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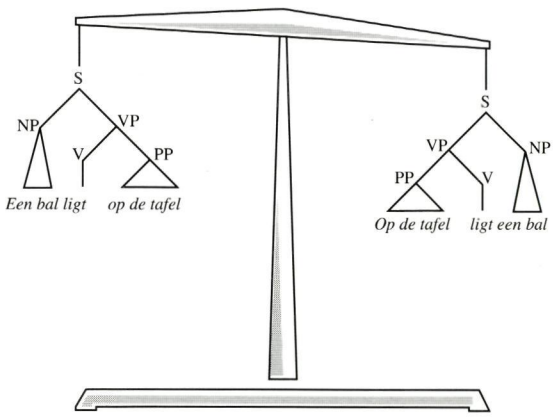
Sentence Production in Normals and Broca's Aphasics:

Stages and Resources



Robert J. Hartsuiker

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Sentence Production in Normals and Broca's Aphasics: Stages and Resources

Een wetenschappelijke proeve
op het gebied van de Sociale Wetenschappen

Proefschrift

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Robert Jan Hartsuiker

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Aan Wim en Willy
(de leukste oom en tante van het Westelijk Halfrond)

Voor Jacqueline

Introduction

Where do sentences come from?[1] That depends If you are listening to someone, the sentences are built from the words she[2] says If you are speaking, sentences are built from your thoughts However simple building sentences from words or thoughts may seem in everyday conversation, they are no easy tasks Consider what you have to do to understand what people say to you First you have to identify the words, which in itself is an impressive accomplishment given the variable nature of speech sounds, environmental noise that may mask part of the speech signal, and the sheer size of the mental lexicon However, even if you correctly identify the words, this is no guarantee you will understand the sentence Sentences are not simple sequences of words Sentences have structure Consider sentence (1)

(1) The boy that is chased by the girl laughed

If you tried to understand this sentence by relying on word meaning only, you would surely get the wrong interpretation First, the sentence contains the sequence (boy-chase-girl) Second, it contains the sequence (the girl laughed) If you disregarded sentence structure, you would think that in fact the boy chased the girl, and that the girl laughed Unfortunately, the speaker intended something different The girl chased the boy, and the boy laughed In order to arrive at the correct interpretation, the structure of the word sequence needs to be analyzed In the literature, this process is known as *parsing,* and the result of parsing can be represented as a syntactic tree An example of a syntactic tree is provided in Figure 1, below

Inspection of Figure 1 may help to appreciate that parsing is by no means a trivial task However, even if you succeed in creating the correct structure, understanding is by no means complete In order to arrive at the sentential meaning, one needs to execute a further process Mapping the structure of the sentence onto the domain of meaning This may be easy for a sentence such as 'John hit Mary' The subject, John, is the one doing the hitting The direct object, Mary, is the one hit However, consider sentence (2)

(2) The experimental results surprise Kay

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[1] Cf Osgood (1971)

[2] Using the feminine pronoun 'she to refer to someone that can both be a 'he or a 'she' at such a prominent place in this dissertation, the third sentence of the introduction, should suffice in showing my political correctness Throughout this dissertation, pronominal reference to an unknown person should be considered as grammatically, but not conceptually marked for gender

Are in this case, 'the experimental results' doing anything? Clearly, they are not. They are just sitting there. 'Kay' is doing something, reading and interpreting the experimental results, and because of their content, she is experiencing a state of surprise. In order to understand what is going on, one needs to map the grammatical information obtained from parsing, on the domain of 'thematic roles', the domain of meaning.

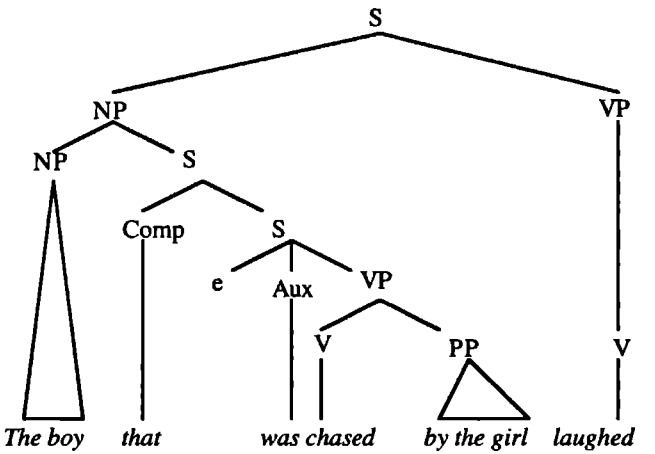

FIGURE 1. Syntactic tree of 'the boy that was chased by the girl laughed'. We do not claim that the present representation strictly adheres to modern linguistic insights.We merely include this tree in order to illustrate the complicated structure of such a seemingly simple sentence.

The speaker, with whom I will concern myself in this dissertation, has the reverse task: His job begins with the domain of meaning. In order to transform his thoughts into speech, he needs to execute a number of difficult steps. First, he has to decide upon what he wants to say. In order to do so, he needs to package his thoughts and intentions into a unit that can be expressed in an utterance. Levelt (1989) called this step 'conceptualizing'. As a result of conceptualizing, one has a conceptual representation (sometimes called a *message*), containing information about the event or state, and the participants in that event or state, which will be communicated to the listener. A second step is the decision how to say it. In order to express the conceptual representation, the speaker has to decide which words to use (a certain concept may be expressed in a number of ways). Furthermore, he has to decide what kind of sentence structure can best express how the participants take their roles (a certain event may be expressed with a variety of sentence types). These processes can not proceed independently: Different words require different kinds of sentence structures and different sentence structure require different words. The job of the speaker (in contrast to the comprehender), is to get every detail of form right: He needs to construct a sentence that adheres to the constraints of the grammar of his language. All the work done during the second step of

speaking, is called grammatical encoding. Like parsing, grammatical encoding is no trivial business, as can perhaps best be illustrated by some examples:

(3) The boy received a parcel from the girl
(4) The girl gave the boy a parcel

It can be argued that sentences (3) and (4) express the same conceptual content. There is a girl, there is a boy, there is a parcel, and there is an action, such that the parcel is no longer in the possession of the girl, but is in the possession of the boy However, sentences (3) and (4) differ with respect to a number of grammatical features First, in (3) 'the boy' is the subject. In (4) the subject is 'the girl'. Different verbs require different participants to become subject In addition, the syntactic structure of these sentences differs· A verb like 'give' allows the two objects to directly follow each other A verb like 'receive', on the other hand, requires the direct object to follow the verb, and requires the other object to be incorporated within a prepositional phrase Getting these details right, is the job of grammatical encoding.

Even if the sentence structure conforms to the rules of grammar, this is no guarantee that the resulting utterance is grammatical. Sentences (5-7)[3] illustrate this

(5) *The time for fun and games are over (From Bock & Miller, 1991)
(6) *Max$_1$ believes that himself$_1$ is the candidate[4] (From Sells, 1985)
(7) *Max$_1$ believes him$_1$ to be the candidate (From Sells, 1985)

In order for English (and Dutch, for that matter) sentences to be grammatical, the subject and the verb need to have the same number Furthermore, the distribution of pronouns is constrained by their syntactic environment Getting agreement and pronominal form right is another aspect of grammatical encoding, and not an easy one.

There is another way in which the question we started out with, 'Where do sentences come from?' may be answered. The answer is the same one that Levelt (1995) supplied to the analogous question 'where do spoken words come from?' The answer is· 'Obviously, from the brain' When certain parts of the brain are damaged, for instance as a result of a CerebroVascular Accident (CVA), the sentences one produces are often distorted Consider patients with brain damage to the anterior cortical areas of the dominant hemisphere Often this brain damage leads to a condition known as Broca's aphasia These patients have severe problems in the production of sentences Their speech is often slow, effortful, filled with pauses and restarts. They often omit so-called

[3]Throughout this disseration, an asterisk (*) will denote an ungrammatical sentence
[4] The subscript 1, denotes that Max' and 'himself' refer to the same person

'closed class' items, such as inflections of number and gender, and the 'little words' not carrying meaning, but important for the structure of the sentence (prepositions, determiners, auxiliaries, etc.). Their speech has often been described as *telegraphic*: Omitting everything redundant (e.g. one patient I tested said: 'Voorzetsels vreselijk' (Prepositions terrible) instead of something like 'Voorzetsels vind ik vreselijk' (I find prepositions terrible). Furthermore, there is a reduced variety of syntactic form: They tend to produce simple sentence structures, and not structures with a number of embeddings, with non-canonical word order, or with two modifiers in a row. In terms of the tree-metaphor, their sentence structures can be depicted as trees with little depth and breadth. Additionally, Broca's aphasics' language deficit in production is paralleled by a deficit in comprehension: When understanding requires a complete parsing of the sentence, for instance when the event roles can not be inferred from the meaning of the words, comprehension is impaired. This dissertation is concerned with sentence *production*, but we will briefly address the parallel with comprehension in the General Discussion.

In sum, when speaking, sentences 'come' from thoughts, or, more specifically, from processes that find the words that express these thoughts, and align them according to grammatical constraints. These mental processes can be disturbed by damage to the brain: Broca's aphasics (sometimes called 'agrammatics') have great difficulty in constructing sentences, and often do not succeed.

