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STAGES OF LEXICAL ACCESS

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1. A SAUSSURIAN INTRODUCTION

One of the most impressive capabilities of the human language user is the ability to access the right word at the right moment. In fluent speech words are produced at a rate of about two or three per second. That means that, on the average, every 400 milliseconds an item (a word, a root) is selected from the speaker's sizable lexicon (which can easily contain 30,000 words, dependent on the speaker's language and education). What is a lexical item? What kind of internal structure does it have? Let us recall Saussure's analysis of the linguistic sign.

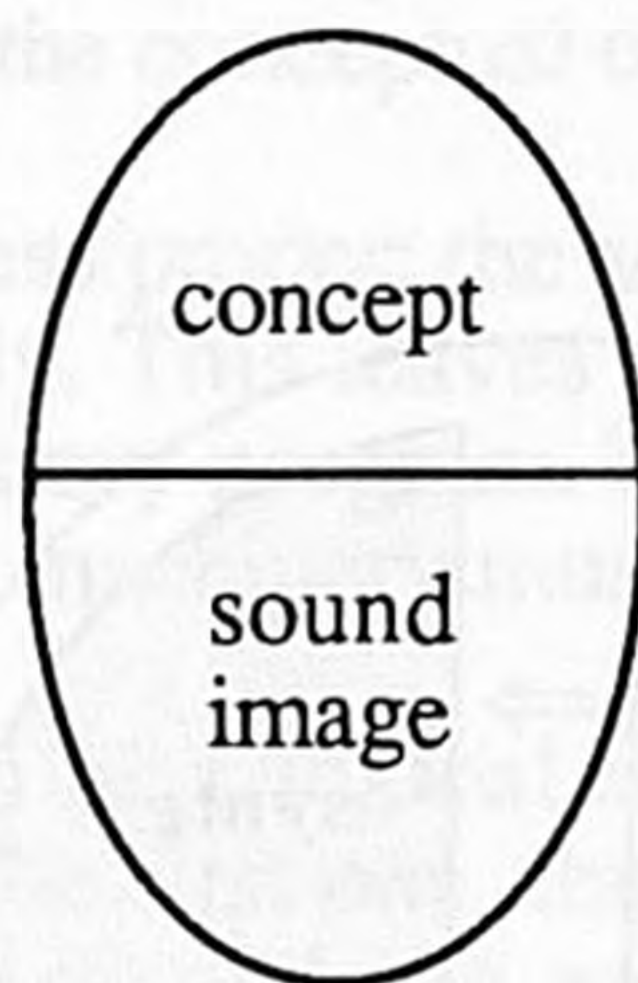


Figure 1. Saussure's egg: the linguistic sign

According to him, it is a two-sided psychological entity, representable as in Figure 1. The two elements, concept and sound image, are intimately linked, he says; each recalls the other. When we consider lexical access in speech, we might rephrase this as follows: A sound image can be recalled through the meeting of its conceptual conditions. This raises some important psycholinguistic questions: What is the nature of the conceptual conditions to be fulfilled, and by what kind of process is the appropriate lexical item singled out from among its many thousands of competitors? That process should meet the real-time requirements mentioned above, as well as others that we will return to in the course of this paper. Though these questions are crucial ones for a theory of the speaker, it should immediately be added that Saussure's picture of the linguistic sign is incomplete. It ignores (at least) a third kind of

information, the item's syntactic properties, or to stay closer to De Saussure, its syntagmatic properties, the ways in which the item can enter into phrasal combinations with other linguistic signs. The obvious expansion of the above picture would be Figure 2.

