Meaning, Sound, and Syntax: Lexical Priming in Sentence Production

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Theories of sentence production based on speech errors divide lexical–syntactic integration processes into two components. The first involves formulating an abstract structural representation that includes semantically specified lexical items. The second involves placing phonologically specified content words into a syntactic frame whose configuration is determined by the initial structural representation. Syntactic form thus may be influenced directly by variations in the semantic processing of words, but not by variations in phonological processing. This hypothesis was tested and supported in two experiments. In both, participants produced extemporaneous picture descriptions. Production of each description was preceded by the presentation of a priming word that was semantically or phonologically related to a target word likely to occur in the description. Semantically primed targets tended to appear as the subjects of active and passive sentences, whereas the same targets when they were not primed were more likely to appear as the objects. Phonological priming, although equal to semantic priming in ability to elicit the target words, was not reliably related to syntactic form.

The coordination of words and syntax is one of the most important problems that must be solved by the processing system that formulates speech. In order to account for the commonplaces of language use, including our ability to use words in sentences that we have never heard before, a certain degree of independence between lexical and syntactic information is required (Lashley, 1951). At some point in the creation of most utterances, then, it is necessary for specific words to be integrated into a syntactic plan. This article is concerned with the processes responsible for the integration of these different types of information in speech.

Two components of the integration process have been identified in theories of sentence production developed from analyses of errors in natural speech (Fromkin, 1971; Garrett, 1975). The first part occurs at what Garrett (1975, 1980, 1982) calls the functional level. Here the meanings of words (but not their phonological forms) are incorporated into a predicate–argument structure or an abstract syntactic structure, which then controls the elaboration of the basic syntax of the sentence.

The second part of the lexical–syntactic integration process occurs at the positional level. At this level, the phonological representations of words are inserted into a planning frame that fixes their locations in a string. The structure of the planning frame can be described in terms of a configuration of closed-class (function) words and bound morphemes that create slots for open-class (content) words. Crudely, the planning frame for a sentence such as The bee is stinging the man might look something like The____is____ing the_____. After phonologically specified content words are assigned to the planning frame, the resulting representation controls the elaboration of the sentence's phonetic form.

This model is motivated by the characteristic scope of certain types of speech errors and relations between interacting elements within those errors. Word exchange errors, such as "I left the briefcase in my cigar" (when what was intended was "I left the cigar in my briefcase"; Garrett, 1980) readily cross phrase and even clause boundaries. They differ in this respect from sound exchanges, such as "he caught tourses" (when what was intended was "he taught courses"; Fromkin, 1973). Sound exchanges are most common within phrases and are strictly clause bounded. This leads to a distinction between one level of representation that codes the proximity of elements in the surface string, the positional level, and one that does not, the functional level.

The interacting elements in exchange errors provide further evidence for a separation between levels. Word exchange errors are governed by grammatical category, so that nouns exchange with nouns, verbs with verbs, and so on. Sound exchanges, however, occur more often between words of different form classes than between words of the same form class. The interacting elements in sound exchanges instead tend to be phonologically similar, as MacKay (1970) has shown. This supports a distinction between a representation that is sensitive to the syntactic characteristics of the elements in sentences, the functional level, and one that is sensitive to their phonological characteristics, the positional level.

Two experiments were designed to test these claims of the speech-error model about the normal lexical–syntactic coordination process. A particular focus of these tests was the hypothesis that words are represented in terms of their meaning (not their sounds) at the level that controls the elaboration of the...
syntactic structure, the functional level. The speech-error evidence for this argument is weak. There is no indication that within-clause word exchanges are sensitive to the semantic characteristics of the words involved, as might be expected if the representation at the functional level specified the meanings of words. Furthermore, Dell and Reich (1981) have shown that such errors reflect phonological similarities more often than would be expected by chance.

The experiments depend in part on the early positioning effect in sentence production (Bock, 1982). This involves the early placement in sentences of information that is relatively more accessible to the retrieval processes involved in formulating an utterance. For example, if one were about to describe an event involving a dog chasing a mailman, recent production or perception of the word mailman might increase the probability of saying "The mailman is being chased by the dog," with the word mailman preceding the word dog. This has been found to occur over and above positioning effects attributable to the ordering of given and new information in sentences (Bock & Irwin, 1980). One hypothesis about this effect is that the sentence production system accommodates variations in lexical retrieval by organizing (or reorganizing) syntactic representations in such a way that words that are retrieved quickly will be produced early in sentences (Bock, 1982; Levelt & Maassen, 1981).

It is not clear whether such early positioning effects result from the accessibility of the meanings of words or from the accessibility of their sounds. Previous research on picture naming and other word generation tasks suggests that the prior occurrence of related words, either semantically related (Higgins, Bargh, & Lombardi, 1985; E. Loftus, 1973; G. Loftus & E. Loftus, 1974; Sperber, McCauley, Ragain, & Weil, 1979; but see Bowles & Poon, 1985 and Roediger, Neely, & Blaxton, 1983) or phonologically related (Bowles & Poon, 1985; A. Brown, 1979; Kozlowski, 1977; E. Loftus, Senders, & Turklelaub, 1974), can facilitate some of the processes involved in word production or increase the probability of producing a particular target word. Thus, words might be placed earlier because their semantic representations are easier to retrieve or because their phonological representations are easier to retrieve.

The sentence production model outlined by Garrett (1975, 1980, 1982) makes a clear prediction on this issue: Because only the semantic representations of words are available at the point at which a sentence's syntactic form is determined, only semantic accessibility should influence the syntactic structure. The accessibility of phonological representations should have no effect.

This prediction was tested by using a production-priming paradigm (Bock, 1983, 1986). The subject's basic task was very simple. On every primed production trial the subject first heard and then repeated a priming word aloud. Then a slide depicting an event was exposed, and the subject described what was happening in the picture.