This dissertation concerns the process of sentence production in normals and Broca's aphasics. The experiments that I report are restricted to one aspect of sentence production, called grammatical encoding: Building a hierarchical structure containing words and inflections from a conceptual representation. What stages of processing are involved in grammatical encoding and how do they interact? What can account for the distorted character of Broca's aphasics' utterances? We will present five studies that have the purpose to provide some answers to these questions. The experimental results have repercussions for theories of grammatical encoding in general, as well as for the hypothesized deficit underlying aphasic language production. In particular, we will show the importance of *sentence structure* for the speaker, normal or agrammatic. In one study, we present a series of experiments that show the possibility to facilitate availability of certain sentence structures, thus yielding credibility to the psychological reality of such structures. In another study, we critically evaluate the hypothesized stage of processing responsible for these facilitation effects. That experiment allowed us to conclude that building up sentence structure is basically a two-part process. First a structure is created that does not contain order. The branches of the trees can be moved around, so to speak. Then, there is a stage that imposes linear order on the structure. Another study concerned the question to what extent the stage of grammatical encoding

has access to information from another stage, the stage of conceptualizing. I present evidence that speakers, when constructing verb inflections, access conceptual information.

I also report experiments with agrammatic speakers. The most important underlying assumption to these studies is that the processing system (processing stages, knowledge of the language) that carries out grammatical encoding is still intact. The impairment is viewed as a disruption of processing. In my experiments, I pursued the theory that the reason for the disruption is a pathological shortage of 'computational resources'. I present evidence for that claim in one experiment. In another study, I attempt to further specify this concept of resources: Is it the case that every processing stage has its own processing resources, or are there more general resources, available to a number of stages? The results of that study support the latter claim.

In the remainder of this introduction, I will first discuss the stages and processes assumed to be involved in sentence production. Then I turn to the question of agrammatism. Some theories of agrammatic sentence production (and understanding) will be briefly presented. I then propose the theory of a resource limitation, and show what predictions follow from it. Following a brief motivation for the assumptions that are tacitly made throughout this dissertation, I will provide an outline of the rest of this dissertation.

Stages and Processes in Sentence Production

There are three broad questions that one can ask about how we produce sentences. What stages of processing are there? How does processing at these stages proceed? What are the units on which processes at each stage operates? Different theories provide different answers to these questions, and may base these answers on different sets of data. Providing an extensive introduction to the various theories around would be far beyond the scope of this dissertation. Instead, we will simply describe the stages of processing as distinguished by Garrett (1975, 1980) and Bock & Levelt (1994) and briefly discuss some alternative proposals.

One particular informative source of data comes from speech errors, observed in every day speech. The reason that students of sentence production have focused on this type of data so often, is that the input to sentence production, the realm of thought, is unavailable for inspection by an experimenter. The output however, the things people say, can easily be observed. Especially the work of Garrett (e.g. 1975, 1980; 1990) is largely based on analysis of error corpora. For instance, Garrett (1990) mentions that at least three stages must intervene between a message (conceptual representation) and articulatory programming. He bases this on two characteristics of speech errors, first the

phenomenon of accommodation, and secondly the distribution of various types of exchange errors. Consider accommodation first. Errors like (8), taken from Garrett (1990) suggest that some morpho-phonological processes must apply after a stage at which segments are positioned.

(8) 'an angwage lacquisition device' (a language acquisition device; 'an' accommodates to new environment)

In Garrett's terminology, this is evidence for a distinction between the positional level, that specifies abstract phonological structure, and a phonetic level, that fixes details of phonetic form. Now consider word exchanges, such as (9), also from Garrett (1990).

(9) 'We'll sit around the song and sing fires' (We'll sit around the fire and sing songs)

In this case, the words 'song' and 'fire' have exchanged place. Importantly, the distribution of word exchanges such as (9) and sound exchanges, such as (8) is different. Word exchanges take place between phrases, and often span a number of intervening words, whereas sound exchanges take place within phrases, and usually do not span any intervening words. Further, exchanged words usually belong to the same grammatical category, whereas the segments involved in sound exchanges are usually phonologically related. On the assumption that elements need to be simultaneously active in order to interact, as in an exchange, there must be a level of processing in which words, although belonging to different phrases, are co-active. This led Garrett to postulate another level, which he called functional level: A stage at which syntactic relations between words are computed.

The same stages Garrett thus distinguished on the basis of speech error analyses can be found in the model Bock & Levelt (1994) presented. The speaker begins with the message, or conceptual representation, following that grammatical encoding, and finally phonological encoding (spelling out sound and prosody) take place. Grammatical encoding is subdivided into functional and positional level processing. At the functional level, two interacting processes take place: Lexical items called lemma's (cf. Kempen & Huijbers, 1983) are selected. Lemma's are abstract specifications of words, containing inter alia syntactic information. Furthermore, grammatical functions are assigned to lemma's. The resulting functional level representation is input to the positional level. Here, a constituent structure is created, based on function assignments and syntactic characteristics of lemma's. Furthermore, inflection is determined at this stage.

Bock & Levelt assume a modular system: Each component is informationally encapsulated from other components. In addition, information flow is assumed to be

feedforward. Processes at lower levels do not influence higher level processing. Furthermore, processing is considered to be incremental. In order for speech to proceed fluently, representations constructed at one level do not have to wait until all processing at the level has terminated: As soon as part of the processing is done, lower level processes commence work on that piece of input. Final characteristics of this model that deserve mentioning are that sentence formulation is lexically driven, that is, the lemma's and the syntactic information incorporated therein highly determine the process; and that grammatical function assignment is thought to be direct: In transforming thought into sound, there is no intermediate representation analogous to D-structure in Government & Binding theory (Haegeman, 1994). The grammatical functions assigned to lemma's are not altered by any kind of movement.

It should be noted that most theories of sentence production propose a division in stages similar to Bock & Levelt, and Garrett (e.g. De Smedt, 1990; Kempen & Hoenkamp, 1987; Levelt, 1989) although important details may differ. Alternative, connectionist, conceptions have been proposed by Stemberger (1985) and Ward (1992). For instance, Stemberger (1985) distinguishes a syntactic level of processing. No distinction, however, is made between a functional and a positional level. Furthermore, different levels such as syntax and meaning are presumed to continuously interact. Ward (1992) even goes a step further, and discards the level of syntactic tree construction altogether: In his model, constituent structure comes about as the result of mutual lexical, syntactic, and other constraints that determine what word follows another word. The model thus basically generates sentences from left to right.

In this dissertation, I will take as my starting point the stages of processing distinguished by Bock & Levelt (1994) and the most important assumptions guiding processing in that model. There are several independent motivations for that. The first motivation is based on Occam's razor: As long as there is no solid evidence for continuous interactions between processing stages, it is theoretically more elegant to postulate a modular (Fodor, 1983) architecture. This implies that processing within each module can not be influenced by processing in another module, and that 'lower' modules do not send feedback to 'higher' modules. In addition, little evidence has been obtained for feedback (however, Levelt, 1989, p.9, postulates one such feedback loop; see also Viglicco, Butterworth, & Semenza, 1995). Secondly, in addition to speech error evidence (e.g. Garrett, 1980), there is empirical evidence that sentence planning does not proceed from left to right (e.g. Bock & Cutting, 1992; Bock & Miller, 1991; Vigliocco & Nicol, submitted). This argues against a model such as Ward's. Thirdly, there is empirical evidence for the role of constituent structure during speaking, lending credibility to the existence of a separate processing stage for syntax (Bock, 1986; 1989; Bock & Loebell, 1990; Bock, Loebell, & Morey, 1992; Branigan, Pickering, Leversedge, Stewart, & Urbach, 1995). Furthermore, there is both evidence from speech

errors (e.g. cited in: Bock & Levelt, 1994; Vigliocco & Nicol, submitted) and from empirical investigation (Bock, Loebell, & Morey, 1992) that supports the distinction between functional and positional levels of processing.

In sum, the four considerations mentioned here lead us to prefer modular, feedforward theories such as Bock & Levelt's (1994) proposal.

Agrammatic sentence production

Having discussed theories of normal grammatical encoding, we now turn to theories of agrammatism. What can account for the pattern of symptoms observed in Broca's aphasia? At this point, it is interesting to make a slight digression to the impact of aging on cognitive performance of adults. In 1988, Salthouse reviewed the evidence for decreased performance with age on a variety of cognitive tasks. He then, based on a bulk of literature on cognitive aging, discussed a number of *types* of explanation for such deteriorations. First, it could be the case that with age, the structure of the cognitive system alters. Second, there could be disruptions in processing. These disruptions, could be (1) decreased efficiency of processing components, (2) failure to apply appropriate strategies, (3) a reduction in computational resources. With respect to the latter explanation, which he argues should be preferred, he mentions that conceptions of computational resources fall into three categories, organized around the metaphors of space, time, and energy. Interestingly, all of these types of explanation have also been put forward to explain agrammatic deficits.