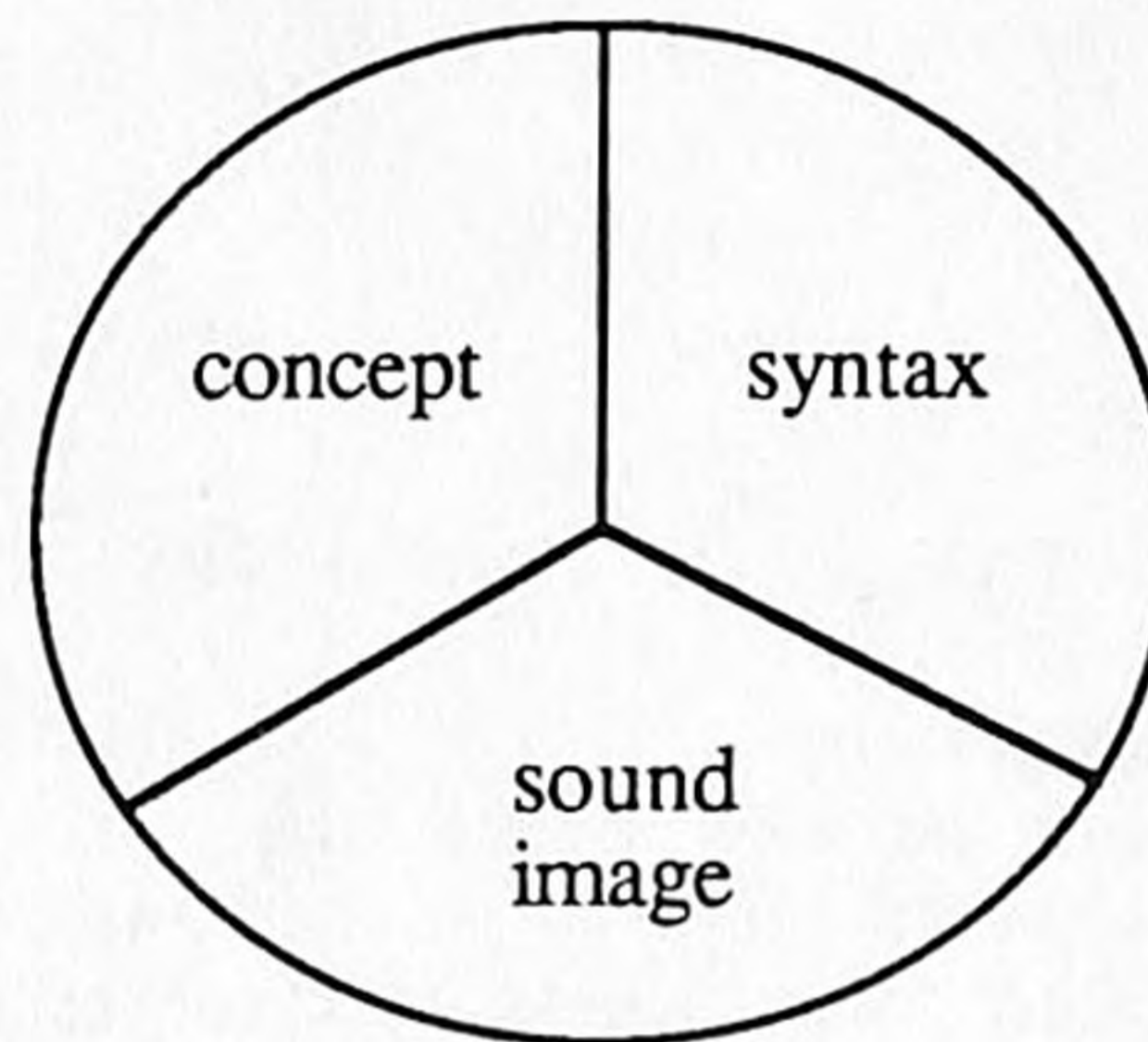


Figure 2. From egg to pie: including the sign's syntagmatic properties

In speaking, certain sound images are retrieved not so much on the basis of conceptual conditions as by prevailing syntactic conditions. The accessing of auxiliaries is conditioned in this way; it is also the case for idiomatic prepositions, certain articles, and items of minor syntactic categories.

An item's syntactic properties always play a crucial role in the sentence generation process. They determine the syntactic environments that must be realized if that item is to be used, and these in turn impose constraints on the syntactic properties of further items to be retrieved. Or to put it differently: where concepts clearly serve as input for lexical access in speech production, yielding sound images as output, syntax plays both input and output roles. These input/output relations can be depicted as in Figure 3.

