic productions. That is, productions in the semantic processing component representing lexical concepts appropriate for roles in particular types of constituents will be associated with syntactic productions capable of realizing those constituents. Thus, different types of nouns are associated with different types of noun phrases, and so forth. Before examining further operations in the syntactic component, then, it is necessary to consider lexical processing.

Productions in the semantic processing component respond primarily to the individuating information in the interfacing representation, with the effect of categorizing nonlinguistic identifications in terms of lexical concepts. Lexical concepts are represented by semantic productions; for ease of exposition, each distinct lexical concept will be regarded as being represented by a different semantic production. The conditions for these productions must be satisfied by certain configurations of concepts in the interfacing representation. There are many different ways in which this mapping can be carried out; for present purposes it will be assumed that alternative lexical concepts may be activated by the same subcomponents of the interfacing representation. The interfacing representation may, for example, underdetermine several possible lexical realizations, so that a particular component of an interfacing representation might map equally well onto lexical concepts for *cheerful* and *genial*, even though the conditions for these lexical concepts might differ in certain respects.

One possible consequence of uncertainty that will be assumed *not* to occur in this mapping, however, is the selection of alternative sets of lexical concepts that presuppose different relational structures, even though their meanings, in construction, may be very similar. For example, even though a particular situation might be described either as "John bought the saw from Fred" or "Fred sold the saw to John," the assumption here will be that processing in the referential arena sufficiently constrains lexical concept selection so that it is generally impossible for these types of alternative lexical concepts both to be retrieved. There is some evidence for this assumption in a find-

ing of Maier's (1980). When sentences like either of the two above concluded stories in which either Fred or John was the protagonist, later recall of the sentences (cued by presentation of the stories, minus their final sentences) showed no thematization effects: There was no tendency for sentences whose subject matched the protagonist to be correctly recalled more frequently than sentences in which the subject did not match the protagonist, nor any tendency for the structure of the originally presented sentence to be changed in recall so that protagonist and subject matched. However, for pairs of sentences like "Alice sold the puppy to Martha" and "Alice sold Martha the puppy," either of which followed a story in which *the puppy* or *Martha* was the protagonist, there was a significant trend toward recalling the expression denoting the protagonist immediately after the verb, with the remaining object constituent at the end. Conditions sufficient to prompt a syntactic bias, then, are not equally effective in creating a bias when a change in the underlying relational structure is required as a concomitant of the syntactic change. Thus, information that is assigned to particular subcomponents of predicate-argument structures in the interfacing representation must be realized by lexical concepts that respect these assignments. This constraint also prohibits such alternatives as "John wasn't happy" and "John was unhappy" from being generated from the same interfacing representation.

In part to realize this constraint, lexical concepts will be assumed to contain information about the types of relational roles they typically realize (e.g., nominal concepts convey agents, instruments, etc.), as well as the types of relational or event structures in which they typically occur (e.g., intransitive verbs convey intransitive action relations). This information may be represented as conditions on the productions representing lexical concepts. In addition, when the conditions of a production representing a lexical concept are satisfied, the production will be bound by the value of the relational role variable of that subcomponent of the interfacing representation that met its conditions. All of the lexical concepts realizing a particular subcomponent are bound by the same vari-

able. Lexical concepts are thus tagged as representing, for example, the patient, or the agent, or the action, and so forth.

The adequacy of the match between the conditions on a production representing a lexical concept and a component of the interfacing representation will determine whether the production executes (a description of criteria for adequacy will require a theory of lexical retrieval in production, which the present framework is not intended to provide). If a production does execute, it performs two actions. First, it activates productions in the syntactic arena that have role and semantic specifications matching those of the bound lexical concept. These relationships may be between the role to which the lexical concept is bound and certain types of syntactic structures, as well as between structures and concepts themselves. For example, agency is a role strongly associated with subject noun phrases, and the word *sleep* denotes an action associated with intransitive verb phrases (see Bresnan, 1978, for detailed linguistic arguments for associating lexical representations with information about syntactic privileges). Second, the production attempts to retrieve (activate) a phonological representation. Phonological representations will be referred to as phonologically specified words, or simply words, with the reminder that these representations are still incomplete and quite abstract with respect to articulation or any other output system.

When productions representing phonological information are activated, they will be bound to the same relational role value tagging the semantic productions that retrieved them. Although there is no direct evidence for such binding operations in the formulation of sentences, there is considerable evidence for a closely related phenomenon in comprehension. In particular, the specificity of lexical comprehension in different contexts (R. C. Anderson & Ortony, 1975; Barclay, Bransford, Franks, McCarrell, & Nitsch, 1974; Merrill, Sperber, & McCauley, in press) may in part be accounted for by variations in imputed event roles.