Early[5] debate centered on the question whether the impairment should be construed as a 'loss of knowledge' or as a 'disruption of processing'. A loss of knowledge hypothesis (e.g. Berndt & Caramazza, 1980) entails that as a consequence of brain damage, representation of linguistic knowledge is permanently erased from the patient's cognitive system. For instance, patients would not be able to produce sentences in the passive voice, because the linguistic knowledge to transform a deep structure into a passive surface structure, would not be present any more. An important consequence of this proposal is that it predicts all-or-none performance. If the rule for making a passive is somehow deleted, the patient should never be able to produce a passive.

Most modern theorists have abandoned this 'loss-hypothesis', because it is hard to reconcile with actual behavior of patients. This behavior can be characterized as being enormously *variable* (Kolk & Van Grunsven, 1985). Not only do different patients vary with respect to performance on linguistic tasks, there is also variation within patients on different tasks, and there is moment-to-moment variation within patients on the *same*

[5]'Early' referring here to research conducted in the 1970's and early 1980's. It should be noted that much earlier theories (e.g. Isserlin, 1922) that can be classified as 'disruption of processing' accounts, have resurfaced in more elaborate form in recent research (Kolk & Van Grunsven, 1985).

task. That kind of variation seems to refute any claims that would entail a complete loss of knowledge.

Furthermore, as mentioned above, a 'loss-hypothesis' should predict all-or-none performance. For instance, in a sentence/picture matching task requiring the comprehension of a 'reversible' passive, a passive that cannot be understood by pragmatic/semantic constraints, e.g. (10), one would expect the patient to never construct the appropriate sentence structure.

(10) The lion is being chased by the tiger

If the patient has to identify the picture corresponding to the sentence, and if there are three distractor pictures, one expects the patient to correctly identify the picture in 25% of the cases: Chance-level performance[6]. In contrast to this, there are experimental results, cited in Kolk & Van Grunsven (1985) that show performance is actually above chance, although far from perfect.

The alternative to a 'loss-hypothesis' is that processing is disrupted. Whereas the grammatical information, for instance the rule to produce a passive, is still present, the patient often encounters difficulties in executing such a rule. But what would hinder execution of rules? Similar to work in cognitive aging, proposals have been made that aphasic impairments can be characterized as follows: (1) Specific processes proceed less efficient (Martin, 1995; Martin & Romani, 1994), (2) Inappropriate strategies are selected (Caplan, 1983; Kolk & Van Grunsven, 1985), (3) There is a limitation of computational resources (e.g. Caplan & Hildebrandt, 1988; Kolk & Van Grunsven, 1985; Lapointe, 1985). Furthermore, turning to the notion of 'computational resources', all three of Salthouse's metaphors of computational resources were somehow postulated to account for (part) of agrammatic behavior: Space (Caplan & Hildebrandt, 1988), energy (Lapointe, 1985), and time (Kolk & Van Grunsven, 1985).

In what follows, I will briefly discuss theories of agrammatism. The focus will be mainly on production, but at the end of this section, when I introduce the approach of Kolk and coworkers, some results from language comprehension will be addressed. I will show an apparent discrepancy between these results, and, following Haarmann (1993), I propose a way out, based on a recent theory of sentence comprehension.

Research on agrammatic speech production in the 1970's and early 1980's mainly focused on one of the defining symptoms, omission of closed-class elements. Gleason, Goodglass, Green, Ackerman, & Hyde (1975), noticed that particularly unstressed, sentence-initial function words were prone to be omitted, confirming earlier

[6]However, Berndt & Caramazza (1980) correctly remark, that 'chance-level' doubles if two out of the three distractor pictures require different lexical items in naming, and if the patient has no lexical deficit.

observations. They suggested that the 'salience' of words (defined as a cluster of characteristics, in particular stress) determines probability of omission. An account in terms of phonological deficits was also proposed by Kean (1977). According to her, agrammatics build an intact syntactic structure, but when transforming this into a phonological structure, the representation is minimized to phonological units, called 'phonological words'. Function words, not being part of such a representation, are left out. Bradley, Garrett, & Zurif (1980) argued that in normal speakers, closed class vocabulary is doubly specified: They are represented in the mental lexicon, just like content words, but they are also part of a specialized store that is used in creating sentence frames. They hypothesized that Broca's aphasics, as opposed to normals, lack specialized access routines for retrieving these items from the specialized store, or have lost that store altogether.

All of these approaches run into some kind of trouble, most notably that a good account of reduced syntactic variety in sentence production is lacking. Furthermore, as Berndt & Caramazza (1980) pointed out, these accounts have troubles in explaining impaired performance in other modalities (in particular, auditory comprehension), and syntactic complexity effects. The alternative they offer as an account of agrammatism is that Broca's area subserves the functions of parsing and of articulation, and that these systems are permanently impaired as a result of brain damage in this area. What they have in mind, apparently, is that the parser and the grammatical encoder are the same system, and that components of that system are permanently deleted. As noted above, most researchers have abandoned this strong version of a loss-hypothesis. In addition, the question whether a single system carries out the functions of grammatical encoding and parsing has not received an unequivocal answer (these issues will receive attention in the General Discussion of this dissertation).

In 1980, Saffran, Schwartz, & Marin claimed that the deficit in agrammatic sentence production is localized even deeper in the processing system. They required agrammatic patients to order noun phrases and a verb. They concluded that 'the agrammatic aphasics could not, with any consistency, produce NP-V-NP orderings that reflect underlying semantic roles' (p. 276). This led them to propose that Broca's aphasics lack the linguistic categories that define relations between different elements, such as subject/predicate and even agent/patient (in terms of Bock & Levelt's 1994 theory, their deficit lies in the stage of 'functional integration'). Mapping concept onto structure proceeds without these intermediate categories and is based on factors such as semantic salience. However, a few years later, Kolk & Van Grunsven (1985) showed that Saffran et al. might have been too hasty. With 11 Dutch agrammatics, they replicated Saffran et al.'s study. They observed that most patients have better-than-chance performance on the noun-ordering task. The overall pattern of results was similar in that the relative difficulty of conditions was the same (locatives were more

difficult than actives), but absolute level of performance was much better in the Dutch group. It seems, therefore, if Saffran et al.'s original contention was too strong: Although it certainly may be the case that mapping semantic roles on grammatical functions poses difficulties for the agrammatic patient, it cannot be the case that agrammatic sentence planning proceeds without these kinds of relations.

A rather detailed model of agrammatic's omissions and substitutions of verbs was proposed by LaPointe (1985). First, he proposed a hierarchy of morphosemantic complexity of Verb Phrases, and then showed that the kinds of VP's produced by Broca's aphasics are among the least complex. He then went on and extended Garrett's (1975) model of normal sentence production with an explicit algorithm of phrase structure selection. Importantly, he assumed that the production of more complex VP's is more resource consuming than the production of simple VP's. He conceives of resources as a kind of 'mental energy' that fuels a look-up process in a table of VP frames. The more complex a VP, the farther away in the table it is, and the more energy is required to select it. He hypothesized that Broca's aphasics have a pathological shortage of this mental energy, and consequently can only select simple VP's.

The *adaptation theory* of Kolk and colleagues (Haarmann & Kolk, 1992; Hofstede & Kolk, 1994; Kolk, 1995; Kolk & Van Grunsven, 1985; Kolk & Heeschen, 1992) shares with LaPointe (1985) the contention that the impaired processing level is that of constructing syntactic structure. However, Kolk et al.'s approach differs in that it is centered around the metaphor of time, rather than of energy, that it is not restricted to Broca's aphasics' usage of verbs, and that it explicitly assigns a role to adaptation. The theory basically consists of two parts. First, it is assumed that the actual output of an agrammatic does not directly reflect the underlying impairment. He may very well resort to certain strategies in order to minimize the consequences of the impairment. Kolk & Van Grunsven referred to this as *adaptation*, and proposed two kinds of adaptation strategies that may be operative. The first, corrective adaptation, assumes that speakers monitor their own speech, and can do so covertly, before speech is actually realized (Levelt, 1983). Because the speech plan generated by an agrammatic speaker is bound to contain errors, the agrammatic speaker would need to repair them. Resulting speech is then slow, effortful, filled with pauses, but with little error of selection (see Haarmann & Kolk, 1992, for discussion of this mechanism in the context of Broca's aphasics and Wernicke's aphasics production of grammatical morphemes). The second form of adaptation, preventive adaptation, assumes that agrammatic speakers, aware of their problems in attempting to realize longer, more complex kinds of sentence, rely heavily on a special register of speech which is also present in normal speakers: The elliptical register. Elliptical utterances are often observed in newspaper headlines, in speech to foreigners ('Passport no good'), and contextually highly constrained discourse ('Two beers, please'). Preventive adaptation implies that the

patient generates a simpler conceptual representation, which will be expressed as an elliptical utterance. Resulting speech would contain many omissions of closed class material, and word order appropriate for ellipsis ('Hersenbloeding gehad', 'Stroke had'). Evidence for agrammatic speech as belonging to the elliptical register is provided in Hofstede & Kolk (1994). Preventive adaptation can thus account for reduced variety of syntactic form.