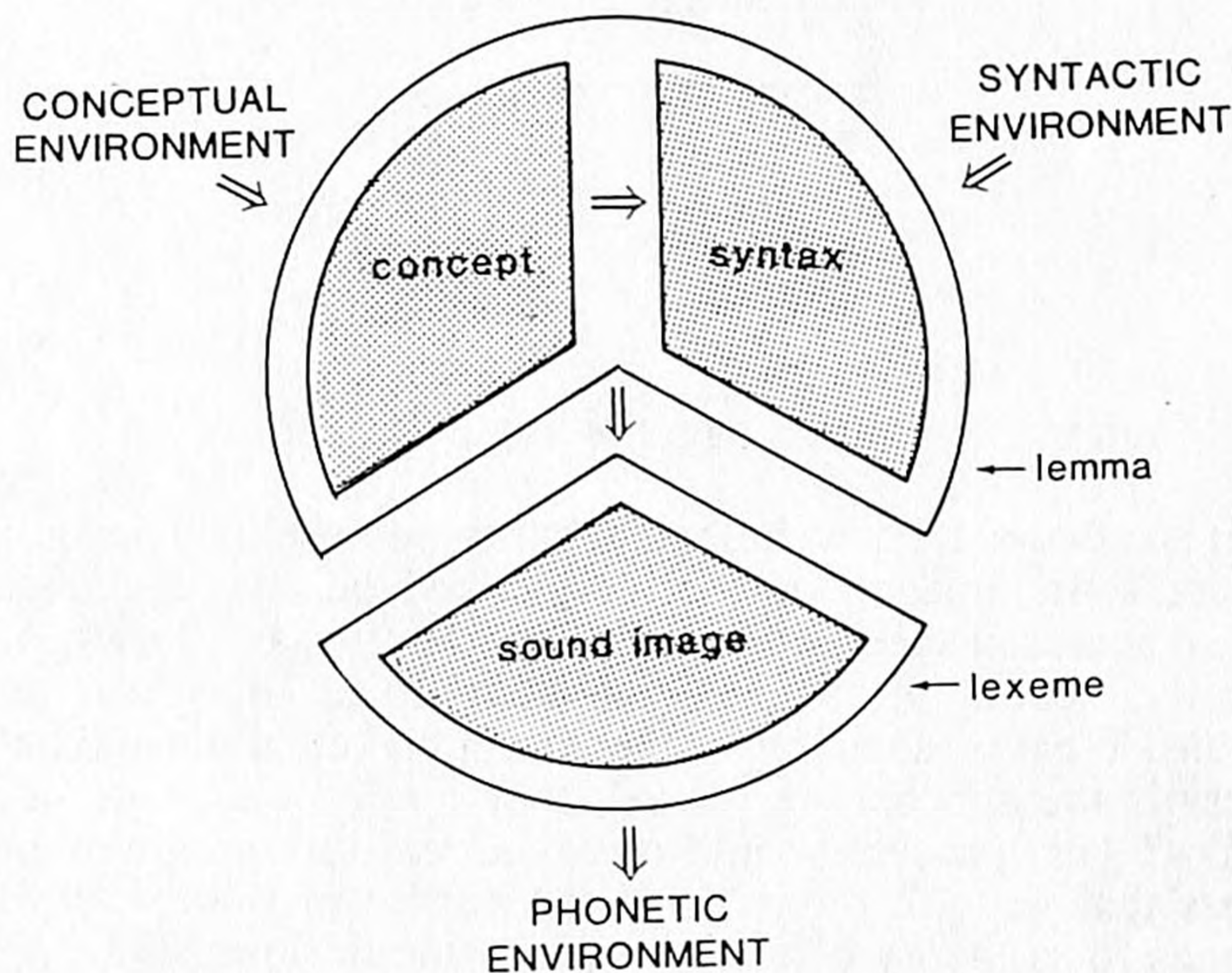


Figure 3. The activation of a linguistic sign in language production

It can be read as follows: The lexical item 'resonates' to the current conceptual environment, the speaker's speech act intention, message, or whatever it is called. When the item's

conceptual conditions are sufficiently present in that environment, its syntactic properties become available for the procedures of sentence generation. The retrieval of other items is directly conditioned by the current syntactic environment. Whatever the cause is for an item's activation, it eventually leads to the recall of its sound image, to use Saussure's terms. In fact, this 'recall' is a highly complex process, involving several steps (see Levelt & Schriefers, forthcoming). Before we leave this Saussurian introduction, it should be noticed that the generation of syntactic surface form may exclusively hinge on the conceptual/syntactic properties of lexical items. There is, indeed, psychological evidence for the assumption that a speaker's construction of surface form is relatively independent of the accessibility of the sound images of the words involved. (That there can be *some* dependence has been argued by Levelt & Maassen, 1981, Dell, 1986 and Bock, forthcoming.) This has led various authors (Garrett, 1980; Kempen & Huijbers, 1983; Levelt & Maassen, 1981; Levelt, 1983) to suppose that lexical access in fluent speech is a two-stage process: In a first stage the conceptual/syntactic properties of a lexical item are activated and used for the generation of syntactic surface form; in a second phase the item's sound form properties are retrieved and made available for the generation of a phonetic plan. Kempen & Huijbers proposed calling the lexical information which is active in the first phase, i.e. the conceptual and syntactic pieces of the Saussurian pie, *lemma*, and the sound form information retrieved in the second phase *lexeme*. These terms have been inserted in Figure 3. It should, however, immediately be added that this two-stage notion of lexical access is an *assumption* in need of empirical verification. It is not entailed by the observation that the generation of syntax is highly independent of the sound form properties of its constituent lexical items.