The words in the phonological component may themselves be associated with certain surface structure patterns. For example,

verbs like *rely*, as Bresnan (1978) points out, are semantically transitive but syntactically intransitive: Relying is logically a transitive relation between individuals (broadly defined), but the word *rely* occurs superficially before a prepositional phrase, rather than before a noun phrase. This prepositional phrase, moreover, is not required to occur immediately after *rely*, (as in "That is not a claim on which you would want to rely"), indicating that it is an independent phrase, not indissolubly bound to the verb. This, so far, does not require an independent link between phonological processing and syntax, because if *rely on* is represented by a unique lexical concept, its requisite syntax may be activated directly by semantic processing. The problem arises if a single lexical concept has phonological realizations with different syntactic privileges. If, for example, both *trust* and *rely on* were represented by the same lexical concept, syntactic structures for both might be activated from the semantic level by the lexical concept. At the phonological level, however, separate links would exist. To encompass this possibility, activation may be permitted to spread from the phonological processing component to certain constituent structures in the syntactic arena.

The formulation processes to this point will have activated sets of syntactic productions in the syntactic component, with activation originating from one direct source and occurring indirectly via a second. The conditions on these productions, however, must be satisfied by information represented in working memory, both in the referential and the phonetic coding arenas, before they may execute. The conditions on referential information, which are coded in the interfacing representation, were discussed above. These will be called hierarchical conditions in what follows.

Selection Among Syntactic Productions

The specification of the hierarchical conditions will not always be sufficient to select among various alternative syntactic structures. Thus, the hierarchical conditions on certain syntactic productions may be very

similar or identical, or the representation itself may, as in the selection of lexical concepts, be compatible with alternative realizations. Which production ultimately executes will depend on several factors.

An important set of factors is related to the activation level of alternative productions. The factors of most immediate relevance are those that increase the accessibility of the lexical information necessary to realize a constituent. The evidence reviewed earlier suggested that contextual influences on lexical accessibility, including semantic and/or phonological priming resulting from repetition or spreading activation, are associated with certain syntactic modifications in sentences. An endogenous factor, concreteness, produces similar syntactic effects. Within the present framework these effects are explained in part by differences in the levels of activation of those syntactic productions associated with particular role, semantic, or phonological information retrieved during lexical processing: Lexical information that is more highly activated or activated faster will produce corresponding effects on any associated syntactic production.

Other factors may also influence the activation of syntactic productions via the lexicon. If some subcomponent of the interfacing representation is entered into lexical processing before other subcomponents, so that its semantic and phonological processing will tend to be completed earlier, its associated syntactic productions will also be activated earlier. Such a mechanism is consistent with the presuppositions of certain referential hypotheses (e.g., Zubin, 1979) about the role in syntax of focused attention to elements of the referential content, although the effect suggested here is indirect. Differential activation will also result from variations in the strength of the association between particular elements of lexical processing and different syntactic realizations of them. For example, Fillmore (1968) and others have claimed that there is a subject hierarchy characteristic of all languages that expresses the likelihood that a particular role will be realizable as the subject of a sentence. Such a constraint may be expressed in the

present framework in terms of differences in the strength of the association between different roles and subject noun phrases.

Finally, different syntactic productions may have different base levels of activation. It is reasonable, for example, to suppose that the productions for realizing simple active sentences may be more highly activated than those for realizing passive sentences, and hence, if all other things are equal, are more likely to execute.

The second set of factors determining execution of syntactic productions may be represented as conditions to be met by information in the phonetic coding arena (and thus also in working memory). These will be called *serial order conditions*. A production's serial order conditions require the prior execution of certain other productions, unless it represents a potential sentence-initial constituent. For example, the prior execution of a verb is a condition for the execution of a direct object noun phrase. The initiating production for a sentence is the production with the highest activation level whose hierarchical conditions are compatible with the interfacing representation in working memory and which has no serial order conditions, or whose only serial order condition is that the phonetic coding of any prior utterance has been completed.

When both the hierarchical and serial conditions on a syntactic production have been met, it executes. In the case of two productions with the same hierarchical and serial conditions, the one that is most highly activated (beyond some threshold) will execute. The effect of execution is to insert a syntactic frame into the phonetic coding arena. This frame contains slots (Garrett, 1980) specifying syntactic, semantic, and role conditions on the lexical content, as well as certain lexical items required by the syntax (i.e., code-regulated lexical information like the semantically empty subject noun phrases required in certain English sentences, such as the *there* in "There is a game this afternoon").

These lexical specifications serve as the conditions on phonological productions. When the conditions of a particular phonological production are met and it executes,

its effect is to retrieve an activated phonological representation and place it into that slot in the syntactic frame whose specifications it matches. Because these phonological representations will consume working memory capacity, representations with less information will finish the retrieval process faster, providing a potential explanation for the syllable length effect found in studies reviewed earlier. The apparent restriction of this effect to conjunctive phrases (e.g., "men and women") suggests the possibility that the elements for which this type of alternative ordering occurs must have identical syntactic and role conditions and so may appear in any position in the syntactic frame for a conjunct. Assuming that the word that is retrieved first is placed in the first position, shorter words should precede longer words, other things being equal.