The priming words were either semantically or phonologically related to particular target words likely to be used in describing the depicted events. For example, a subject might hear the word honey; repeat it aloud, and then describe a picture of a bee stinging a man. Another subject would hear and repeat the word fee (in Experiment 1) or bay (in Experiment 2), and then describe the same picture. In the first case, the word honey is semantically related to a word that is commonly used in describing the event (bee), and in the second, case fee and bay are phonologically related, by rhyme or initial sound, to the same word. Other subjects received semantic or phonological primes for the patient (man) depicted in the picture. The priming trials occurred amidst a large number of filler words and pictures in order to reduce the salience of these word–picture relations.

Two of the possible descriptions that could be produced for each picture were designated the basic descriptions and consisted of an active sentence and its corresponding passive. (The basic descriptions were not prescribed to the participants, who were relatively unconstrained in how they chose to describe the pictures.) In the pair of basic descriptions for any given picture, the target words could occur either as grammatical subjects or as objects. Thus, the agent (e.g., the bee in the picture of the bee stinging the man) could appear as the surface subject of an active sentence, or as the surface object of a passive, and the patient (man) could appear as the subject of a passive, or as the object of an active. The effects of the primes were assessed by comparing the frequency of occurrence of the primed target words as the subjects of the basic descriptions with their frequency of occurrence as the objects. In other words, what was examined was the tendency of primed target words to appear earlier than unprimed targets in the participants' utterances.

According to the speech-error model, only semantic priming should produce the early positioning effect. Because the alteration between active and passive sentences is argued to result from differences in the form of the representation at the functional level, and because lexical specification at that level is semantic, only variations in semantic processes should be associated with syntactic variations. Although phonological priming ought to increase the accessibility of the phonological representations of words, increased phonological accessibility should not influence functional-level processing.

The priming trials were embedded in a recognition memory test that was designed primarily to make speaking appear incidental to the purpose of the experiment. This reduces the likelihood of participants engaging in ad hoc strategies when describing the pictures, or paying more attention to the syntactic features of their speech than they commonly do. The syntactic patterns observed should therefore be reasonably representative of normal speech styles.

Experiment 1

Method

Participants. The participants were 64 Cornell University undergraduates. Each was paid $3 for the 45-min session.

Materials. The primary materials for the experiment consisted of 24 test pictures with two semantic and two phonological primes for each. Figure 1 gives examples of four of the test pictures along with the semantic and rhyme primes for those pictures.

The test pictures each depicted a transitive action involving an agent (an animate or inanimate object whose movement appeared to cause the depicted action) and a patient (recipient of the action). Half of the pictures had human agents, and half had nonhuman agents. The pictures were drawn in black ink on white paper and photographed for presentation on slides.
nearly so.

and the final syllables in the prime and target words were identical or tisyllabic prime-target pairs, the stressed syllables had the same vowel, target differed, but the stressed vowels were generally the same. For mul-
syllable, the beginnings (typically initial consonants) of the prime and the stressed syllables differed. The effect of these constraints was that ambulance, primes for the targets and a similar ending. The only exceptions to these requirements were the target word, the same vowel in the syllable receiving highest stress, and for the remainder they were very weakly related or unrelated. Each prime was selected so as to be more closely associated to its target than to the unprimed target likely to appear in the same utter-
ance. On the association task the unprimed targets were never given as responses to the primes.

The modal labels for the agents and patients in the test pictures were the designated target words. Each of the semantic primes was related in meaning to one of these targets. The priming words were taken from the stimulus words in published free association norms (Palermo & Jen-
kins, 1964) whenever one of the targets was frequently elicited by a given stimulus word. However, because few of the target words occurred fre-
quently in the free association lists, most of the primes were selected on the basis of four judges' agreement that a particular word was closely related in meaning to, and likely to elicit, the target word. The semantic relations represented were heterogeneous, and included paradigmatic relations such as hyponymy (canine-dog) and synonymy (cop-policeman), as well as associative or functional relations (e.g., worship-church, drive-car, honey-bee).

The phonological primes rhymed with the same two target words. The rhymes were selected from lists of rhymes for the target words culled from rhyming dictionaries. The rhyme primes were required to have the same number of syllables and the same stress patterns as the target word, the same vowel in the syllable receiving highest stress, and a similar ending. The only exceptions to these requirements were the primes for the targets woman and ambulance, in which the vowels in the stressed syllables differed. The effect of these constraints was that for prime-target word pairs in which each of the words had only one syllable, the beginnings (typically initial consonants) of the prime and target differed, but the stressed vowels were generally the same. For multi-
syllabic prime-target pairs, the stressed syllables had the same vowel, and the final syllables in the prime and target words were identical or nearly so.

The target words for different pictures were sometimes the same. Boy was a target for nine pictures, man for three pictures, girl for six pictures, and woman for four pictures. Because of the difficulty of finding different priming words for all of the occurrences of the targets in these cases, the same primes were used on a subset of the occasions when the same target occurred in different pictures. Five different rhyme primes were used for boy and three for girl. When the same rhyme prime was used, the same semantic prime was also used, so there were also five different semantic primes for boy and three for girl.

To compare the effectiveness of the semantic and phonological primes in eliciting the target words, two different groups of raters performed controlled association tasks. Both groups contained 10 raters. The first group was asked to supply the first word that came to mind that was related in meaning to each of the 41 semantic primes. The second group supplied the first word they thought of that rhymed with each of the 41 phonological primes. The mean percentages of times that target words were given were 23.7% and 25.9% for the semantic and phonological primes, respectively. This was not a significant difference, t(18) = .30.

The two target words for each picture were designated on the basis of informal observations and previous research using the same test pic-
tures. There were no regular phonological relations between them. The strength of the semantic relations varied. For roughly half of the pictures the two targets were themselves semantically related (e.g., truck-car, horse-cow), and for the remainder they were very weakly related or un-
related. Each prime was selected so as to be more closely associated to its target than to the unprimed target likely to appear in the same utter-
ance. On the association task the unprimed targets were never given as responses to the primes.