2. STAGES, MODULES, AND PARALLEL PROCESSING

The potential stages of lemma and lexeme access are necessarily preceded and followed by additional processing stages. A preliminary step to lexical access is, of course, to create the conceptual environment which includes the conceptual conditions for the activation of the lexical item.

This stage is followed by lexical access proper: the activation of lemma and lexeme, either in two successive stages or simultaneously. This leaves us with the 'sound image', the basis for the construction of a phonetic or articulatory program. To execute this articulatory program, i.e. to utter the lexical item, the articulatory machinery must unpack and execute the program. This is the articulatory stage.

These four stages in the generation of a lexical item relate to four processing modules involved in the generation of speech: The first one, the *conceptualizer*, maps a communicative intention onto a preverbal message. The second, the *grammatical encoder*, takes a message as input and produces a surface structure as output. The third module, the *sound form encoder*, maps the surface structure onto a phonetic or articulatory plan. The fourth one, finally, the *articulator*, interprets and executes the phonetic plan for an utterance as an articulatory motor program. This is depicted in Table 1.

Before turning to lexical access proper, we should say a few words about these processing modules. The *conceptualizer* is the rather open set of mental procedures involved in the planning of speech acts, in message encoding. This planning is an intentional non-automatic activity, which relies heavily on the speaker's attentional resources. Message encoding begins with the speaker's conception of some communicative intention, some goal to be achieved by speech. It may, for instance, be the speaker's goal to let the interlocutor know his intention to have her believe that P.¹ The speaker will then find a speech act which will have the intended effect. In the example case, a good choice will be: Declare P (see Appelt, 1985 for a detailed analysis of these issues).

But P can be declared in different ways. If P is that X has a dog, where X is a particular friend of the speaker, he may refer to X by using his name (*Harry*), by mentioning their mutual relation (*my friend*), by anaphoric reference (*he*), or otherwise. These choices depend on the

¹ In the present paper the current speaker and addressee are taken to be male and female, respectively.

discourse situation, the mutual knowledge of the interlocutors, and so forth. Also, the possession relation may take different shades, which will eventually surface as, for instance, *have* or *own* or *possess*. This, again, depends on subtle features of the discourse context, the formality of the interaction, etc. The final result of specifying the speech act in all this precious conceptual detail we call the *preverbal message*; it includes the conceptual conditions for the activation of one or more lexical items.

Table 1. Processing modules in speech generation and their relation to phases of lexical access.

PROCESSOR	INPUT	OUTPUT	RELATION TO LEXICAL ACCESS
1. Conceptualizer	communicative intention	preverbal message	creating a lexical item's conceptual conditions
2. Grammatical encoder	preverbal message	surface structure	retrieval of the lemma, i.e. making the item's syntactic properties available, given appropriate conceptual or syntactic conditions.
3. Sound form encoder	surface structure	phonetic or articulatory plan for the utterance	retrieval of the lexeme, i.e. the item's stored sound form specifications, and its phonological integration in the articulatory plan.
4. Articulator	phonetic plan	overt speech	executing the item's context-dependent articulatory program

This preverbal message is the input to the *grammatical encoder*. Grammatical encoding is lexically driven in that the conceptually activated items specify how conceptual relations are to be mapped onto grammatical relations. The lemmas for verbs, in particular, require the realization of specific grammatical relations for their conceptual arguments (or theta-roles). The syntactic categories of the lemmas trigger the grammatical encoder to build phrases that can be headed by that category: VPs for verbs, NPs for nouns, and so forth. This phrase-building involves the assignment of order over the constituents involved, and the attachment of phrases to higher level nodes. Kempen & Hoenkamp (in press) have proposed an artificial encoding system which involves these features and which has the additional psychological attraction of being able to generate surface structures incrementally from left to right. The grammatical encoder also assigns focus to particular elements in surface structure. This originates in conceptual focussing, but is further shaped by phrase-constructive processes.