The phonetic coding arena completes the formulation of constituents before their transfer to motor programming. These finishing processes include phonetic adjusting and elaboration and, optionally, verification that the formulated utterance is adequate to convey the communicative intention. There are two verification procedures compatible with the proposed framework. The first is "comprehension" of the formulated utterance: A referential representation of the formulated utterance is derived via comprehension processes (not represented in the model) and compared with the input representation. The second is reformulation of the utterance and comparison of the alternative phonetic realizations. If they differ both may be submitted to the comprehension check.

An Illustration of Sentence Formulation

These proposals may be made more concrete with an example illustrating the formulation of a very simple hypothetical utterance, briefly sketching a few of the possible interactions among the components of the system. Suppose that a speaker wants to bring about the transfer of a certain toy from one child to another. The interfacing representation for this communicative intention will include, among other things, information relevant to type of speech act (a com-

mand might be likely here), to event or action type (in the present example the desired action involves the bitransitive relation of transferring), to designation of relational roles (minimally, in this example, an agent, a recipient, an object, and an action), and to selection of a perspective (agent perspective may be obligatory in commands, however, and so may not require separate specification). Intended referents will be identified and represented in terms of different conceptual patterns that may, of course, vary with context; thus the same child might be identified (nonlinguistically) as a particular, uniquely designated entity on some occasions, and as a specific instance of some more general concept on other occasions. The event or action must also be identified, and each of these identifications must be bound to a relational role. The identifications for the present example will be nonlinguistic representations for an addressee, the female sibling of the addressee, a specific ball in the sight of and hence known to the addressee, and an activity involving the use of one's arm to propel an object released from the hand through the air.

For lexical processing the interfacing representation first undergoes lexical-semantic categorization in the semantic processing component. The nonlinguistic identifications provide the basis for lexical-semantic mapping. In the present example, the addressee will be labeled by the lexical-semantic representation of a second-person pronoun (*you*); the recipient by the lexical-semantic representations of the word *sister* and a possessive pronoun (second person to designate the addressee as the possessor); and the object by the lexical-semantic representation of the word *ball*, designated as definite (*the*). The action that the speaker has identified roughly matches the lexical-semantic representations of both the verbs *throw* and *toss*. However, the conditions on the production representing *throw* will be more completely satisfied in the absence from the speaker's interfacing representation of additional information that would bias the categorization toward *toss* (e.g., the ideas that the throw should be soft, arcing, etc.). All of the semantic productions whose conditions are satisfied (beyond some criterion)

by the interfacing representation are bound by the role values of those subcomponents of the interfacing representation that they instantiate. Thus, the production representing the lexical concept of *you* is bound to the agent variable, those for *your* and *sister* are bound to the recipient variable, those for *the* and *ball* to the object variable, and that for *throw* to the action variable. These productions then execute.

The execution of each semantic production has the effect of activating a production for an associated phonological representation that is in turn bound to the role value of the semantic production, and of activating syntactic productions appropriate for the realization of the activated lexical concept in its designated role. Syntactic activation is possible because each lexical concept specifies the syntactic contexts in which it may appear, as does each role value. Thus, given agent perspective, the roles of agent, recipient, and object will most strongly activate subject, indirect object, and direct object noun phrases, respectively, and the action will activate verb phrases; *you*, *sister*, and *ball*, all nouns, activate noun phrases; *the* and *your*, both determiners, activate noun phrases containing determiners; and *throw*, a verb requiring a direct object but admitting an indirect object, will activate verb phrases for realizing only a direct or both a direct and an indirect object. Activation may also spread to the syntactic productions from the bound phonological productions and, in the present example, will intersect with the direct activation from the semantic productions.

In the syntactic processing component, the conditions of only a small set of productions will actually be met by the interfacing representation (the hierarchical conditions) and information represented in phonetic coding (the serial order conditions). By specifying that the utterance is to be a command, the interfacing representation (given the remaining sentence content) requires a production representing an imperative subject noun phrase (a null element). This will also be the only production consistent with the hierarchical conditions in force whose serial order conditions permit initiation of the sentence. Bitransitive verb phrases will be des-

ignated (two alternatives are possible in the example, one in which the direct object precedes the indirect and a second in which this order is reversed) with two definitely determined noun phrases, one direct and one indirect, and a nonfinite verb. Execution of these productions will depend primarily on their hierarchical and serial order conditions being met, though in the case where alternatives are available the relative activation levels of the productions at the time their conditions are met will also affect execution.

Execution of the production representing the imperative subject satisfies the serial order conditions on the production representing the verb. Execution of the verb, however, satisfies the serial order conditions for the noun phrase initiating both sets of bitransitive noun phrases, one direct and one indirect object noun phrase. If the production representing the direct object noun phrase is above threshold and more highly activated than the indirect object noun phrase, it will execute. As a result of its execution, the only production whose serial order conditions will be satisfied is the one representing that indirect object which follows a direct object in a bitransitive verb phrase. (See J. R. Anderson, 1976, for a related account of the selection between direct and indirect objects in sentence generation within a production system framework.)