Four recognition lists were assembled from these materials. Every list contained all 24 test pictures, with half of the pictures preceded by a phonological prime and half preceded by a semantic prime. Half of the primes of each type were agent primes, and half were patient primes. Across all four lists, each picture was primed exactly once with a prime in each of the four conditions formed by crossing the semantic versus phonological priming factor with agent versus patient priming.

Each recognition list consisted of 80 pictures mixed pseudorandomly with 80 words. These included 56 filler words and 56 filler pictures in addition to the pairs of priming words and test pictures. The filler words were selected in such a way that as a group they were difficult to distin-
guish from the set of priming words. They included common as well as rare words, proper names, and words from several different form classes.

The filler pictures were also comparable in style to the target pictures, but they depicted a wider variety of events. These included intransitive actions (a boy shivering in the snow, a man sleeping), dative actions (a clerk showing a man a dress, a girl giving a teacher flowers), reflexive actions (a girl looking at herself in a mirror, a man shooting himself), as well as additional transitive actions (a girl combing her hair, one boy kicking another).

The serial positions of the filler items and the priming word/test pic-
ture pairs were the same across all four lists, with the priming words occurring immediately before the appropriate test pictures. All of the priming pairs were preceded by a minimum of one filler item. No more than three words or three pictures occurred consecutively. Except for these constraints, the order of the items in the test lists was random.

A single 80-item study list was constructed of 40 pictures mixed with 40 auditorily presented filler words. The pictures consisted of the 24 test pictures and 16 filler pictures (the test pictures were presented during the study phase to familiarize the participants with their contents and facilitate their subsequent description). The order of words and pictures in the study list was random, except for the constraint that no more than two pictures or words could occur consecutively. Words and pictures that might be seen as related were not permitted within the same neighbor-
hoods in the list.

Procedure. The recognition memory format was established in the first phase of the experiment by presenting the study list. Participants
were run individually and were instructed to examine the pictures and write down their descriptions in preparation for an upcoming recognition test. They controlled the presentation of the slides themselves, advancing the carousel after viewing a picture or hearing a word. Blank slides appeared in those list positions at which words were presented, read by the experimenter.

After the study phase the participants received instructions for the recognition test. They were asked to indicate which pictures and words they had encountered in the study phase by saying "yes" or "no" after each of the test items. They were also instructed to perform one of two secondary tasks before making their recognition decision on each trial. On the word trials, they were told to repeat each of the words aloud after the experimenter read them, on the pretext of ensuring that they heard them correctly. On the picture trials, they were instructed to describe what was happening in each picture, with the understanding that the recorded descriptions would later be used to identify the pictures. They were told that they should describe each event in a single sentence, without using pronouns. They were otherwise free to say what they liked. A practice list of four pictures was given to ensure that the recognition and description instructions were understood.

The recognition test together with the two secondary tasks determined the sequence of events on the pairs of items that constituted the priming trials. That sequence was as follows: The experimenter read a word, and the participant repeated it aloud. He or she then made a recognition decision (the correct decision was always "no"), received feedback on the decision, and advanced the projector to reveal a picture. The participant described the event, made another recognition decision (the correct decision was always "yes"), and again received feedback. Because the slide advance was under the participant's control, there was considerable variability in the stimulus onset asynchronies for the words and pictures, but the average time that elapsed between the participant's production of the priming word and exposure of the picture was roughly 2 s.

At the end of the experimental session, the participants were asked a series of debriefing questions. These queried their awareness of relations between the words and the pictures, their awareness of the effect of any relations on their picture descriptions, deviations in their picture descriptions from their usual speech style, and their perception of the purpose of the experiment.

The sessions were recorded on audio tape. Participants' descriptions of the test pictures and their responses to the debriefing comments were transcribed from the tapes.

**Results**

The primary dependent measure was the percentage of times the basic descriptions were used to describe the pictures. The analyses contrasted the frequency with which primed words appeared as grammatical subjects with the frequency of their appearance as direct objects in each condition. This contrast involved summing the number of active sentences that were produced under agent priming and the number of passives that were produced under patient priming, creating the category of subject-primed descriptions, and comparing this to the sum of the number of actives that were produced under patient priming and the number of passives that were produced under agent priming, creating the category of object-primed descriptions. Analyses of variance were performed on the mean percentages of subject- versus object-primed basic descriptions that occurred in the semantic and phonological conditions for each participant and item. Unless noted otherwise, effects were considered significant when their associated probabilities were less than or equal to .05.

Figure 2 shows the mean percentages of basic descriptions in which the subject had been primed, designated primed word subject, and those in which the object had been primed, designated primed word object. The error bars represent the 95% confidence intervals for the differences between the participant means.

Figure 2. Mean percentages of basic descriptions in which primed target words preceded unprimed target words as the subjects of active or passive sentences (primed word subject) or followed unprimed target words as the objects of active or passive sentences (primed word object). (The error bars represent the 95% confidence intervals for the differences between the participant means.)

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Figure 2 shows the mean percentages of basic descriptions in which the subject had been primed, designated primed word subject, and those in which the object had been primed, designated primed word object. The error bars represent the 95% confidence intervals for the differences between the participant means. In the semantic priming condition, significantly more utterances occurred with the primed word early, as the subject of the sentence (33.6%), than with the primed word late, as the object (29.0%). In the phonological priming condition, however, the difference was slightly in the opposite direction, 30.1% to 32.7%, although not reliably so. This interaction was significant for both participants, $F(1, 63) = 5.84$, and items, $F(1, 23) = 5.66$. 
20 participants (31%) indicated that they were unaware that presentation of the study list. The comments of the remaining potentially aware, although their remarks suggested that the re-

pictures in the recognition test list. An additional 14 (22%) were

many of the participants (30, or 47%) were clearly aware of the

action between priming status and type of prime.