The *sound form encoder* takes successive fragments of surface structure, as they become available, as input and produces a phonetic representation which the articulator will have to interpret as a speech motor program. Sound form encoding is, again, lexically driven. The metrical and segmental form specifications stored with each lexical item (i.e. its lexeme) are made available; they impose rhythmic and coarticulatory restrictions on the item's environment. The sound form encoder builds phonological phrases around focussed elements, which are given pitch accent. An element's free sound form parameters, such as metrical stress, syllable length, vowel quality (reduced/ non-reduced), and pitch movement are adapted to conditions prevailing in the phonological phrase. Still, the resulting phonetic representation for an utterance is probably quite context-free as far as the articulatory motor context is concerned; the

representation is probably not different for situations where the speaker has or does not have a pipe in his mouth, has or does not have a cold, etc.

It is precisely the task of the articulatory system to translate the phonetic plan in a sequence of context-sensitive articulatory gestures. The articulatory goals laid down in the phonetic plan can, within limits, be reached in a variety of ways. Groups of muscles form so-called *synergisms* or *coordinative structures* which function as units to reach a certain goal, compensating for prevailing contextual conditions. This involves no effort or attention on the part of the speaker; it is rather the wisdom of the body.

Since, after message encoding, each module operates on the output of the previous one, it is reasonable to ask how the previously mentioned speed of lexical processing, some two or three words per second, can be attained when so many stages have to be chained. Can one run through all these processing steps in less than some 400 milliseconds? The answer is 'no'. Still, a high speed in speaking can be attained by what Kempen & Hoenkamp (in press) call *incremental production*. The modules operate in parallel and deliver their characteristic output in small chunks 'from left to right'. Once a module has delivered an element, it is immediately picked up and processed by the next module, for which it is characteristic input, and so forth. This puts substantial constraints on the modules' processing. If there were a lot of backtracking, such a system could not function; speech would be dysfluent, with frequent restarts and long lapses. Incremental processing is both serial and parallel processing. The parallelness of the modules' functioning is essential for the maintenance of a high speaking rate and fluency. Seriality does imply relatively long 'front-to-end' processing durations. The latter is especially apparent in tasks, such as object naming, which involve single-word responses. These consist almost entirely of lexical processing. From the presentation of a familiar object, such as a table, to the end of the naming response involves, on the average, one and a half seconds. Of this, only about 300 to 400 milliseconds are used to recognize the object, i.e. for visual processing; all of the rest of the time is spent on lexical access and articulation.

We will now turn to a discussion of some recent experimental results which, we believe, support and further qualify the framework just sketched. The first set of experiments was designed, among other things, to localize in this processing framework some peculiar accessing effects which were observed in the use of semantically marked versus unmarked comparatives. The second set addresses the issue, raised above, of whether lemma and sound form (lexeme) information are successively or simultaneously retrieved during lexical access. The final section of this chapter will return to the important theoretical issue of how a lexical item 'recognizes' its conditions of use in the conceptual environment.

3. LOCALIZING ACCESS EFFECTS: THE CASE OF SEMANTIC MARKEDNESS

In a recent series of experiments (Schriefers, 1985) it was discovered that, in making comparative judgments, speakers take more time to generate a semantically marked adjective than a semantically unmarked one. The effect arises, for instance, in an experimental task where the subject is presented with a pair of objects which differ only in size (cf. Figure 4).