The execution of each production, with the exception of the production representing the imperative subject, reads a syntactic frame into the phonetic coding arena. The imperative subject production might be hypothesized to place a null element into phonetic coding, and the production representing the verb reads in the verb frame. If the production representing the direct object noun phrase were to execute next, a frame for a noun phrase that includes a determiner and a noun would be placed in phonetic coding. The production for the indirect object would then be the last to execute. Because the indirect object when it follows the direct object must be preceded by *to*, execution of the corresponding production also places a phonological representation for *to* within the syntactic frame in phonetic coding.

To deal with cases in which the productions representing both the direct and indi-

rect object are equally activated, a number of procedures are possible. A plausible suggestion is that one of the bitransitive verb phrase constituent structures is the default: All other things being equal, one of the orders may be preferred to the other. There does seem to be a general bias toward the direct object-indirect object order (Bock & Brewer, 1974), and this order also appears earlier in language acquisition (Osgood & Zehler, 1981).

The conditions on the productions for phonological representations must be met by the lexical specifications on the slots in each syntactic frame, and by the role to which the frame is bound. The production for *throw* will meet the specifications for the verb slot; those for *the* and *ball*, requiring a determiner and a noun realizing the role value of the object, will be met by the direct object frame; and those for *your* and *sister*, also requiring a determiner and a noun, but realizing the role value of the recipient, will be met by the indirect object frame. The conditions on the production representing *you* will not be met, and so it will not execute. (Note that this account of imperative subject formulation is offered only as an example; many alternative coding schemes are possible within this framework.)

After the lexical information for each slot has been retrieved, the phonetic coding arena contains (though not necessarily simultaneously) an ordered set of phonological representations for elements of the utterance "throw the ball to your sister." These are elaborated and adjusted by phonetic coding processes, which are not explicitly included in the proposed framework. Finally, the utterance is prepared for articulation in the motor programming component.

Sources of Errors

There are obviously a variety of ways in which the formulation of utterances may go awry. Many impressively regular characteristics of mistakes involving words and phrases have been described in the speech error literature (Fay & Cutler, 1977; Fromkin, 1971, 1973; Garrett, 1975, 1976, 1980) in addition to the more frequent sound errors, and it is important that the proposed frame-

work be able to account for them. The most consistently noted feature of errors involving entire words is a form-class constraint on between-phrase word exchanges: Words that interchange between two phrases generally represent the same part of speech. Thus, errors like "give my bath a hot back" (Garrett, 1975) are much more frequent in error collections than an error like "give my hot a bath back." The form-class constraint follows, in the present system, from the similarity of syntactic conditions on the phonological productions representing words that are the same part of speech: A phonological production may execute whose syntactic, through not role, conditions are the same as those for the correct word. The conditions on the production representing the correct word may then provide the best match for a slot in a subsequent frame, producing the interchange.

Certain types of errors that are predicted by the present framework have received little attention. Because syntactic representations, like lexical representations, are subject to activation processes, errors should occur that result from the priming of syntactic productions. Along these lines, we might expect syntactic errors comparable to the branching (Reason, 1979) and capture (Norman, 1981) errors noted in taxonomies of planned action errors. In such errors a planned activity diverges from one component into a second that is not part of the plan, but at least some of whose prior conditions have been met, and which is stronger, more activated, better automated, and so forth, than the target component. Various errors potentially fitting these descriptions have been analyzed by Fay (1980a, 1980b; Foss & Fay, 1975), though he interprets them within a transformational framework. Thus, Foss and Fay (1975) argue that an error such as "And when they chew coca, which they chew coca all day long" (instead of ". . . which they chew all day long") is a failure of an elementary deletion operation within a relative clause transformation. However, an alternative explanation is suggested by the similarity of the syntactic environment that precedes the constituent *chew coca* in both of its occurrences (a subordinating word followed by a pronominal subject noun phrase),

which argues that the error is not in the failure of a component of a transformation to apply, but in the erroneous repeated execution of the production that realized the initial verb phrase in an environment that meets its serial order and many of its hierarchical conditions. To determine whether such analyses are generally tenable, however, will require more extensive documentation of the context in which such errors occur, as well as specification of the serial order conditions on syntactic productions.

The automatic operations that support sentence formulation thus can and do fail. When this occurs working memory may take a more active role in the formulation process, whether in initiating the retrieval of words to fill out already formulated syntactic plans, the reformulation of utterances for which the lexical and syntactic retrievals do not mesh well, or the reformulation of an utterance that does not match the communicative intention. One likely, and seemingly frequent, condition for this type of intervention would be the failure of lexical processing to make information available for phonetic coding (Boomer, 1965; Goldman-Eisler, 1968; Maclay & Osgood, 1959).

It should be clear that the automatic mechanisms of lexical retrieval assumed above are intended only to explain the formulation of utterances using words established in the speaker's lexicon. The use of neologisms, the novel use of productive morphological devices, the productive transformation of the conventional form-class privileges of words (e.g., the uses of denominalized verbs discussed by E. V. Clark and H. H. Clark, 1979), and the accompanying application of appropriate inflectional morphology are only a few examples of ways in which the lexicon can be employed creatively. Although description of the procedures that form rule-governed lexical inventions is outside the scope of the present paper, it is possible to suggest how such procedures may be incorporated. It is reasonable to assume that because these procedures serve special purposes, and entail the novel manipulation of information, they require the participation of working memory (Carr, 1979). Sets of productions not routinely employed in utterance formulation

may thus be assembled in working memory in order to control those aspects of lexical processing that participate in the creation of novel words or expressions. Such productions may be readily interfaced with the rest of the processing system by constraining their actions, at some point, to those that mesh with the conditions of productions within the other components of the formulation process.