The second part of Kolk and coworkers' theory, is that the underlying impairment is a disturbed temporal synchrony (see also Friederici, 1988; 1995; Hagoort, 1990). In order for representational elements to interact they need to be simultaneously active. Disturbances of computational simultaneity, for instance a pathological slow activation, or a pathological fast decay of representations, would lead to a breakdown in production or comprehension. In addition, more complex sentences require deeper, and hence more time consuming, processing. It follows that temporal asynchrony is particularly devastating for more complex sentence types. One objection easily raised is that as long as, for instance, a delay in activation applies equally strong to all elements involved, temporal synchrony is restored, and no breakdown of processing is to be expected. However, in a computer simulation study on parsing, Haarmann & Kolk (1991a), managed to reject that objection. With respect to production, Kolk (1995) presented a model of morpheme production in which a delay in constituent structure building is coupled to normal lexical access. He showed that this model predicts the same pattern of errors, on bound as well as on free morphemes, as Haarmann & Kolk (1992) obtained empirically.

Two kinds of temporal asynchrony were proposed, slow activation and fast decay. Assuming that one of these indeed can account for agrammatics' inability to construct constituent structure, which one is it? Results have only been obtained with language comprehension, and the results are mixed. In 1991(b), Haarmann & Kolk obtained evidence for slow activation. In a lexical decision paradigm, target words were preceded by syntactic environments which were congruent (the man WALKS) or incongruent (the man NOSE). Normal controls showed an effect of facilitation when the target word was congruent. Moreover, they showed this effect regardless of temporal interval separating target and preamble. Broca's aphasics, on the other hand, only showed an effect at the longest interval, thus indicating slow activation.

Evidence for fast decay has also been presented (Friederici & Kilborn, 1989; Haarmann & Kolk, 1994). Haarmann & Kolk (1994) found such an effect in a word-monitoring paradigm (i.e. the participant presses a button as soon as he hears the target word). Targets for which the participant had to monitor were sometimes preceded by syntactic violations such as subject-verb agreement errors. Normal controls showed longer response latencies following such a violation, even if 750 msec separated the

violation and the monitoring target. Broca's aphasics on the other hand only showed an effect of monitoring at the shortest interval.

So, evidence for fast decay as well as for slow activation has been reported. This is unfortunate, as it is unclear when either of these processes will occur. In the concluding chapter of his dissertation, Haarmann (1993), proposed a way out. His proposal is based on Just & Carpenter's (1992) theory of sentence comprehension which assigns an important role to verbal working memory resources. Verbal working memory needs to be distinguished from Short Term Memory in the traditional literature (Miller, 1956), and from working memory in the sense of Baddeley and colleagues (e.g. Baddeley & Hitch, 1974) because it is specific to verbal processing only. In addition, Just & Carpenter assume separate working memory capacities for language comprehension and language production. Crucially, their conception of working memory is not a passive repository of information, but rather a pool of resources, applied for two purposes: Maintaining information and fueling processes that transform this information. However, this pool of resources is limited, and individuals vary with respect to how many resources they have. When a comprehender encounters a situation in which processing requires more resources than are available, i.e. when demand exceeds supply, allocation of activation for maintenance and for processing is decreased. Each informational element loses some of its activation in such a way that total demand, defined as total demand for processing plus total demand for maintenance, equals total capacity. Importantly, there could be trade-offs in this scaling back scheme: Activation allotted to processing and maintenance might trade-off with each other. A decrease in activation for maintenance would result in fast decay. A decrease in activation for processing would result in slow activation. The final assumption necessary to rhyme this theory with Haarmann & Kolk's (1991, 1994) results, is that the way processing and maintenance trade-off with each other is task dependent. A task requiring maintenance, such as a task in which a word needs to be integrated with a syntactic representation, results in de-allocation of resources to processing, and hence slow activation. A task requiring processing, such as fast identification of words in order to determine whether it is the target, results in de-allocation of resources to maintenance, and hence fast decay.

Clearly, this proposal, which integrates Salthouse's (1988) 'energy and time metaphors' is attractive. It postulates a single explanatory mechanism, limited verbal working memory capacity, that, depending on task requirements, can result in both postulated kinds of temporal asynchrony. Furthermore, it places Broca's aphasics on a continuum, ranging from participants with large working memory resources, to participants with smaller working memory resources, to agrammatic patients with pathologically limited working memory resources. (For experimental evidence for the latter hypothesis, see Miyake, Carpenter, & Just, 1994).

To summarize, most theories of agrammatic language production have focused on omission of closed class items, rather than on reduced variety of sentence structure. (Gleason et al., Kean, Bradley, Garrett, & Zurif). In addition, many of the proposals can be characterized as a loss-hypothesis (Berndt & Caramazza, 1980; Bradley, Garrett, & Zurif, 1980). As argued above, we reject the loss-hypothesis, as it is inconsistent with the data.

In terms of Salthouse's taxonomy of explanations, we are left with processing accounts. We are unaware of any theory of agrammatic sentence production that characterizes the deficit as an 'inefficient' operation of some components. However, it seems that such an explanation is equivalent to an explanation in terms of a limitation in computational resources, *that are specific to a certain component,* and we will return to that issue below. An account of incorrect use of strategies in agrammatic sentence production has been proposed by Caplan (1983) and by Kolk & Van Grunsven (1985). These accounts share the contention that agrammatics overrely on a certain strategy. In the case of Kolk & Van Grunsven (1985) and especially Hofstede & Kolk (1994), it is assumed that syntactic simplification is a form of a specialized speech register also used by normals. It is inappropriate in the sense that agrammatics use such a strategy, when the discourse context is not constrained enough to switch to that register. However, obviously, a strategy account has to be extended with an account of the underlying impairment that necessitates the application of such strategies. That leads us to the third of Salthouse's processing explanations, limitations in computational resources. Both Lapointe (1985) and Kolk and colleagues have proposed such explanations. There are two drawbacks to LaPointe's approach. First, in accounting for function word omission as well as for reduced syntactic form in Broca's aphasia, he contends that there is a general limitation of resources, affecting the cognitive system as a whole. From that, the very strong prediction follows that all mental resource consuming processes should be impaired. That prediction seems hard to reconcile with the specificity of aphasic impairments for the language modality, dissociations between production and comprehension sometimes observed (e.g. Kolk, Van Grunsven, & De Keyser; see also General Discussion), and even dissociations between different aspects of production (e.g. Friedmann & Grodzinsky, 1995, observed a dissociation between agreement and tense). Furthermore, detailed predictions with respect to language output are restricted to morphological aspects of verb phrases. This scope appears to be too limited in order to explain reduced variety of syntactic form: How, for instance, would the model explain the effect of 'padding' adjectives which is among the most difficult sentence structures for Broca's aphasics (Gleason et al., 1975).

Kolk and co-workers' theory, that limitations of resources for temporal processing underly agrammatic deficits, has received most attention in the field of sentence understanding, and not in production. In addition, although Kolk's (1995) model of

production, assumes a slow build-up of constituent structure, eventual constituent structure, in which grammatical morphemes are inserted, is intact.

Testing the theory of resource limitations in Broca's Aphasia

As the discussion in the preceding section shows, previous studies leave open a gap: If the adaptation theory is right in that reduction of syntactic variety results from preventive adaptation strategies, what underlying impairment necessitates this adaptation?

Is the underlying impairment in Broca's aphasia a pathological reduction of computational resources? Furthermore, does this hypothesized pathological resource limitation affect resources specifically applied to the generation of one subcomponent (e.g. generation of syntactic structure) or is it a shortage of resources fueling the whole process of sentence production? This question of specificity has recently been vigorously debated in the field of parsing (Caplan & Waters, 1995; Martin, 1995; Miyake et al., 1994, 1995) and we think an empirical evaluation of that question in production contributes to that debate.

This dissertation contains an attempt to test a theory of the underlying deficit in Broca's aphasia with respect to sentence production. The theory we test can be summarized as follows: The underlying impairment in Broca's aphasia is a pathological shortage of *computational resources*. The limitation of these resources hinders the mechanism of grammatical encoding, in particular the mechanism of constituent structure assembly, as a result of which utterances are not as complex and as well-formed as the utterances of normal speakers. In addition, resources are not specific for the subcomponent of phrase structure generation, but of a more general scope. As a result of that, usage of one subcomponent trades off with usage of another component in the face of a resource limitation.

Furthermore, a crucial assumption underlying the resource-approach is that speakers with Broca's aphasia rely on the same processes and stages of sentence production as normal speakers do. Therefore, the research reported in this dissertation also addresses questions of normal sentence production: In particular, we attempt to specify further, or at least constrain, those parts of the system most relevant for our hypotheses regarding agrammatic sentence production.

The theory allows us to come up with two broad predictions, and those predictions are tested in the different chapters that comprise this dissertation. First, we predict that Broca's aphasics should be able to produce sentences of relatively high complexity when the sentence structures are made, temporarily, more available (i.e. producing them costs less resources than normally). A corollary to this prediction is that

it is indeed possible to temporarily enhance availability of sentence structure in normal speakers, and this corollary was also tested. Second, we predict that Broca's aphasics, as opposed to normal controls, are unable to simultaneously use information from different levels of processing during grammatical encoding: Such influences are resource-requiring, and Broca's aphasics do not have enough of these resources. A corollary to *that* prediction is that there indeed exist sentence production tasks which show that normal speakers simultaneously use these different information sources. We provide evidence for that corollary as well.