10. The most important result was that there was no reli-

$p < .

than when they were not. This trend was significant for partici-

pants, $t(73) = 4.75$, and marginal for items, $F(1, 23) = 3.43$, $p = .058$ by a sign test). In the phonological priming condition, with the same items, the primed target preceded the unprimed (46.4% and 43.2%, respectively, in line with the general tendency of the targets. Another analysis was conducted on these residual descriptions. There were other descriptions of assorted syntactic types in which both target words occurred, not including the basic active and passive forms. There were 58 in the semantic and 49 in the phonological priming conditions of Experiment 1, and 105 in the semantic and 111 in the phonological priming conditions of Experiment 2.

The contrasts for items in the semantic and phonological conditions yielded trends comparable to those for subjects. The 95% confidence interval for the difference between the mean percentages of utterances with the primed word early versus late was 4.57%, which is less than the difference in the semantic condition but greater than the difference in the phonological condition. Closer inspection of the items revealed that 14 of the 20 non-nonties in the semantic priming condition were in the predicted direction, with the primed target preceding the unprimed ($p = .058$ by a sign test). In the phonological priming condition, with the same items, the primed target preceded the unprimed in 8 of the 22 nonties.

The analyses reported thus far were restricted to the basic descriptions. There were other descriptions of assorted syntactic types that included both target words, although too few (less than 2% of all the descriptions) to yield any regular patterns (see Table 1). The primed target preceded the unprimed in 58% of the 1536 picture descriptions produced, of which 46.4% placed the primed word early and 46.8% placed the primed word late. The corresponding percentages for the matched aware group were 53.6% and 46.3% of 149 basic descriptions). The difference thus favored the matched aware group, although it was less than 1%. The matched group slightly underestimated the effect for the whole group of clearly aware participants, in which 55.4% of the descriptions placed the primed word early. In general, however, the similarity between the matched aware and unaware groups suggests that awareness of the semantic relation between the priming words and test pictures was not necessary for primed words to precede unprimed words in descriptions of the pictures.

The participants who were aware of the semantic relations may also have been more likely to notice the phonological relations, but simply failed to mention them. However, examination of the influence of awareness of the semantic relations on descriptions in the phonological priming conditions showed no notable effects. For the matched aware and unaware groups the percentages of descriptions with the primed word early were 46.4% and 43.2%, respectively, in line with the general tendency for the primed word to appear later after a phonological prime.

Responses to other debriefing questions indicated that the

<table>
<thead>
<tr>
<th>Prime type</th>
<th>Experiment 1</th>
<th>Experiment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semantic</td>
<td>49.0</td>
<td>58.1</td>
</tr>
<tr>
<td>Phonological</td>
<td>50.0</td>
<td>49.6</td>
</tr>
</tbody>
</table>

Note. Nonbasic descriptions were picture descriptions of assorted syntactic types in which both target words occurred, not including the basic active and passive forms. There were 58 in the semantic and 49 in the phonological priming conditions of Experiment 1, and 105 in the semantic and 111 in the phonological priming conditions of Experiment 2.

Table 2

Percentages of Residual Utterances With Target Words After Phonological or Semantic Priming

<table>
<thead>
<tr>
<th>Prime type</th>
<th>Priming status of target words used</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Semantic</td>
</tr>
<tr>
<td>Experiment 1</td>
<td></td>
</tr>
<tr>
<td>Primed</td>
<td>35.7</td>
</tr>
<tr>
<td>Unprimed</td>
<td>44.1</td>
</tr>
<tr>
<td>Experiment 2</td>
<td></td>
</tr>
<tr>
<td>Primed</td>
<td>38.6</td>
</tr>
<tr>
<td>Unprimed</td>
<td>43.4</td>
</tr>
</tbody>
</table>

Note. The residual utterances were picture descriptions in which one or both of the two target words were not used. There were 238 in the semantic and 244 in the phonological priming conditions of Experiment 1 and 396 in the semantic and 391 in the phonological priming conditions of Experiment 2.
participants were overwhelmingly convinced that the experiment's purpose was to investigate memory for pictures and words. Almost all felt that their picture descriptions reflected their normal speech patterns. Some of the participants who noticed the semantic relations thought that these relations might have influenced the way they described the pictures, although the modal opinion about the nature of this influence centered on word selection. None of the subjects noted an initialization or ordering strategy.

Discussion

Lexical priming appears to influence the syntax of sentences. However, this influence may depend on the relation between the priming word and the subsequently produced word. Semantic priming affected sentence formulation processes in such a way that target words related to the primes occurred earlier in picture descriptions, in the subject constituent of active or passive sentences, whereas unrelated target words occurred in the object constituent. Phonological priming had no significant effect on the ordering of constituents, despite the fact that the phonological primes did not differ from the semantic primes in their ability to elicit the target words. These results are consistent with the hypothesis that the syntactic structure of an incipient sentence is determined at a level at which the meanings of words are available but at which their phonological form has yet to be retrieved or has little impact.

The differences between semantic and phonological priming in their effects on word order cannot be attributed to changes in the ease with which target words were retrieved after different prime types. In a set of descriptions in which target words were sometimes omitted, there was no difference in the frequency with which target words appeared after phonological or semantic priming nor any detectable difference in the magnitude of the change in their frequency as a function of priming. In conjunction with the similarity between the phonological and semantic primes in their ability to elicit the targets on association tests, these results are consistent with the assumption that the effects of priming on ordering are attributable to processes that occur when lexical representations are integrated with syntactic plans.

The effect of priming on lexical selection, as assessed in the residual utterances, was somewhat paradoxical. The tendency of semantically primed targets to occur earlier in the basic descriptions suggests that those words were more accessible when they were primed than when they were not. However, the target words were less likely to appear in the residual utterances when they were primed, either semantically or phonologically, than when they were unprimed. In evaluating this effect, it may be crucial to consider its context of occurrence. Because it was possible to observe variations in target word use only within the subset of descriptions in which nontarget words also occurred, the presence of the nontarget words may be related to the apparent suppression of the primed targets. This possibility will be considered in more detail in the General Discussion section.