Comparison With Alternative Systems

The type of formulation system proposed here contrasts with autonomous syntactic and functional syntactic models, while at the same time incorporating significant features of both. With respect to functional syntax, the primary contrast lies in the placement of certain effects on syntactic structure outside of the referential arena and, hence, outside of the purview of "attention," which many functional accounts have relied on implicitly (Givon, 1979) or explicitly (Zubin, 1979) for explanations of various syntactic phenomena. There are similarities, however, in that the framework assumes a relatively transparent relationship between referential processing and syntax and readily admits, by way of both lexical and syntactic processing, various syntactic effects attributable to the salience of information in the referential arena. In a number of ways, the present framework may be regarded as an extension of functional approaches to include the functions of linguistic, as well as nonlinguistic, information processing.

With respect to autonomous syntax, the major departure in the present framework is the admission of effects on syntactic structure in production that do not originate with the factors most directly responsible for the formulation of the syntactic structure of the sentence, but instead in the retrieval or processing of the lexical information that partially instantiates that structure. There are, nonetheless, also significant similarities, most clearly in the allowance for a dissociation between some aspects of referential processing and syntax and in the equation of syntactic productions with phrase structures: The internal composition of such representations is thus treated, for proficient speak-

ers, as a completely autonomous feature of syntactic processing.

The present framework diverges from both autonomous and functional approaches, however, in placing a degree of influence over syntactic processing within the lexical processing component. The obvious effect of this move is that factors which influence the retrieval of lexical information for an incipient utterance may also influence the syntax of that utterance. A somewhat less obvious implication, but one that constitutes a more radical departure from previous sentence production theories, is that it requires a more interactive processing system. Both functional and autonomous theories presuppose hierarchical systems in which the coding of communicative intentions determines both the surface syntax and the lexical content via a series of entirely top-down steps. By contrast, the present approach suggests that the system permits both top-down and bottom-up processes: The lexicalization of the information for an incipient utterance, rather than proceeding completely within the specifications of a deep syntactic or referential representation that in turn determines surface syntax, may itself influence significant features of a sentence's syntactic structure.

The proposed framework is not, of course, without antecedents. Dell and Reich (1980) outline a model of speech errors in which spreading activation plays a crucial role. The general idea of competition among language elements is fairly common, particularly in the speech error literature (Baars, 1980; Motley, 1980; see Garrett, 1980, for discussion). Bates and MacWhinney (in press) have argued that multiple partitions of information compete for control of constituent order in sentences, and J. R. Anderson's (1976) production system for language generation provides for the selection of alternative surface realization on the basis of races between syntactic productions. What has been gained in the present system is explicit identification of certain factors that influence the outcome of syntactic competitions, of potential avenues of interaction among the information sources that operate in sentence formulation, and coordination of these formulation processes within a constrained performance system.

This framework is, in addition, flexible enough to allow syntax to be sensitive to, and to accommodate, facilitatory factors that operate at different levels of processing and retrieval. If facilitation of processing can be reflected in the earlier output of information that benefits from the facilitation, it becomes possible to account for the several factors that appear to influence the word and constituent order of sentences, integrating a disparate set of sentence and speech production phenomena. Beyond this, however, the framework provides a simple resolution for a contradiction occasionally noted in the functional syntax literature between two constituent order principles (H. H. Clark & E. V. Clark, 1977; Osgood & Bock, 1977). The next section examines this contradiction and a potential resolution for it within the principles of the processing system outlined above.

Focus of Attention Versus Givenness

One of the major obstacles to a coherent account of the use of alternative constituent orders in sentences is the implicit contradiction in pragmatic or functional syntax theories between the explanation of certain effects in terms of focus of attention and other effects in terms of discourse recoverability or givenness. One aspect of this contradiction is particularly salient in an interchange between Costermans and Hupet (1977) and Johnson-Laird (1977) regarding the interpretation of earlier experiments by Johnson-Laird (1968a, 1968b). Costermans and Hupet report several similar experiments in which subjects were given pairs of sentences, either of which truthfully described a particular stimulus display, and were asked to indicate which sentence of the pair was the better description for the display. For example, the preferred description for a strip divided into two successive segments of red and blue, with the red segment larger than the blue segment, was the French equivalent of the sentence "After the red, there is some blue," rather than "Before the blue, there is some red." This preference reversed when the blue segment was larger. The experiments showed generally that the smaller portion of different types of displays tended to be mentioned in the assertion of preferred