Let us try to specify further the two broad predictions. The first prediction concerned the effect of resource-limitations on syntactic complexity. Because syntactically complex sentences are more resource demanding, Broca's aphasics, having fewer resources, have more difficulties with more complex sentence types. However, if it were possible to induce a state in which producing a given sentence type is less resource demanding, more complex utterance types ought to be expected. Is it indeed possible to decrease demand on resources for a certain construction? That would be the case if the availability of that construction were somehow facilitated. Evidence for such a facilitatory effect of priming was reported, inter alia, by Bock (1986b; 1989); Bock & Loebell (1990); Bock, Loebell, & Morey (1992).

In 1986, Bock showed that speakers have a tendency to reuse the syntactic structure of a previously produced sentence. This is merely a tendency: The previous sentence is not the sole determinant of the syntactic structure of the current sentence (as will be argued, syntactic structure appears to be determined by many variables, e.g. pragmatics, perceptual variables, conceptual variables such as animacy, conceptual accessibility, lexical accessibility). However, there were significantly more responses of a certain type, say a passive, when the previous sentence was of that same type, *than when the previous sentence was of an alternative type, say an active*. So, hypothetical data would be that following an active prime sentence 20% of the responses are passive, but following a passive sentence 30% of the responses are passive. Even though the total number of actives may be higher than the total number of passives in that latter condition (perhaps because of all these other variables) we can still refer to the increase in number of passives as a priming effect.

How did Bock show these priming effects? She requested participants to repeat sentences and describe pictures, under the disguise of a memory experiment. Participants had to respond with 'yes' if they encountered a certain item (picture or sentence) for the second time during the course of the experiment and otherwise with 'no'. Repetition and picture description was required in order to 'aid the memory for these items'. Most of the items were actually filler items, in order to avoid the participant noticing the experimental manipulations. Experimental trials consisted of

two items: A prime sentence and a target picture. For instance, a prime could be sentence (8).

(8) The diet doctor was killed by the headmistress several years ago

A target could be a picture such as Figure 2.

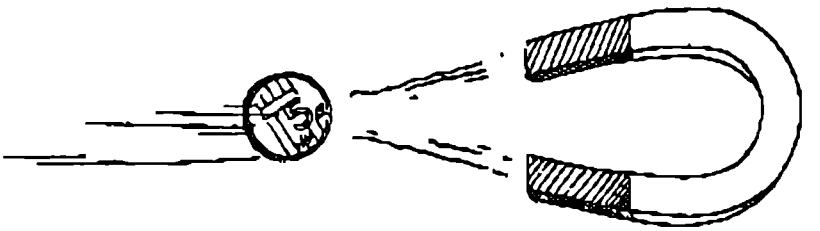

FIGURE 2. Example of a target picture (this one was used in the experiments reported in Chapters 2 and 3). Bock et al. used similar types of pictures.

Crucially, such a target picture can be described in two ways: Using the same overall syntactic structure as the prime sentence, or using a syntactic alternative. This allows testing the hypothesis that syntactic structure is 'persistent', i.e. syntactic structure can be temporarily made more available. Importantly, in follow-up studies Bock and colleagues have elegantly excluded a number of alternative explanations for these effects (i.e. that the effect would be a consequence of lexical, thematic, or prosodic factors). We therefore assume that construction of a certain syntactic structure can be facilitated with this priming paradigm, and we apply the paradigm in the experiments reported in Part I of this dissertation.

The paradigm of eliciting syntactic persistence thus seems an appropriate candidate for testing the effect of an increase in availability of a certain structure on agrammatic's ability to produce that structure. However, syntactic persistence effects have never been reported in a language other than English, nor for structures other than datives and transitives. In addition, none of the published experiments included a baseline condition, in order to find out whether the priming effect was facilitatory for all tested structures, or, for instance, facilitatory only for the most marked structure. Therefore, we set as our first goal to extend the generality of these findings to another language, to different structures, and to compare the effects to baseline measurements. In addition, we observe that previous studies have localized the structure priming effect at the level of constituent structure assembly (see Bock & Levelt, 1994; Bock, Loebell,

& Morey, 1992). We critically examine this claim in one of the studies reported in the present dissertation, and tentatively conclude that it is incorrect. Instead, we argue that (1) priming effects for transitives and datives occur at the level of functional integration (2) there is a stage of *linearization* of constituent structure, and this stage can be primed as well.

With respect to agrammatic sentence production and priming, a complicating factor is the possible involvement of strategies: For instance, an aphasic speaker may have just enough resources to produce e.g. passives, but may strategically avoid these sentences because of the effort it would require. Furthermore, in a primed picture description task, a strategy may surface, for instance, to reuse the structure of the prime sentence and simply replace content words with other ones appropriate for the picture at hand. Therefore, in our study with agrammatics, we attempted to experimentally manipulate the possibility to apply strategies, and supplied control conditions such as baseline picture description, and an analysis of spontaneous speech.

The results reported in Part I have a number of interesting consequences for the theory of grammatical encoding. In addition, the results are in good agreement with the hypothesis of a resource limitation in Broca's aphasia: Facilitation of sentence structure allows elicitation of relatively complex sentences in agrammatics.

Whereas Part I focuses mainly on constituent structure, Part II investigates the construction of verb inflections. The main reason is that it allows us to further specify the concept of resource limitations. In particular, are computational resources specific, i.e. each component has its own separate pool of resources? Or are, on the other hand, resources more general, with different components utilizing the same resource pool? If the latter option is correct, there should be a trade-off between different components during sentence formulation (see Linebarger et al., 1983; Schwartz et al., 1987; Kolk & Weijts, 1996, for debate on a similar trade-off in sentence understanding). As a result of a trade-off, it would be impossible to simultaneously use information from both components.[7]

A necessary corollary is that there do indeed exist processes of which it can be shown that speakers take different information sources into account. The process I investigated is that of constructing subject-verb agreement during speech. The paradigm I applied to study this process is that of eliciting subject-verb agreement errors in sentence fragment completion. Bock & Miller (1991) were the first to use this paradigm. Relevant follow-up studies were conducted by Vigliocco and colleagues (Vigliocco, Butterworth, & Semenza, 1995; Vigliocco, Butterworth, & Garett, in press).

Bock & Miller presented participants with sentence fragments such as (11):

[7]Notice that there could be an alternative prediction: both involved components suffer equally from the resource limitation. This issue is taken up in the General Discussion.

(11) The claim about the newborn babies

Participants were instructed to repeat the fragment and complete it to a full sentence. This naturally leads to the production of a verb, which needs to be correctly inflected with respect to number (in example (11) the verb needs to be singular, because the head noun 'claim' is also singular). The dependent variable was the number of erroneous verb inflections. Each sentence fragment contained a head noun (subject noun) and a 'local noun', the noun contained in the modifying prepositional phrase (PP). Bock and colleagues obtained a number of interesting results with this paradigm. The main conclusions were that construction of subject-verb agreement can be disturbed by manipulations at the level of grammatical encoding (such as grammatical number of head and local noun, constituent structure of preamble, length of modifier), but not by manipulations at the level of conceptualizing. This latter point is illustrated by the results with sentence fragments such as (12):

(12) The label on the bottles

In order to be in line with our knowledge of the world, this fragment has to be interpreted as meaning that there are several labels. There are several bottles, and one instance of the generic 'label' is on every bottle (see also Figure 1 in Chapter 4). This implies that the grammatical and 'conceptual' number of 'label' differ. Whereas it is grammatically singular, it is conceptually plural. With sentences such as (12), Bock & Miller (1991) found no increase in the number of errors as compared with sentences having grammatical as well as conceptual singular head nouns. That result was replicated by Vigliocco et al. (1995).

However, as Vigliocco et al. (1995) remark, English may not be the ideal language to base any generalizations on, because of its very limited verbal inflexional system (basically restricted to marking number in the present tense, third person). Therefore, Vigliocco and colleagues also studied Italian and Spanish with sentences such as (13) and (14).

(13) (Italian) Il numero sulle targhe (the number on the plates)

(14) (Spanish) El numero de las tarjetas (id.)

In contrast to the English results, clear effects of conceptual number were observed in these languages. This can be interpreted as the morphosyntactic process of subject-verb agreement not being 'informationally encapsulated' from conceptual information. It makes this paradigm a promising candidate in our search for a task that can support our

corollary: Speaking tasks exist, in which normal speakers (of Italian or Spanish) simultaneously use syntactic as well as semantic information.

In Part II of this dissertation, the error-elicitation task is applied to French and, in particular, to Dutch. With respect to normal grammatical encoding, we address the question why English, as opposed to Italian and Spanish, failed to show an effect of distributivity. The rationale for testing French and Dutch was that these languages share a number of structural characteristics with English on the one hand, and with Italian and Spanish on the other hand. Importantly, some of these characteristics were proposed by Vigliocco et al. (in press) to account for the crosslinguistic difference. These characteristics were (1) possibility to omit subject pronouns (Spanish, Italian +; Dutch, French, English -) (2) possibility to have post-verbal subjects (Spanish, Italian, Dutch +; French, English -) (3) relatively complex verbal morphology (Spanish, Italian, Dutch, French +; English -)[8]. We observed distributivity effects both in French and in Dutch, thus excluding the first two language characteristics as the key to explaining the differential results for English.