The differences in the effects of semantic and phonological priming on sentence structure were paralleled by differences in subjects' awareness of the semantic and phonological relations between the priming words and test pictures. Nearly half of the subjects were obviously aware of the semantic relations, whereas fewer than 1 in 10 noticed the phonological relations. Although none of the subjects appeared to have been conscious of the syntactic effects that these relations had on the way they described the pictures, it is clearly possible that awareness of the relation contributed to or was responsible for the differences between semantic and phonological priming. If so, subjects unaware of the semantic relation should have shown no evidence of the priming effect. However, there was little difference between the unaware subjects and a matched group of aware subjects in the magnitude of the semantic priming effect. The possibility remains open that awareness of the relation magnifies the effect, but it does not appear to be necessary for it to occur.

The differences between phonological and semantic priming in their effects on syntax support the hypothesis that the syntactic structure of sentences is created at a level of processing that represents the meanings but not the sounds of words. This result is consistent with the characteristics of the functional level proposed in the speech-error model of sentence production (Garrett, 1982). However, the absolute magnitude of the semantic effect was small. To check on its generality as well as the generality of the phonological noneffect, a second experiment was conducted using a revised set of target pictures and semantic primes, a different type of phonological prime, and a larger sample of subjects.

Experiment 2

Several sources of evidence suggest that some components of the phonological representations of words are more central than others. In the speech errors known as malapropisms, in which the speaker appears to have the correct meaning in mind but selects the wrong phonological form (e.g., "He's the kind of soldier a man wants to emanate"; "He was a prodigy of Hubert Humphrey's"), there are very regular phonological relations between the erroneous word and the intended word. Fay and Cutler (1977) have shown that the intruding words tend to have the same initial segments, stress patterns, and number of syllables as the intended words (cf. emanate and emulate, prodigy and protege). R. Brown and McNeill (1966), in their classic investigation of tip-of-the-tongue states, found that their subjects frequently gave accurate information about the initial sounds and lengths (in syllables) of words that were otherwise unretrievable. The beginnings of words seem to have special status in laboratory memory tasks as well: Initial fragments are better than final or middle fragments in eliciting particular target words as free associations or as prompts for recalling previously presented words (Horowitz, White, & Atwood, 1968). These parameters of word form thus seem to play an important role in phonological representations. Accordingly, the phonological primes in the second experiment began with the same sounds as the target words, had the same number of syllables and the same stress patterns, and represented the same part of speech. They were roughly complementary to the phonological primes of the first experiment, in that the emphasis on similarity in vowel sounds in Experiment 1 was replaced by an emphasis on similarity in consonants in the present study.
LEXICAL PRIMING IN SENTENCE PRODUCTION

Table 3
Examples of Phonological and Semantic Primes From Experiment 2

<table>
<thead>
<tr>
<th>Target word</th>
<th>Phonological prime</th>
<th>Semantic prime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bee</td>
<td>Bay</td>
<td>Honey</td>
</tr>
<tr>
<td>Church</td>
<td>Charge</td>
<td>Worship</td>
</tr>
<tr>
<td>Cow</td>
<td>Caw</td>
<td>Milk</td>
</tr>
<tr>
<td>Nun</td>
<td>Nine</td>
<td>Convent</td>
</tr>
<tr>
<td>Devil</td>
<td>Diver</td>
<td>Hell</td>
</tr>
<tr>
<td>Torpedo</td>
<td>Tarpaulin</td>
<td>Submarine</td>
</tr>
<tr>
<td>Missile</td>
<td>Mason</td>
<td>Bomb</td>
</tr>
<tr>
<td>Ambulance</td>
<td>Ambience</td>
<td>Stretcher</td>
</tr>
</tbody>
</table>

Method

Participants. The participants were 96 Cornell University undergraduates, each of whom received $3 for his or her assistance.

Materials. As in the first experiment, the materials included a set of 24 test pictures and two sets of priming words. There were again 48 semantic primes and 48 phonological primes.

The test pictures consisted of 17 from Experiment 1 and 7 new pictures. The new pictures replaced several of those in which the people depicted were typically denoted as man, woman, boy, or girl with other human agents and patients likely to be given more diverse labels (e.g., king, queen, priest, nun, fireman, sailor, boxer, referee). Two pictures remained in which one of the target words was woman, two in which one of the targets was boy, and three in which one of the targets was man. The pictures were prepared in the same way as in the previous experiment.

The 48 semantic primes were comparable to those of the previous experiment, except for the changes required by the new test pictures. As a result of these changes, there were no duplicates among the priming words.

The 48 phonological primes were selected to have the same number of syllables, the same stress patterns, and the same initial consonants, consonant clusters, or (in the case of vowel initiations) vowel and consonant as the target words. Whenever possible, the onsets of the second and third syllables were also the same as those of the targets. Except for three cases in which the target word began with a stressed vowel, the vowels in the stressed syllables of the primes and targets were different. Because all of the targets were nouns, all of the primes were nouns on at least one reading (though not always the dominant reading). Examples of the phonological and semantic primes are shown in Table 3.

Four 176-item recognition lists and a single 88-item study list were constructed in the manner described for Experiment 1. The counterbalancing and randomization constraints were also the same. The filler materials were comparable, except that the number of filler pictures and words was increased from 80 to 88, with 44 of each in the recognition lists.

Procedure and scoring. The procedure was identical to that of the first experiment, including an initial study phase to establish the cover recognition task and a subsequent test phase in which the subjects performed the secondary word repetition and picture description tasks that instituted the priming manipulation. The scoring methods were also the same.

Results

The primary contrast was again between the percentage of times that primed target words appeared as the subjects of the basic (active or passive) picture descriptions and the percentage of times that they appeared as the objects. As shown in Figure 2, there was once more a significant effect for the semantic primes, and a nonsignificant reversal for the phonological primes. In the semantic priming condition, the primed target word occurred as the subject of the produced sentences significantly more often than it occurred as the object, 30.6% to 27.3%. In the phonological priming condition, the direction was reversed, 27.4% to 29.1%, although the difference did not reach significance. The interaction between type of prime and prime location was reliable in an analysis of variance in which participants were treated as the random factor, $F(1, 95) = 4.07$, although not in an analysis with items random, $F(1, 23) = 2.84$.