sentences, and the assertion was always second in the sentences used by Costermans and Hupet. With respect to the finding that there is a preference for sentences mentioning the smaller area second, the results essentially replicated those of Johnson-Laird, but Costermans and Hupet interpreted their results quite differently. Johnson-Laird (1968a, 1968b) suggested that the larger, perceptually more prominent area was mentioned first because it was viewed by subjects as the more important area. But the more fundamental issue, according to Costermans and Hupet, is whether presuppositions or assertions should be regarded as more important; they strongly favored viewing assertions as more important. Because presuppositions (given information) generally precede assertions (new information) in sentences (Hornby, 1972), they concluded that speakers generally place more important information second in a sentence. Faced with the problem presented by their data—why a speaker might view the smaller area of a picture as the more important one—Costermans and Hupet claimed that assertions represent what speakers wish to emphasize, and that what needed emphasis in their displays was the smaller area.

Johnson-Laird (1977), in his reply to Costermans and Hupet, placed the origin of their dilemma in what he identified as the discourse function of constituent order: A discourse topic may be placed in the surface subject and the new information placed in the object to provide continuity. Johnson-Laird's resolution is a contextual analysis in which a sentence "in context" (presumably a linguistic context) places what is important (the asserted, new information) in the object position, whereas a sentence lacking such a context places what is most important in the subject position. The argument, then, is that what governs early placement in a discourse context is different from what governs early placement in a nondiscourse context.

What makes this argument somewhat suspicious, beyond its obvious problems with parsimony, is that the factors presumed to be associated with early placement in nondiscourse contexts are in certain respects very similar to the factors associated with late placement in discourse contexts. Gen-

erally, the paradox that arises when a pragmatic theory tries to accord constituent order functions to both discourse givenness and perceptual salience or focus of attention is that, at the referential level, given information seems much less likely to attract the speaker's attention than new information. Given-new ordering thus appears to directly contradict the basis of a focus-of-attention explanation.

In addition to Johnson-Laird's analysis, attempts to resolve this contradiction in terms of the conflicting demands of speaking versus listening have also appeared in the literature (e.g., H. H. Clark & E. V. Clark, 1977; Osgood & Bock, 1977). This account accepts the premise that new information in a sentence is more salient to the speaker than given information (because, on an analogy to perception, novelty and change control what we attend to, to a large degree). If the speaker permits salience to control word order, then new information should precede given. However, if the assumption is made that speakers generally try to take account of the listener's need for a prior perspective from which to interpret new information, and such a perspective is supplied by the old information, given-new ordering becomes a Gricean courtesy (Grice, 1975).

Taxonomies of discourse functions often include different principles to account for both types of patterns (given-new versus salient-nonsalient). Allerton (1978), Halliday (1970), and Quirk, Greenbaum, Leech, and Svartvik (1972) thus contrast given-new ordering with theme-rheme (Halliday, 1967) ordering, where the theme represents, roughly, what is at the forefront of the speaker's mind—what is most salient. Chafe (1976) disregards constituent order as a correlate of givenness, giving the burden of marking this information chiefly to intonation (see also Chafe, 1974). Although this may simplify the problem, it ignores considerable empirical evidence for given-new ordering in analyses of written and spoken discourse (Smith, 1971; Tomlin, Note 8) and experimental investigations (Bock, 1977; Bock & Irwin, 1980; Carroll, 1958) and makes the English constituent order system qualitatively different from those of languages that rely more on constituent order

than intonation to express the distinction between given and new information (MacWhinney & Bates, 1978).

These apparent inconsistencies become somewhat more orderly when analyzed in terms of the proposed processing framework. If we assume that focus of attention or perspective factors affect relational coding in the referential arena, their effects should show up principally in the selection of particular syntactic structures. These, to the extent that they allow only one realization, will determine constituent order. However, if alternative realizations are admitted, lexical processing factors may bias the selection of one of the alternatives. A number of factors that facilitate lexical processing are likely to be at work in the case of givenness resulting from repeated reference. In particular, appropriate semantic and phonological productions will have been activated during prior formulations of the information, and related productions will have benefitted from automatic spreading activation. Even without lexical repetition the representations of the lexical information chosen to convey a repeated referent are likely to be in many ways less complex and more accessible than those selected for new information: Given information is often realized simply as a pronoun. As a result of any or all of these processes, given information should tend to be formulated faster than new information. Given-new ordering is therefore explainable as one consequence of a system that structures sentences in such a way that information that is lexicalized earlier may be produced earlier. When discourse givenness is irrelevant—when there is no prior discourse or when the topic is changed—lexical processing differentials should be smaller and will therefore play a smaller role in determining constituent order than referential processing.