Crucially for testing the resource theory of agrammatism, we showed that normal speakers of Dutch make use of the semantic as well as the syntactic component of sentence production. From the hypothesis of a limitation in resources subserving both these components in Broca's aphasia, we predict a trade-off: Too few resources remain to utilize both of these components, therefore agrammatics' construction of verbal inflections is determined by only one of them, the syntactic component. With respect to the subject-verb agreement task, we then predict that Broca's aphasics, as opposed to normal controls, show no effect of distributivity.

Assumptions about the Cognitive System

Having presented the main purposes of this dissertation, I will now attempt to make explicit some of the assumptions about the cognitive system that are, sometimes tacitly, sometimes explicitly, made in the present series of five studies.

Our way of conceiving the process of *sentence production* relies heavily on the blueprint of the speaker, as sketched by Levelt (1989) and the more recent theory proposed by Bock & Levelt (1994). This implies that we assume (1) several levels of processing (2) a system that is in principle modular (3) incremental processing -- one processing level already delivers output to the next one, before processing at that level

[8]Two things should be noted about these characteristics: First, post-verbal subjects do occur in French, but only with a preverbal subject clitic. Second, some of these characteristics are graded rather than absolute: for instance, Dutch has more complex verbal morphology than English, but not as complex as Spanish.

is complete (4) sentence production is lexically driven, i.e. there is a processing level at which the lexicon is searched for an item that can express a concept, and this item, rather than being the phonological form of the word, is an abstract unit containing inter alia grammatical information.

Especially in the first part of this dissertation, we will often assume the '*activation metaphor*', which has received much attention in the last decade with the rise of connectionism (see Rumelhart & McClelland, 1986; Quinlan, 1991). Because connectionist models of sentence production are scarce (MacKay, 1987; Stemberger, 1985; Ward, 1992) and none of these models seem to directly fit in with the architectural and processing assumptions made earlier, we will not commit ourselves to any particular connectionist model. Instead, we will simply adhere to the assumptions most connectionist models share. First, different representational elements have 'activation levels', changing over time. Further, activation levels are a function of (1) previous activation level (2) input received from other representational elements. Net input can be positive, leading to an increase of activation level, or negative, leading to a decrease. Furthermore, different representational elements, sometimes called nodes, compete with each other in order to be selected, and selection probability depends on activation level of the particular node and of the other nodes. It is important to note that the activation metaphor does not imply interactionism, the school of thought that assumes every information element can interact with any other information element. For extensive argumentation for modular connectionist models and implementation of a modular connectionist architecture, the reader is referred to Murre (1992).

Psycholinguistic research borrows from linguistics, and this dissertation is no exception. However, although we sometimes need linguistic terminology to provide accurate descriptions, we are not committed to any particular theory. Two points should be made in advance, though: We do share with theories such as Government & Binding theory (Chomsky, 1981; Haegeman, 1994) and Head-Driven Phrase Structure Grammar (Pollard & Sag, 1994) the notion of syntactic structure. In fact, we provide empirical evidence for the psychological reality of syntactic structure. Furthermore, although we certainly acknowledge that transformational approaches may provide us with a very accurate *description* of sentence structure, we will assume that the speaker generates syntactic structure directly, without an intermediate D-structure representation (cf. Bock et al., 1992, for empirical evidence in favor of this 'direct mapping' view).

What assumptions do we make with respect to *Broca's aphasia* and how it is best studied? As mentioned above, our theoretical starting point is the adaptation theory of Kolk and colleagues (Kolk & Van Grunsven, 1985). In particular, we will assume (1) that the language impairment can be characterized as a disruption of processing, not as loss of knowledge (2) the symptoms observed in actual speech are a function of an underlying impairment and of the patients adaptation to that impairment (3) the

impairment is one of grammatical encoding in language production and of parsing in language comprehension (4) even though there is much variation between patients, they share a common impairment. Variation comes about because of differences in strategy and of differences in severity.

Our approach is that of the group study rather than the case study. Even though we are aware of the danger in doing group studies (i.e. can one ever be sure to have a homogeneous group with respect to underlying impairment?) we believe that this approach can make a valid contribution to the progress in the field of neuropsychology, next to the case-study approach. The point is that individual patients do not only differ from one another, but also show communalities in their language behavior (Kolk & Weijts, 1996). The only way to test a theory of these communalities is to do a group study (see also Zurif, Gardner, & Brownell, 1989). I do accommodate to the criticism of heterogeneity though, by providing individual results as well as group results.

Outline of this dissertation

Although this dissertation is divided into two parts, its structure can perhaps best be characterized by a two-by-two table, such as presented below. The rows of this table designate the experimental paradigm applied (facilitation of syntactic structure or elicitation of agreement errors) and the columns denote the type of participants tested (university students or Broca's aphasics and their age-matched controls).

TABLE 1
Outline of this dissertation

	University Students	*Broca's aphasics/controls*
Syntactic Facilitation (Part I)	Chapter 1 Chapter 2	Chapter 3
Subject-verb agreement (Part II)	Chapter 4	Chapter 5

Part I of this dissertation, containing Chapters 1 through Chapter 3, deals with the phenomenon of Syntactic Persistence (also known as Syntactic Priming, Syntactic Facilitation and Structure Priming). In Chapter 1, we present a series of four experiments that show that this phenomenon can be reliably replicated in Dutch with

respect to the so-called dative alternation (John gave a book to Mary - John gave Mary a book). Furthermore, we generalize the finding to a dative variant not tested in previous investigation, the 'medial' dative (John gave to Mary a book). However, we failed to obtain an effect for transitive sentences (The lightning hits the church - The church is hit by the lightning). Various hypotheses that could account for this null effect were tested in the experiments reported in Chapter 1, and we were able to exclude all of them. The data did allow us to make two empirical generalizations. First, we observed that the frequency of target utterances was higher in the experimental conditions than in the baseline condition. Because the baseline trials always occurred at the beginning of the experiment, this seems to imply that availability of target responses is determined by previous trials, not just by the directly preceding prime sentence. Second, the data suggested that a necessary condition for obtaining a priming effect, is that the alternative sentence types have equivalent baseline frequencies. We accounted for that in terms of a 'Competition Hypothesis': When structures have equivalent baseline frequencies, and can therefore be assumed to have equivalent resting levels of activation, priming disturbs a delicate balance, such that one structure wins the competition. That would explain the lack of priming for transitives: The passive sentence type has such a low resting activation level that it can not win the competition with the active, even when given an advantage by priming.

In Chapter 2, the range of syntactic alternations showing syntactic persistence was extended to locatives, in which the prepositional phrase incorporating the location was either placed sentence-finally ('The ball lies under the table') or sentence-initially ('Under the table lies the ball'). The importance of this syntactic contrasts exceeds just an enlargement of the set of structures that 'work'. As we will argue, this finding supports the notion that there exists a stage of processing, 'constituent linearization', that imposes linear order on syntactic structure. In Chapter 3, we apply the syntactic persistence task to Broca's aphasics' sentence production. As mentioned before, we predicted that due to a temporarily increased availability of complex sentence types such as passives, these sentence types can be elicited. However, an important consideration is that the actual speech produced by Broca's aphasics is a function of (1) an underlying impairment in formulation (2) adaptation to that impairment. This makes it conceivable that a study of Broca's aphasics' syntactic repertoire underestimates their abilities: They may strategically avoid those constructions that require great effort. It makes it furthermore conceivable, that any effects of syntactic persistence should be ascribed to strategy, as opposed to an automatic facilitatory priming effect. In order to deal with these considerations, we studied the incidence of target sentence structures in spontaneous speech, in picture description without a prime sentence (the baseline condition), and in picture description with a prime sentence. Furthermore, we varied task requirement: In one session we disguised the task as a recognition task, thus

directing away attention from the sentence production part, in another session we removed recognition instructions, but did not mention the purpose of the experiment, and in a final session, we explicitly instructed participants to reuse previous sentence form. We reasoned that if it is possible to do so on our request, it is possible to apply a task strategy. Conclusions from this experiment were clear: First, we obtained priming effects with the group of Broca's aphasics, both for passives and for datives. Second, these effects were stronger in the group of Broca's aphasics than in the group of normal controls. Third, the incidence of passives was extremely low in spontaneous speech and in the baseline condition for Broca's aphasics, but it increased substantially in the experimental conditions. Fourth, for Broca's aphasics there was no effect at all of task instructions, thus excluding the possibility of strategic involvement. In general, these results are conform our prediction. However, the finding that Broca's aphasics are more sensitive to priming than normal control was unexpected. We offer a number of possible explanations for this difference. We further suggest that these findings constrain any models of agrammatic sentence production that assume a resource deficit.