The 95% confidence interval for differences between the item distributions was 4.30%, exceeding the differences between the means in both the semantic and phonological conditions. However, of the 22 nontied items in the semantic priming condition, 16 placed the primed target before the unprimed target ($p < .05$ by a sign test); of the 23 nonties in the phonological condition, 9 placed the primed before the unprimed target.

There were 216 descriptions of other syntactic types that contained both target words. Inspection of these (see Table 1) showed ordering patterns comparable to those in the basic descriptions, with the primed word tending to precede the unprimed in the semantic but not in the phonological condition. However, the interaction was not significant ($F < 1$).

There were 787 residual descriptions that omitted one or both target words, 49.7% of which occurred in the phonological condition and 50.3% in the semantic condition. These were examined for effects of priming on the frequency of use of target words (see Table 2). The results were similar to those of the previous experiment: Target words were significantly less likely to be used when they were primed than when they were not, $F(1, 95) = 4.17$ for participants and $F(1, 23) = 9.27$ for items. The interaction with prime type (phonological versus semantic) was not reliable, with both $F$s less than 1.

Debriefing comments were available for 94 of the participants (tape damage prevented transcription of the comments for the remaining 2). The contents were similar to those of the first experiment. They revealed that a large proportion of the participants, 61%, were clearly aware of the semantic relations, with 23% expressing no awareness of any relations between the words and pictures. The remaining 16% could not be unambiguously classified as aware or unaware. Only 3% of the participants mentioned the phonological relations.

The ordering effects for the basic descriptions in the semantic priming condition were compared for the unaware group and a matched group of clearly aware participants. They were matched according to recognition list received, as in the first experiment, so that the number of aware participants equaled the number of unaware on each list. This comparison revealed no differences between the two groups. In the unaware group, 52.0% of the basic descriptions placed the primed word early, compared to 52.7% in the matched aware group. The matched subset of clearly aware participants showed a somewhat larger effect than the full clearly aware group, which showed no difference at all: Exactly half of the basic descriptions of the full group placed the primed word early.

The descriptions in the phonological priming condition also revealed no systematic effect of awareness of the semantic re-
lutions. The percentages of basic descriptions with the primed target early were 48.6% and 49.7% for the matched aware and unaware groups, respectively.

Discussion

The second experiment replicated the major results of the first: Semantic priming of sentence constituents reliably affected the syntactic form of sentences, but phonological priming did not. This further supports the view that the semantic representation of lexical items is more important than the phonological representation at the point of the sentence production process at which syntactic form is determined.

Although the findings across the two experiments were generally similar, there were some disparities between them in the strength of effects. The magnitude of the semantic ordering effect for active and passive sentences was somewhat smaller in the second than in the first experiment, perhaps because the picture descriptions were distributed differently. Fewer basic descriptions (active and passive sentences) occurred in the second experiment, with correspondingly more utterances of assorted other types (see Table 1). These other categories showed more ordering variation in the second experiment than in the first, with trends comparable to those found in the analyses of the basic descriptions. Combining the basic descriptions with these other descriptions in both experiments reveals very similar differences between conditions. In the semantic priming condition in Experiment 1, there were 4.6% more descriptions with the primed target early than with the primed target late, compared to 4.8% more in Experiment 2. In the phonological condition in Experiment 1, there were 2.6% fewer descriptions with the primed target early than with it late, compared to 1.7% fewer in Experiment 2. The ordering effect thus may have persisted to roughly the same degree, but was spread over a broader range of syntactic categories.

General Discussion

Experiments 1 and 2 support two conclusions. First, the accessibility of information related to the meanings of words appears to affect the syntax of the sentences in which those words occur. Second, the accessibility of information about the sounds of the same words in the same sentences seems to play a different role.

These conclusions confirm the predictions of the speech-error model (Garrett, 1975, 1980, 1982). According to this model, normal sentence production requires the creation of an abstract sentence representation or plan that includes semantically specified lexical items. Because this abstract representation directly controls the syntax of the sentence, guiding the creation of an ordered string of morphemes, factors related to semantic representation and semantic access have the potential to influence sentence form. Because, according to the model, phonological specification occurs after the ordered string is created, factors related to phonological representation and access should have no direct effect on sentence structure.

Additional evidence for a separation between semantically elaborated and phonologically elaborated levels of representation in production has been found by J. P. Stemberger (personal communication, May 18, 1985). In spontaneous speech errors, it is relatively common for an unintended word to be used that is semantically related to another word in the sentence (e.g. "A fork wrapped up in a spoon?", where what was intended was "A fork wrapped up in a napkin?"). Such errors differ from the exchange errors discussed earlier, but are also consistent with the argument that the semantic representations of words are specified at a point in the production process at which the phonological representations have not been retrieved. At this point, they are able to influence the selection of other words, hence the semantically related intrusions. There is no comparable influence on phonologically related words: Errors are rare in which an intrusion is phonologically but not semantically related to another word in the sentence (e.g., "dragon drapes," when what was intended was "tiger drapes"). The two-stage lexicalization process implicit in these proposals has received experimental support in work reported by Kempen and Huijbers (1983).

The Explanation of Ordering Effects

To explain the ordering patterns observed in the present experiments, analyses of representational levels must be coupled with more detailed processing assumptions about the coordination of lexical information with syntactic structures. In one model of this process (Bock, 1982), variations in the order of constituents in sentences are explained in terms of the outcome of competitions among constituent-structure representations comparable to planning frames. One of the factors that influences the decision in this competition is the match between conditions on the use of a particular structure and the relational or grammatical roles temporarily assigned or linked to activated lexical-semantic representations.