There are other ways of resolving this ordering paradox within the proposed framework. One draws on Posner and Snyder's (1975a, 1975b) distinction between automatic activation and conscious attention, extending it to processing in the referential arena. Although it seems intuitively plausible that an attention focus should be the informational focus of an utterance, it does not

directly follow that the information focus should be first; the fact that focal stress routinely falls at the ends of sentences suggests that it is, indeed, usually last. What claims about the role of attention (or some factor that is presumed to draw it) in constituent ordering generally overlook is that it takes time to focus one's attention; it is not instantaneous (for review and discussion see Posner, 1978). Automatic activation, on the other hand, works very fast. A number of comprehension studies have suggested the possibility that activation processes may operate within the referential arena, so that the representation of a referent may remain activated after it has occurred in a sentence. This evidence comes from experiments on the effects of repeated reference in text, which show that sentences with referring expressions having a discourse antecedent in an immediately preceding clause are more readily comprehended than either sentences whose referring expressions do not have a discourse antecedent (Garrod & Sanford, 1977; Haviland & Clark, 1974) or sentences whose referring expressions have discourse antecedents farther back than a single clause (Carpenter & Just, 1977; Chang, 1980; H. H. Clark & Sengul, 1979; Lesgold, Roth, & Curtis, 1979). This effect is not simply a result of lexical repetition (Garrod & Sanford, 1977; Haviland & Clark, 1974; Yekovich & Walker, 1978). If similar effects influence the formulation of utterances (and there is no reason to think they do not), the already-activated representations of referents will have a distinct processing advantage over representations that require attention to reach a similar or higher level of activation: Unless it is inhibited, in order that the attended referent may be the first entered into lexical and syntactic processing, an activated referent may generally precede an attended one through these components.

A related resolution of the ordering paradox starts from the assumption that it only arises within an overly idealized view of sentence production. This idealized view, which is related to the analytic view of sentence production proposed by Wundt (1900; see Blumenthal, 1970, for a translation), suggests that we assemble at least the contents of a complete underlying proposition before

we decide to talk. A somewhat more realistic view, related to Paul's (1886; Blumenthal, 1970) synthetic theory of sentence production, may be that people often decide to talk about something before they have the slightest idea what it is that they are going to say about it. The "something" is quite likely to be the current topic of a conversation or discourse, that is, given information. This view suggests that the assembly of given information may often temporally precede that of new information in the referential arena; the output order then simply reflects the input order. Because sentence production is likely to be sometimes more analytic and sometimes more synthetic (Pillsbury, 1915; Stern, 1931), any firm conclusions about the origins of contributions of salience and givenness to constituent order may depend on the possibility of differentiating these two types of processing.

These explanations are closely related, in different ways, to Johnson-Laird's (1977) attempt to reconcile givenness and attention-focus principles in terms of differences in the contexts in which speakers use them. Discourse contexts, which in Johnson-Laird's analysis bias speakers toward the use of given-new ordering, should provide both lexical processing facilitation and activated referents; discourse contexts may also be more likely to promote synthetic production, because they may depend more on retrieval from long-term memory for the assembly of information in the referential arena. Conversely, nonlinguistic perceptual contexts, which in Johnson-Laird's analysis should result in the use of an attention-focus ordering strategy, may be less likely to provide either lexical processing facilitation or previously activated referents, and they may favor more analytic processing by providing relatively complete perceptual-referential schemas. The present proposal, however, has the advantage of avoiding the need for qualitatively different processing principles in different types of contexts, suggesting instead the underlying unity of the processing mechanisms that serve utterance formulation.

The proposed framework thus offers an integrated account of the influence of both referential and lexical factors, interacting

with processes of information representation and retrieval, on constituent order in adult language use. In general, then, it appears to provide a reasonably strong basis for the development of a detailed psychological model of the cognitive components of the language production process.

General Discussion

This section will briefly review the major conclusions that have been drawn from the arguments and evidence presented, discuss their implications for theories of sentence production, and examine an important limitation of the suggested framework.

The first conclusion is that the use of syntax, even though it reflects features characteristic of both automatic and controlled processes, cannot be fully explained by a simple division of syntactic procedures into defaults that apply automatically and options that require controlled processing. This conclusion follows in part from the rejection of the derivational theory of complexity. Instead, automatic deployment of a certain alternative from among a set of syntactic options may be used as a means of accommodating transient processing demands while simultaneously keeping the syntactic processing burden of working memory to a minimum.

Second, evidence from sentence production, sentence recall, and word processing experiments indicates that the retrieval of words during sentence formulation influences sentence form, partially independent of the sentence's intended substance. Thus, factors that facilitate lexical retrieval are also associated with the early placement of words and constituents in sentences. It appears, then, that lexical retrieval processes in fact do create transient effects that are accommodated by adjustments in the syntax of sentences.

Third, incorporating these lexical effects on syntax into a model of sentence production permits a resolution of certain superficially contradictory claims in the functional syntax literature about the determinants of constituent order in sentences. In particular, the salience and the givenness of information are in certain respects opposing factors, yet

both have been argued to result in early placement in sentences of constituents that exhibit them. However, because the givenness of a referent is correlated with factors likely to be associated with the facilitation of lexical access, its early placement may be interpreted to some degree as a consequence of the effects of lexical access on syntax.