Part II of this dissertation, containing Chapters 4 and 5, describes experiments in which errors of subject-verb agreement are experimentally elicited. We were especially interested in a comparison of sentence fragments which had a distributed, conceptually plural reading and sentence fragments which had a grammatically and conceptually singular reading. In Chapter 4, we show that speakers of Dutch and French are sensitive to this manipulation, as has previously been observed with speakers of Italian and Spanish, but not with speakers of English. This allowed us to exclude a number of structural explanations for this crosslinguistic difference: The explanation that conceptual information controls grammatical agreement in languages which can omit subject pronouns, and the explanation that conceptual control of agreement depends on freedom of word order. Most important, this experiment clearly showed that speakers, when executing a morphosyntactic process such as getting agreement between subject and verb right, take into account both syntactic and semantic information. In Chapter 5, finally, we conducted the same experiment with a number of Broca's aphasics and age matched control subjects. We predicted that Broca's aphasics, as opposed to normal controls, should be insensitive to conceptual number, because they lack the necessary resources to simultaneously use both conceptual and grammatical number. The results confirmed this prediction: We observed that both Broca's aphasics and normal controls made a substantial number of errors, and that both groups showed an effect of 'attraction' (more errors when head and local noun mismatch in number). However, normal controls showed a significant effect of distributivity, whereas there was no such effect for Broca's aphasics.

Where does all this leave us? The results we present in the various chapters have repercussions both for theory of grammatical encoding and for theory about the

underlying deficit in Broca's aphasia. Let us summarize the main conclusions, again in a two-by-two table: Table 2.

Finally, in the General Discussion section, we tie together any 'loose ends' that were not addressed in previous chapters, thereby integrating results reported in various chapters. We will conclude by evaluating the present status of the resource theory.

TABLE 2

Outline of this dissertation along with main conclusions

	University Students	*Broca's aphasics / controls*
Syntactic Facilitation (Part I)	Chapter 1: Partial replication and extension of syntactic persistence. Chapter 2: Specification of loci of effect: the levels of functional integration and of constituent linearization.	Chapter 3: Syntactic facilitation allows to elicit relatively complex sentence type from Broca's aphasics. This is evidence for a 'limited resource' hypothesis.
Subject-verb agreement (Part II)	Chapter 4: Evidence for speakers of Dutch and French drawing simultaneously on syntactic and semantic information sources during grammatical encoding.	Chapter 5: Broca's aphasics, as opposed to normal controls, do not simultaneously use syntactic and semantic information. This constrains the kind of limited resources involved: They are not specific to syntax.

Part I

Syntactic Persistence

Chapter 1
Syntactic persistence in Dutch[1]

Abstract

Four experiments are reported that attempt to generalize the effects of syntactic priming in speaking obtained by Bock and colleagues (e.g. Bock, 1986b; Bock, Loebell, & Morey, 1992) to syntactic structures not tested before. Bock et al. showed that production of a sentence with a certain syntactic structure, the prime sentence, enhances the probability that a subsequent sentence has the same structure. However, these experiments were restricted to a small set of tested syntactic structures. In the present experiments the test language was Dutch. The relatively free word order of this language allows testing with structures that do not occur in English, i.e. a passive with a sentence-final past participle, a 'medial' dative, and a 'frontal dative'. We compared the obtained frequencies of syntactic structures with baseline frequencies (i.e. with the frequencies of these structures in the absence of syntactic persistence effects), in order to address several questions regarding the nature of the priming effects. We obtained evidence for syntactic priming with prepositional dative sentences, double object dative sentences, and with a structure not tested in previous experiments, the medial dative (e.g. 'the man gives to the girl a present'). No effect was obtained for another dative structure, the frontal dative (e.g. 'to the girl gives the man a present'). A transitive priming effect was only found in one experiment, and only for passives. Four explanations for the mixed results with transitives were tested in Experiments 2-4. A comparison of baseline and experimental conditions suggested two empirical generalizations: (1) Syntactic priming is a long-term event, lasting at least several experimental trials, (2) Priming is most effective when the primed structure and its alternative have equivalent baseline frequencies.

Introduction

In speaking one often involuntarily repeats material from previous discourse. Levelt & Kelter (1982) cite studies as far back as the 1930s in which this phenomenon has been observed. Repetitions occur at the levels of sounds, words, and syntactic structures.

[1] The data reported here were presented as: Hartsuiker, R.J. & Kolk, H.H.J. (1995), Syntactic Persistence in Dutch, poster presented at the CUNY conference on Sentence Processing, Tucson, Arizona.

In this chapter we will restrict ourselves to the study of repetition of syntactic structures. There is evidence, both from informal observations and from experimental studies, that syntactic structures tend to be somewhat persistent. For instance, Levelt & Kelter (1982) required subjects to answer questions. In one experiment, they telephoned shopkeepers, and either asked the Dutch translation equivalent of 'what time does your shop close?' or 'at what time does your shop close?'. They found that questions containing a preposition tended to elicit a response containing the preposition as well (i.e. 'at five o' clock), and questions without the preposition more often yielded answers without the preposition ('five o'clock'). Hence, the syntactic structure of the question was repeated.

Tannenbaum & Williams (1968) asked subjects to read six-sentence preambles. The sentences were either phrased in the active voice or the passive voice. Following the preamble, a picture was presented together with a cue that indicated whether an active or a passive sentence had to be produced, and the response latencies were measured. There was a trend for the response latency to be shorter if the preceding sentence fragments had the same syntactic structure as the target utterance[2].

Weiner & Labov (1981) analyzed spontaneous speech in order to determine sociolinguistic variables involved in a preference for using passive sentences. They found that the probability of producing a passive is significantly higher if another sentence of that form occurred in the five sentences preceding the utterance.

In a number of studies with the 'structure priming' paradigm (see below), Bock and colleagues (Bock, 1986b, 1989; Bock & Loebell, 1990; Bock, Loebell, & Morey, 1992) showed that the form of a sentence used to describe a picture tends to be congruent with the form of an immediately preceding sentence. In addition, these studies showed that repetition of syntactic structures occurs irrespective of prosodic, lexical, or semantic similarities between the two sentences. For instance, the structure of a sentence will be repeated, whether some of the lexical items, both content words and function words, are the same or not (Bock, 1989). In sum, syntactic structures are somewhat persistent, and this persistence effect emanates at the level of constructing constituent structure.

In this article two main questions are addressed. First, in the literature on syntactic persistence, only a limited number of syntactic structures have been tested. Can the claim that syntactic structures exhibit priming effects be generalized to a broader range of structures? In the experiments reported here, the test language is Dutch. The relatively free word order of this language (as compared to English) provides us with the opportunity to test more syntactic structures.

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[2]In testing the interaction between prescribed (cued) voice and preamble voice, Tannenbaum & Williams (1968) obtained an F-value of 2.82, with 1 and 70 df. They report incorrectly, that $p > .10$; in fact, the obtained F already exceeds the critical value for F with 1 and 60 df (2.79 when $\alpha=.10$).

Second, in earlier studies there was usually no attempt to determine a baseline frequency of production for each tested structure That is, the set of prime sentences usually did not include a 'neutral' sentence A sentence with a structure not feasible for reuse in a subsequent picture description [3] Picture descriptions following such a neutral prime yield a baseline frequency for the produced structures It is important to obtain these baselines, for two reasons First, with such baseline data, it is possible to evaluate inhibitory effects on the production of a certain syntactic structure as well as facilitatory effects Consider the production of active transitive sentences If these sentences are elicited in a priming paradigm with active and passive prime sentences, and more actives are observed following active primes than passive primes, three interpretations are possible First, active primes facilitate production of actives, Second, passive primes inhibit production of actives, Or third, both of the above With appropriate baseline data, we can distinguish between these possibilities

There is a second reason baseline data are important Frequency differences between the baselines of the tested structures could influence the degree of syntactic priming, analogous to frequency effects in other kinds of priming For instance, studies on repetition priming (e g Forster & Davis, 1984) suggest that frequency is an important variable in priming experiments In repetition priming, stimuli are presented to subjects repeatedly, separated by the presentation of other items It is generally found that tasks like lexical decision and word naming are facilitated when an item has been processed earlier D L Scarborough, Cortese, & H S Scarborough (1977) showed that infrequent words benefit much more from repetition priming than frequent words This result has been replicated a number of times (e g Forster & Davis, 1984, Rajaram & Neely, 1992)

Given this frequency effect and assuming that priming of syntactic structures shares properties with repetition priming (in both types of experiment, a stimulus is processed repeatedly), it is reasonable to consider the possibility of frequency effects in experiments with syntactic structures as primes

Because there are no frequency counts for the relevant syntactic structures available in Dutch, we need baseline data to indicate possible frequency differences An advantage of collecting baseline data using the same procedure and with the same materials as the production experiments is that we take into account characteristics of the particular pictures selected (e g animacy, size, perceptual salience, and position of agent and patient) that may contribute to frequency differences

In the experiments reported here, the structure priming paradigm of Bock (1986b) is used In this paradigm, subjects are presented with sentences to repeat The prime sentences Immediately following repetition of the prime sentence, they are required to

[3] With the exception of Bock (1986b), Experiment 1

describe a picture. The picture has to be described using a single, grammatically correct sentence. The prime sentence and the subsequent picture are not semantically related. However, the syntactic structure of the prime sentences can be used in a sentence with which the picture is to be described. The participants are kept unaware of the nature of the task, in order to avoid any strategy effects. They are led to believe they participate in a memory test, and that the only purpose of repeating sentences and describing pictures is to aid their memory of these items.