The early positioning effect can be explained in terms of this linking of grammatical roles (subject of the verb, direct object, etc.) to the lexical representations selected to convey particular components of the message. These roles have to be assigned, rather than stored, because the same lexical items can serve different grammatical roles on different occasions. The assignment process can be hypothesized to operate according to a hierarchy in which the subject role is assigned first, the direct object second, and indirect or other oblique objects later (Bock & Warren, 1985). Although content features of the message seem to contribute heavily to these assignments, processing factors such as the ease with which message elements are categorized or find appropriate semantic representations may also play a part. Thus, other things equal, a message element that is categorized faster will be assigned to a higher level grammatical role than one that is categorized more slowly. It can then begin the process of finding an appropriate constituent structure realization.

There are two general sets of factors that have been argued to influence the speed or ease of the categorization process. One set has to do with message-level features or the characteristics of the referents to be categorized. Referents that are readily categorized, or those that receive priority in the categorization process because of their prominence in the message, should tend to be assigned to higher level grammatical roles (e.g., the subject role). Referents with prominence include those that for
some number of experiments have suggested their contribution to grammatical role assignments (for reviews see Bates & MacWhinney, 1982; Bock, 1982; MacWhinney, 1977). Readily categorizable referents are those that map onto lexical-semantic representations with relatively little uncertainty (this has also been called categorizability; cf. Brown & Lenneberg, 1954), and evidence that something like this influences grammatical role assignments has been reported by Bock and Warren (1985) and James, Thompson, and Baldwin (1973). Bock and Warren (1985) labeled this property conceptual accessibility.

The second set of factors that might be hypothesized to influence categorization relates to properties of the language processing system, rather than to messages themselves. The form of this argument is that processing within the lexical or syntactic system can influence the way in which a message is conveyed, independently of message features (Baars, 1980; Bock, 1982). If so, the speed or ease of categorization could be influenced by the momentary state of the lexical processing system. This is supported by studies of picture naming, which show that activated semantic information can be applied more readily in the assignment of a lexical category (i.e., a name) to a referent than nonactivated information (Carr, McCauley, Sperber, & Parmelee, 1982; Huttenlocher & Kubiczek, 1983; Kroll & Potter, 1984; McCauley, Parmelee, Sperber, & Carr, 1980). The results of the present experiments can thus be explained by assuming that semantic priming makes category information more accessible, thereby increasing the likelihood that words which benefit from priming will be assigned to the subject role and appear early in a constituent frame.

This argument assumes that the reported effects on sentence form resulted from characteristics of the sentence production system's processing of a message or communicative intention, with the messages in the two experiments corresponding to mental representations of pictured events. In other words, the effects are attributed to the information-handling features of a language output system. Another possibility is that the relevant processes can be traced to features of the message or its creation. For example, prominence of the sort mentioned above may have been operative, or the temporal patterning of message formation (encoding) processes may have been translated more or less directly into variations in the order of information in an utterance. Apparent consequences of perceptual processing patterns on constituent order are well known (Clark & Chase, 1974; Flores d'Arcais, 1975; Osgood, 1971): There is a strong preference for describing spatial information from top to bottom and left to right. In the present research, the priming manipulation could have caused subjects to inspect or represent pictures differently when there was a semantic relation between a pictured element and a previous word.

One way to evaluate this suggestion is to examine the likelihood of omitting sentence constituents as a function of semantic priming. If subjects were more likely to focus on or pay attention to particular components of pictures when they were semantically related to the preceding priming word, they should have been more likely to mention those components when they were primed than when they were not. Because a number of the pictures were sometimes described with truncated passive sentences in which there was no mention of the agent (e.g., "The car is being towed"; "The building is being demolished"; "The man is being stung"), it is possible to look at the probability of using a truncated passive (i.e., not mentioning the agent) as a function of whether the agent was semantically primed. There were 78 truncated passives produced in the two experiments combined. Exactly half of these occurred when the agent was primed, and the other half when it was not. Although hardly conclusive, there is no support here for the hypothesis that priming influenced attention to or encoding of the elements of the picture (see also Biederman, Teitelbaum, & Mezzanotte, 1983).

A related point concerns the role of the subjects' awareness of the semantic relations on their picture descriptions. In both experiments a large proportion of the subjects were clearly aware of the semantic relations. However, expressed awareness of them appeared to have little to do with the observed ordering effects in the picture descriptions. There was virtually no difference between the unaware subjects and matched groups of clearly aware subjects in either experiment, and in the second experiment the semantic ordering effects were more consistently observed for those subjects who were less likely to have noticed the relation between the words and pictures. This also casts doubt on the encoding or message prominence explanation of ordering variations: If the influence of semantic priming on the order of constituents in sentences were traceable to message formation or representation processes, one might expect awareness of the relations to have some influence.

The final argument against a message-level interpretation of the results comes from the similarity in the total numbers of basic descriptions produced in the semantic and phonological priming conditions within each experiment. These numbers in essence estimate the frequency with which the same propositions occurred (e.g., *sting [bee, man]*) regardless of syntactic form, after semantic or phonological priming. In Experiment 1, 481 basic descriptions were produced in the semantic priming conditions (62.6% of all the descriptions), and 484 in the phonological priming conditions (63.0% of all descriptions). In Experiment 2, 667 basic descriptions were produced in the semantic priming conditions (57.9% of all utterances), and 651 in the phonological priming conditions (56.5% of all utterances). Thus, within each experiment, roughly equivalent numbers of basic descriptions were produced after phonological and semantic priming.

The most parsimonious explanation of the similarity in these figures within experiments, and the difference between experiments, is in terms of the messages underlying the descriptions: Exactly the same pictures (and the same subjects) were used in the semantic and phonological conditions within experiments, but somewhat different pictures (and different subjects) were used across experiments. If message variations were responsible for the changes in syntactic form, the similarity between the semantic and phonological conditions would be somewhat surprising: There is no obvious reason why the total number of occasions on which two different messages are expressed should be equivalent across two different types of priming conditions, particularly when the proportions of each message vary substantially within those two conditions. A more reasonable explanation is that the messages were the same; what varied was...
the coordination of lexical information with grammatical roles in the production process.