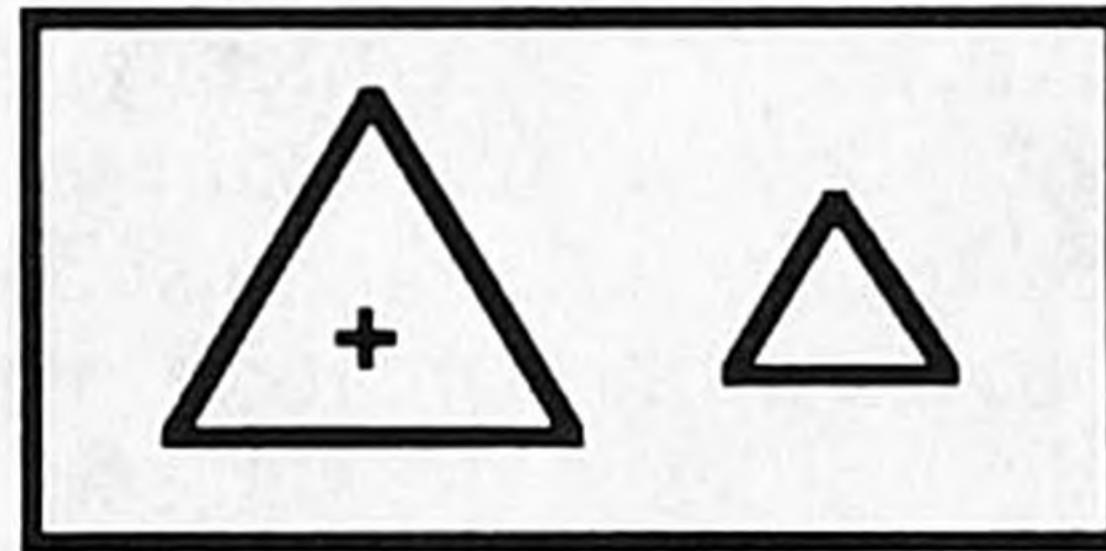


Figure 4. Example of stimuli used in a relation-naming experiment

After 1.5 seconds a cross appears near one of the two objects, and the subject is to say whether that object is the bigger or the smaller one of the two. We measured the time from the appearance of the cross to the speaker's speech onset. It took about 40 milliseconds longer to initiate the response 'smaller' than the response 'bigger'. The same markedness effect was

found for situations where the judgment was 'longer' versus 'shorter'. These effects were statistically highly significant.

Which accessing stage is responsible for this difference? A first possibility is that the effect is due to conceptual decisions, i.e. decisions made in the message-encoding stage. One might well argue that it is easier to judge that an object is bigger or longer than to judge that it is smaller or shorter; people may have judgmental biases of this sort. If this is so, the markedness effect should also arise in a nonverbal judgment task, i.e. in a task where the subject does not give a verbal response but rather pushes one button when the indicated object is bigger and another button when the object is smaller. This experiment was done, and the results were unequivocal: The markedness effect disappeared completely. This shows that the effect is not due to conceptual decision making. The effect can only be obtained if the response is verbal. In other words, the effect must reside in either the lexical-access phases or in the final articulatory phase.

Is the effect articulatory? Is it harder to initiate the speech motor program for a semantically marked item than for an unmarked one? To test this possibility, an experiment was done where the speaker was presented with the printed words *bigger* or *smaller* (or with the words *longer* or *shorter*). In half of the trials the word was, after 1 second, followed by a cross. This was the signal for the subject to pronounce the word. Again, speech onset latencies were measured. In this task, the subject could prepare the verbal response and release it as soon as the cross appeared. Would response initiation take more time for *smaller* and *shorter* than for *bigger* and *longer*? It did not. There was no statistical difference between speech onset latencies for marked and unmarked items. That means that the markedness effect cannot be located in the final articulatory stage.

By exclusion, the markedness effect must be due to lexical access proper, the retrieval of the lexical item from the mental lexicon. We do not know what is so hard to retrieve for a marked element, the lemma information or the lexeme information or both. Is it the case that a semantically marked lexical item requires more time for the recognition of the satisfaction of its conceptual conditions than does a semantically unmarked item? Or is the effect rather due to sound form access? The more general issue is whether these are indeed distinguishable successive phases. We will return to this in the next section.

The present series of experiments also showed the existence of a so-called *congruency effect*. The effect is the following: When the two figures to be compared in the comparative judgment task were both relatively large (or relatively long), this facilitated the *bigger (longer)* response, and interfered with the *smaller (shorter)* response. If, however, both figures were relatively small (or short), the *smaller (shorter)* response was facilitated at the expense of the *bigger (longer)* response. In other words, naming a relation which was congruent with the absolute size of the two figures in the picture involved shorter speech onset latencies (by about 70 milliseconds) than did incongruent reactions. Congruency and markedness effects were, moreover, fully additive.

This congruency effect could also be located with respect to processing stage. In order to test whether it is preverbal in nature, i.e. originates in the conceptual decision making which precedes lexical access, the experiment was repeated with nonverbal responses; the subject had to push a 'longer' or a 'shorter' button to express the comparative judgment. The results of this nonverbal task were, again, unequivocal: The congruency effect reappeared in undiminished fashion. What disappeared was the additive markedness component, and this was to be expected given the above-mentioned results with the pushbutton task. Unlike the markedness effect, the congruency effect also arises in the situation with the nonverbal response mode, which shows that it must be due to difficulties in the subjects' comparative decision making. In other words, it arises during the conceptualization stage.