These conclusions have a number of implications for theories of sentence production, some of which the general framework outlined above attempts to incorporate. An important one is that the sentence formulation system is not strictly hierarchical, with control flowing only in a top-down direction. Rather, the processing of information that is inserted relatively late into syntactic frames interacts with earlier syntactic processing. As a result, whereas constituent order is potentially correlated with partitions of information at the referential level, it need not be a completely reliable guide to processing at that level, as functional syntax implies, nor can it be completely specified at a single structural syntactic level, as autonomous syntax implies. Such indeterminacy suggests that deviations from the dominant constituent order of a language should not by themselves (i.e., without some additional marking) explicitly convey communicatively important information. Instead, as Chafe (1976) has argued in part, we may signal such distinctions as given versus new, presupposition versus assertion, theme versus rheme, by such means as intonation, definitization, passivization, subordination, and so forth. It is nonetheless necessary for a theory of sentence production to be able to explain correlations between such relations and the order of information in sentences.

A second implication is that the syntax of language may to some extent reflect certain general mechanisms of information retrieval. If so, a complete account of syntax will require a description of its interactions with the information processing system that supports skilled human performance and of the ways in which syntax accommodates and is constrained by that system. The provision of alternative sequences of constituents capable of realizing the same content was proposed earlier as one way in which the syntactic system of a language might be adapted

to the need for flexibility in the coordination of syntactic and lexical processing. Another possible manifestation of the effect of this coordination may be found in an interesting exception to the flexible deployment of these options. In certain constructions that generally permit alternative orders of postverbal elements, notably sentences containing various bitransitive verbs and verbs with bound particles, these alternatives are never used (i.e., they are ungrammatical) or are used so rarely as to sound odd. For example, although "John called Hal up" and "John called up Hal" are both acceptable, only "John called him up" is possible; "John called up him" is unequivocally ungrammatical. Similarly, "John fed a dime to the meter" and "John fed the meter a dime" are quite commonplace alternatives, but "John fed a dime to it" hovers on the edge of acceptability. In passives, as well, final pronouns are exceptionally rare (Svartvik, 1966); a sentence such as "The pedestrian was struck by her" requires contextualization and/or contrastive stress on the pronoun to sound remotely natural.

One way (though certainly not the only way; see Bolinger, 1977, for suggestions about the possible role of prosodic factors in similar constructions) of accounting for these exceptions is in terms of the relative accessibility of pronouns: Pronouns, if their frequency is any indicator (Kucera & Francis, 1967), are among the most accessible words in English. As a result they may so regularly bias production of the structures in which the pronoun directly follows the verb or initiates the sentence that the alternatives, when a pronoun is involved, become unacceptable. To the degree that a theory of sentence production is capable of providing principled accounts of such apparent exceptions to syntactic rules by incorporating general performance factors, the integration of linguistics with cognitive psychology optimistically decreed by Chomsky (1965) comes closer to being a reality.

The proposed framework omits some clearly critical elements of utterance formulation. One of these deserves some comment. The model does not precisely specify the structures or units within the components of the formulation system. Its primary

purpose, instead, is to suggest the nature of processing interrelations among information sources, rather than to define the form or structure of the information. It was of course necessary to make assumptions about what the major information sources are and to roughly delineate the types of information they provide. Thus the model includes a level of referential structure representing the ideational underpinnings of utterances, a component in which the meaning of words is represented, and a component where their phonological structure is represented. These assumptions are themselves disputable. As for the form of the representations within these components, there are competing hypotheses within as well as, in some cases, across disciplines.

With respect to the syntactic component and its relationship with lexical processing, somewhat more explicit assumptions were made. Specifically, it was assumed that syntactic processing might be described in terms of a context-free constituent structure grammar, along lines proposed by Gazdar (1981). Although such grammars seem to offer significant advantages over transformational grammars in terms of real-time processability and learnability, a final decision about their viability within a psychological model will require evidence bearing, in particular, on the correspondence between the types of representations these grammars propose for complex sentences and the comprehension, production, and acquisition of such sentences.

The proposed mediators between syntactic and lexical processing, consisting of the stored specifications of the syntactic privileges of lexical representations, and of the logical and semantic privileges of syntactic representations, are also speculative. Although such mediators are necessary in order to realize the role accorded to lexical retrieval factors in the present framework, they introduce considerable redundancy into the sentence processing system. This apparent lack of parsimony is, however, in line with current linguistic trends, including recent revisions of generative grammar (see especially Bresnan, 1978). Lexical interpretive grammars (Chomsky, 1971) in general sacrifice the representational economy of

earlier models with large transformational components for the processing economy of a model that stores a major portion of the information required to build a surface structure in the lexicon.

In summary, this paper has argued for an approach to sentence formulation in which syntactic processes are influenced both by the structure of the ideas an utterance is intended to convey and by the retrieval of the words that assist in conveying those ideas. Because of the interaction between lexical retrieval processes and syntax, syntactic processing within this system is a moderately flexible coordinator of the information that composes a sentence. The claim that syntactic flexibility functions in the service of both communicative goals and processing efficiency permits a resolution of the conflict between the hypothesized constituent ordering functions attributed to salience and to givenness. At the same time, it suggests a way in which the resources of the processing system may be committed primarily to thinking and speaking—more to what is to be said, and saying it, than to how.

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