Although the ordering effects resulting from semantic priming were reliable in both experiments, they may seem weak. It is important to keep this in perspective. The major source of constituent order variation in this research was the alteration between active and passive sentence forms. However, English speakers make relatively little use of the passive construction: Given an event with a human agent and patient, there is a massive bias toward the use of the active. Passives were elicited in the present experiments by including actions with nonhuman agents, but there was still not much variability in constituent order: Of the basic descriptions in Experiments 1 and 2, 83% were active sentences with the agent as subject. Restricting the analysis to sentence form thus gives a very conservative estimate of the potential impact of lexical factors on sentence formulation processes in language performance. More sensitive assessments might be achieved by supplementing analyses of sentence form with measurements of onset latencies and durations (cf. Levelt & Maassen, 1981).

The results of both experiments failed to support the hypothesis that phonological activation might contribute to the early positioning effect. Phonological effects of this sort would be compatible with models that assume interactions or feedback relations between syntactic and phonological processes (Bock, 1982; Dell, 1986; Stemberger, 1985); their absence indicates that, if such interactions occur, their impact is relatively weak. However, the failure of phonological priming to produce reliable variations in constituent order may help to reconcile some conflicting results of experiments on the influence of lexical processing on sentence structure, as suggested by Kempen and Huijbers (1983). Levelt and Maassen (1981) found no effects of lexical retrieval on word order in studies in which subjects described displays of moving geometric forms. The forms varied in the ease with which they were named, but this manipulation did not affect word order. Other studies requiring the re-construction of sentences from memory, either as answers to questions or conclusions to stories (Bock & Irwin, 1980; Kelly, Bock, & Keil, 1986; Perfetti & Goldman, 1975), have suggested that words are likely to appear earlier when they are made more accessible by prior occurrence or are naturally more accessible. In Levelt and Maassen’s (1981) work, however, a control experiment ensured that the variations in lexical difficulty were confined to retrieval of the figures’ names. In consequence, their manipulation affected the process of retrieving the phonological form more than the semantic categorization process, so the absence of an ordering effect in their experiments is compatible with the failure to find reliable consequences of phonological priming in the present studies. The positive results of other experiments thus may be attributable to facilitation of the semantic processing of repeated words or to other semantic factors.

The possibility nonetheless remains open that phonological processes affect sentence structure, although in a different way than semantic processes. In both experiments there was a weak tendency for phonologically primed words to occur later in the descriptions than unprimed words. Because there are reasons to predict that hearing or producing a word results in the inhibition of phonologically related words (McClelland & Rumelhart, 1981), and because there are scattered suggestions of articulatory or phonological inhibition resulting from word repetition and phonological similarity in a variety of tasks (Crowder, 1978; Durso & Johnson, 1979; Meyer & Gordon, 1985; Nairne & Healy, 1983; Slowiaczek & Pisoni, 1985; Stemberger, Elman, & Haden, 1985), the late appearance of phonologically primed words was perhaps due to decreased accessibility relative to the unprimed words. However, firmer evidence for effects of this sort is clearly needed.

**Priming and Lexical Selection**

The impact of lexical priming on word order contrasted with its apparent influence on word use. From the perspective of the present work, the most important feature of the lexical selection data was the absence of any systematic variation between the phonological and semantic conditions in the use of the target words. This argues against the simplest explanation of the word order results, that the phonological primes were less effective than the semantic primes. It remains possible that other measures might reveal differences between the two types of primes in their influence on lexical selection, but there was no evidence for such differences in these studies.

One paradoxical effect of priming on lexical selection was found in both experiments. In the subset of utterances in which either or both of the two target words were omitted (the residual descriptions), there was a significant tendency for primed target words to be used less often than unprimed target words. This was equally true for phonological and semantic priming. A possible explanation for this suppression is in terms of a general inhibitory effect: Perhaps the occurrence of the priming word typically inhibited retrieval of the semantic (Blaxton & Neely, 1983; A. Brown, 1981) or the phonological representation of the content word. However, this is at variance with the effect of semantic priming on word order, in which the tendency of the primed target to precede the unprimed target suggests facilitation.

There is an alternative account of the lexical selection effect that eliminates the apparent contradiction with the ordering pattern. It rests on the assumption that the observed inhibition may have been specific to the residual descriptions. The defining feature of those descriptions was omission of or substitution for one or more of the target words. The absence of the target words, which were the modal labels for the depicted objects, suggests that lexical retrieval may have failed or been unusually difficult in this subset of utterances. If unusual effort in retrieving a particular word for an utterance is commonly accompanied by inhibition of any active or competing lexical forms, the primed target words would be more likely to be inhibited than unprimed targets.

A probable result of such inhibition on subsequent production is suggested in a Stroop color-naming experiment reported by Neill (1977). Neill found slower responding on trials in which the color of the printed word was the same as the color named by the previous word. For example, in a sequence in which the word red printed in blue (requiring the response “blue”) was followed by the word yellow printed in red (requiring the response “red”), the latency to say “red” on the second trial was substantially slower than when the trials were unrelated. Neill’s interpretation of this effect was that inhibiting the
word response on the first trial decreased its accessibility on the following trial. In the present experiments, then, inhibition of primed target words might have made them less available for use in the eventual utterance. Unprimed targets, because they were less likely to have been activated, would have been less likely to be inhibited, yielding the observed patterns of lexical selection.

Conclusion

The higher level mechanisms of sentence production have received scant attention in psycholinguistics and cognitive psychology, in part because of the problems of examining these mechanisms in an experimental context. It is difficult to identify and control theoretically significant components of the process, and to restrict what speakers produce to an interesting class of responses without inducing ad hoc strategies. The two experiments reported here attempted to overcome some of these obstacles. Both tested the predictions of a theory developed from observations of speech errors, but within an experimental situation that manipulated the accessibility of linguistic information while minimizing attention to speech. Despite the preliminary nature of the research, the theory was relatively successful and the data relatively regular. It appears that a highly disciplined processing system underlies the creation of spoken sentences.

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