What are the difficulties? Apparently, the subject in this task not only generates a *comparative* judgment, involving the concept *BIGGER* or *SMALLER*, but he cannot fully suppress the generation of another judgment, an *absolute* judgment, as well: It is a pair of *BIG* figures, or a pair of *SMALL* figures. It is easier to generate the *BIGGER* judgment in the presence of the concept *BIG* than it is in the presence of the concept *SMALL*, and inversely for the *SMALLER* judgment. This interference is very much like the one obtained in so-called 'Stroop tasks', such as reading the word *green* when it is printed in red letters. The source of

interference is also apparent from the occasional speech errors subjects make: The inappropriate response (i.e. *smaller* for *bigger* or inversely) is made almost exclusively when the comparative size relation is incongruent with absolute size. Many real-life speech errors, in particular the Freudian ones, are no doubt due to a similar competition between concepts.

4. ARE LEMMA AND SOUND FORM ACCESS TWO SUCCESSIVE STAGES?

Though there is independent empirical evidence (especially from the analysis of speech errors) for the assumption that the grammatical encoding module and the sound form encoding module function in relative independence and are serially ordered, this does not imply that lexical access also proceeds in two phases, one for lemma retrieval and one for lexeme or sound form retrieval. An alternative view could be that an item's lemma and sound form information are always simultaneously retrieved when the conceptual and/or syntactic conditions are fulfilled; the two kinds of information are only *employed* by different modules, and therefore in different stages of the speech generating process.

We have tried to test these alternative views in a series of experiments. These studies will be reported elsewhere, but the basic idea is this: If the lemma and sound form are retrieved in subsequent phases, one should be able to find a moment in time during lexical access at which there is measurable semantic activation but no phonological activation. In addition, a strong version of this view would imply that there is a later phase where there is only phonological activation, but no semantic activation. In the experiments, the subjects performed an object naming task. They saw a series of slides, each depicting an object, and were asked to name each object. When they saw a table, they had to say *table*; we will call this the 'target word'. In one-third of the cases the subjects also performed a secondary task. Shortly after presentation of the slide, but before the naming response, the subject heard an acoustic stimulus. This was either a word or a nonword. The subject's task was, apart from naming the displayed object as always, to push a 'yes' button when the stimulus was a word, and a 'no' button when it was a nonword. The subject was instructed to give priority to the lexical decision response over the naming response. A little training was enough for most subjects to learn to do this. Only the 'yes' responses were relevant for the experimental purposes; the corresponding stimulus word we will call the *test word*.

The test word could stand in various relations to the target word. It could, first, be semantically related to it; for example, when the target word was *table*, the test word would be *chair*. It could also be phonologically related to the target word, as would be the case with *tailor* as the test word. As a control, there were also unrelated test words; *chicken* would be such a case. Finally, the identical word (i.e. *table* when the target word was *table*) could appear as test word. If there are two successive phases in accessing the target word, a semantic and a phonological one, one would expect to find an early moment in time, i.e. very soon after presentation of the slide, where lexical decision times for the semantically related test word would be affected, but where there would be no effect for the phonologically related test word. Also, it would be pleasant to find a late moment, i.e. just before the naming response, where the response to the phonologically related test word would show an effect, but the response to the semantically related one would not.

We did obtain the latter result: There is clearly a moment in time in the preparation of a naming response where the item's sound form representation is in an active state but where its semantic representation is inactive. However, we were not able to obtain the inverse effect. When we presented our test words right after the slide (70 milliseconds after the onset of the slide, on the average), we did find the expected effect of semantic activation, but there was always also evidence for phonological activation: The lexical decision times for both the semantically and phonologically related test word were significantly delayed in this early phase of lexical access.

The tentative conclusion from these experiments is that lemma and lexeme information are *simultaneously* accessed, i.e. not in two successive phases. An item's conceptual information, however, may be subject to faster decay than its sound form information. The longer

availability of the sound form information is functional, given its role in the later processing stages.

5. HOW DOES A LEXICAL ITEM CHECK THE SATISFACTION OF ITS CONCEPTUAL CONDITIONS?

Psycholinguists have devoted surprisingly little attention to a fundamental problem of lexical access in production, namely, how the lexical item is retrieved, or becomes activated, when its conceptual conditions are satisfied. In Artificial Intelligence, Goldman (1975) was the first to propose a solution to this problem in the framework of a Schankian Conceptual Dependency system. Goldman introduced discrimination nets to mediate between a conceptualization (message) and a lexical response. In essence, his discrimination nets are binary tree structures. Each nonterminal node in the tree represents some predicate which is either true or false for the conceptualization at hand. Terminal nodes correspond to lexical items. The access procedure starts by running the test for the tree's root predicate. If it yields the value *true* for the conceptualization at hand, control moves to the node's right-hand daughter; if it is *false*, it goes to the left-hand daughter node. The next test concerns the daughter node's predicate. The procedure is self-terminating; it iterates until a terminal node is reached. The lexical item at that terminal node is the system's lexical response to the concept. With these means, which were enriched and qualified in several ways, Goldman could build a working model for generating paraphrases in a limited conceptual domain. No claims were made with respect to linguistic or psychological adequacy of the model.

But using the discrimination net approach as a psycholinguistic model probably leads to insurmountable problems. In order to find a lexical item in, say, a 30,000 word lexicon, between 15 and 15001 binary tests are necessary to reach a lexical item, on the average. The serial arrangement of these tests leads to unrealistic real-time properties. This argument is strengthened by another unrealistic consequence. Conceptually more complex items will take longer to retrieve than less complex ones, because they involve a larger number of successive tests. There is, however, no evidence that access to semantically more complex words systematically takes longer than access to less complex ones. Though the above results on semantic markedness seem to be in support of such a view, there is as much evidence for the opposite position: Levelt, Schreuder & Hoenkamp (1978) and Schreuder (1978) found that more complex verbs take systematically less time to access than less complex ones do. They related this finding to the greater *specificity* of the complex verbs. We will return to this notion shortly.

An additional problem with discrimination nets is that there are large parts of the lexicon which do not seem to be hierarchically organized; there are cross-classifications, circular arrangements, and so forth (cf. Miller & Johnson-Laird, 1976). Finally, hypernymy creates serious problems. When the conditions for *dog* are met, those for *animal* are also met, because the *dog* predicates imply the *animal* predicates. But then, how can a discrimination net have a terminal node for *dog* when it has one for *animal*? When the concept is that of a dog, testing will necessarily be terminated at *animal*; its hyponyms cannot be represented on the same tree. This would predict that we speak in hypernyms only, or alternatively that there are no hypernym relations in a lexicon.

Alternative accessing mechanisms have been proposed by Miller & Johnson-Laird (1976). They arranged conceptual components (predicates, semantic tests) and lexical items in so-called *decision tables*. Allowing for parallel execution of all tests, high-speed access can be achieved: The (first) lexical item whose characteristic column pattern of *true*, *false*, and *not applicable* evaluations is matched will be the one accessed. Elsewhere (Levelt & Schriefers, forthcoming) we have discussed some of the problems with this approach. One major obstacle resides again in the case of hypernymy. If an item's column is matched by the test outcomes, the columns for all of its hypernyms will also be matched. Matching the hypernym will, moreover, never be slower than matching the target item, but potentially faster. (The slowest test sets the pace in a parallel system.) Hence, though hyponyms are representable in this model, hypernym reactions will be preferred.

Though we are not able to present an alternative model at this point, we wish to sketch one step towards solving the hypernym problem. For each (open class) lexical item, we propose that it contains a *unique* conceptual condition. We have termed this the item's *core sense*. There are reasonably reliable empirical procedures for determining this semantic core. One is Miller's (1969) negation test (for various applications see Noordman, 1979; Levelt, Schreuder & Hoenkamp, 1978; Schreuder, 1978). Negating the item affects its core sense only. When asked to complete the sentence 'They do not walk, but they...', most subjects react with 'run'. This leaves the sense of locomotion, which is shared between *walk* and *run*, unaffected. But the specific manner of locomotion which is uniquely characteristic of walking is given up. Given this notion of core sense, one may conjecture that the following access principle holds:

A lexical item is retrieved if and only if its core conditions are fulfilled by the concept to be expressed.

Since these core conditions are unique to the lexical item, their satisfaction in the concept to be expressed guarantees the item's retrieval. This is a first step towards solving the problems with hypernyms discussed above. But what about the hypernym's core conditions? Let us compare *eat* and *devour*, where the former is a hypernym of the latter. According to the accessing principle, a speaker will retrieve *devour* if its core condition, something like the voracious manner of eating, is satisfied. But, since devouring implies eating, isn't the core condition for *eat* always simultaneously satisfied when the conceptual conditions for *devour* are satisfied? If so, *eat* should also be retrieved. There is a way out of this dilemma. It is to invoke an additional principle of specificity. Accessing would then be governed by the following dual principle:

- (a) *A lexical item is retrieved only if its core conditions are fulfilled by the concept to be expressed.*
- (b) *Of all items whose core conditions are satisfied by the concept, the most specific one is retrieved.*

The addition of the latter principle prevents *eat* from becoming activated when the core condition for *devour* is satisfied. It is reminiscent of Grice's maxim of quantity. It is not immediately obvious what kind of processing mechanism would realize this specificity principle, but this does not appear to be an insoluble problem.

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