In the work of Bock et al., two types of syntactic structures were typically studied: Transitives and datives. For the transitive type, active or passive prime sentences are followed by pictures that can be described with an active or passive sentence. For the dative type, prime sentences are either prepositional datives (e.g. the corrupt inspector offered a deal to the bar owner) or double-object datives (e.g. the corrupt inspector offered the bar owner a deal). A typical picture for the dative type would represent a girl handing a paintbrush to a boy. This picture can equally well be described with both dative syntactic structures mentioned above. Persistence occurs if the same syntactic structure is used in the picture description and the prime sentence. In Bock's 1986b study a rather strong persistence effect for the dative sentences was obtained, but the effect for the transitive sentences was of a much weaker magnitude. Similar results were obtained in consecutive studies (Bock, 1989; Bock & Loebell, 1990; Bock et al., 1992).

We will now discuss a number of experimental variables that have been shown to determine syntactic structure in sentence production. These variables could therefore interfere with the persistence effect. We will restrict discussion to experiments with a picture description task, as these are the most relevant for our present purposes. See however, Bock (1977) for effects of pragmatic factors on sentence structure, Bock & Warren (1985) for effects of conceptual accessability, Bock (1986a) and Bock (1987) for effects of lexical accessability, Ferreira (1994) for the influence of thematic roles, McDonald, Bock, & Kelly (1993) for the influence of word length, animacy, and prosody, and Bock et al. (1992) for a discussion of the relation between animacy, agency and subjecthood.

To begin with, Flores d'Arcais (1973) showed that perceptual characteristics of pictures to be described, like size of agent and patient, position of agent, and direction of action, are determinants of syntactic structure. For instance, in pictures with the agent on the left and patients on the right, latencies for producing active sentences are shorter than in pictures with the reversed order of agent and patient.

Recent findings by Tomlin (1994) confirm the role of visual salience. If subjects have to describe short animations, for instance of a red fish eating a blue fish, visually cueing either the agent or the patient, 150 ms before the action took place, strongly determined the syntactic structure of the utterance. So if there appears an arrow pointing

at the agent of the action, participants very consistently used the active voice in their descriptions. If the patient was highlighted, participants produced passive responses.

Harris (1978) obtained effects of animacy in children's descriptions of pictures. The more animate the agent is (ranging from inanimate-animal-human), the more likely an active sentence is produced. A corpus study on written Dutch also reports animacy effects (Cornelis, 1995). In full passives, 66% of the agents tended to be inanimate. In actives, only 33% of the agents were inanimate.

In Bock's (1986b) Experiment 1, animacy of the agents and patients on the pictures possibly interfered with the effects of syntactic persistence: In half of the material the agents were animate and patients inanimate. These pictures were almost exclusively described with active sentences, regardless of the preceding prime sentence. In addition, Bock et al. (1992) observed an effect when the animacy of subject and object in the prime sentences was varied. They found that following a prime sentence with animate subject and inanimate object, there was a tendency to produce a sentence that repeated this assignment of elements with a certain animacy to grammatical functions. For instance, a picture depicting a boy being awakened by an alarm clock, would be more often described with:

(1a) The boy is being awakened by the alarm clock
following the prime
(2a) Five people carry the boat
But more often with:
(1b)The alarm clock awakens the boy
following the prime
(2b)The boat is being carried by five people.

Clearly, as in this example, such a tendency can reduce a structure priming effect in some conditions.

Another variable that could reduce priming is the (mean) number of fillers separating consecutive experimental trials (where a trial consists of a prime sentence and a target picture). Bock (1989) showed that the priming effect is smaller if this number is smaller. Finally, it is important to what degree participants pay attention to sentence form (Bock et al., 1992). There is a stronger priming effect when participants are instructed to pay attention to the form of sentences, than when they have to pay attention to the meaning of sentences.

The main variable of interest in the present experiments was the syntactic structure of prime sentences. In particular, Dutch word order allows for more syntactic structures than English for both datives and transitives. In all experiments, the set of transitives consisted of the Dutch equivalents of the active and passive transitive

sentences we know from English. In Experiments 1 and 2 the set of transitives was extended with a passive sentence with a sentence final past participle (e.g. de man wordt door de hond gebeten, the man is by the dog bitten). The set of datives (consisting of Dutch equivalents of the prepositional dative and double-object dative) was extended with a frontal dative (e.g. aan de vrouw geeft de man de kwast, to the woman gives the man the paintbrush) in Experiment 1. In Experiments 2 and 3, yet another dative structure was added to the dative set, a medial dative (e.g. de vrouw geeft aan de man de kwast, the woman gives to the man the paintbrush).

Baseline data were gathered in Experiments 2-4 by presenting subjects with target pictures that were preceded by filler sentences. Repetition of the prime sentence structure is not feasible in these cases, because the pictures cannot be described using a sentence with the structure of the preceding sentence. Therefore, the frequency of each syntactic structure in this condition can be taken to reflect a baseline frequency: The frequency in the absence of any structure priming.

Experiment 1

In Experiment 1 we attempted to obtain syntactic priming with transitives and datives in Dutch. Furthermore, we included transitive and dative sentence types not tested previously.

Method

Participants

The participants were 36 undergraduate students of Nijmegen University who were either paid for their participation or obtained course credits in an introductory psychology class. All were native speakers of Dutch.

Materials

There were 30 pictures depicting an event involving an agent and a patient (transitive pictures), 30 pictures depicting an event involving an agent, a theme and a recipient (dative pictures), 30 sets of transitive prime sentences and 30 sets of dative prime sentences. In addition, there were 45 filler sentences and 45 filler pictures, three practice sentences and three practice pictures.

Pictures.

Half of the transitive pictures, most of the dative pictures, and all filler pictures were taken from Bock's materials (Bock, 1986b, 1989; Bock & Loebell, 1990). Some of these pictures were adapted, in order to ensure that the event on the picture would not be too atypical for the Dutch culture. Pictures were all black and white line drawings.

They were scanned into an Apple Macintosh computer, and edited for clarity if necessary using an image-enhancement software package. The pictures filled a rectangular area on the computer screen of approximately 15 cm by 10 cm.

Transitive pictures depicted events that could be well described with an active sentence and with both types of full passives allowed in Dutch (e.g. 3a through 3c, followed here by their literal English translation).

(3a) Active De bliksem treft de kerk.
the lightning hits the church
(3b) Passive 1 De kerk wordt getroffen door de bliksem.
the church is hit by the lightning
(3c) Passive 2 De kerk wordt door de bliksem getroffen.
the church is by the lightning hit

In this chapter, actives as in (3a) will be referred to as 'AC' for short. We refer to passives as in (3b) with 'Passive of type 1' or 'P1' for short, and with passives as in (3c) with 'Passive of type 2' or 'P2'.

The agent of the action was displayed on the left side in 53% of the pictures, and on the right side in 47% of the pictures. In view of Bock's (1986b) observation that pictures with animate agents primarily elicited active sentences (see also Harris 1978) we decided to avoid such pictures. The only pictures that did show animate agents (13% of all pictures) also had animate patients, and the agent was "less animate" than the patient (e.g. a small animal biting a person; cf. Harris, 1978). About half (53%) of the pictures had inanimate patients and agents, and the remaining 47% had animate patients with inanimate/less animate agents. Three of the transitive pictures reoccurred as their mirror image (thus reversing left and right side of the picture), in order to replace three pictures that had been shown to elicit too few analyzable responses in a pilot study.

Dative pictures involved events that could be described with sentences involving an agent, a theme and a recipient. Examples of the tested structures are given in (4a-c).

(4a) PP-dative De advokaat geeft de brief aan de rechter.
the lawyer gives the letter to the judge
4b) DO-dative De advokaat geeft de rechter de brief.
the lawyer gives the judge the letter
(4c) FR-dative Aan de rechter geeft de advokaat de brief.
to the judge gives the lawyer the letter

We refer to the sentence in (4a) with 'Prepositional dative' or 'PP-dative' for short, to the sentence in (4b) with 'Double-object dative' or 'DO-dative' for short, and to the sentence

in (4c) with 'Frontal dative' or 'FR-dative' for short. In 47% of the dative pictures, the agent was on the left side and in the other 53% pictures the agent was on the right side. The theme was always in the middle. In all the 30 pictures both agent and recipient were animate, and the theme was inanimate. Six of the dative pictures reoccurred as their mirror image in order to replace six pictures that had been shown to elicit too few dative responses.

There were 45 filler pictures and three practice pictures. These pictures could be typically described with intransitive sentences and locatives (a cat sleeping, a girl sitting on the hood of a car).

Prime sentences.

The 30 transitive pictures were paired with 30 sets of transitive sentences, to be used as prime sentences. Each set consisted of three syntactic variants of the same sentence: An active, a passive of type 1 and a passive of type 2.

Agent and patient of prime sentences varied in animacy: Ten of the sentences had inanimate agents and patients, ten had animate agents and patients, and ten were of a mixed type, with mainly animate agents and inanimate patients. An attempt was made to minimize any semantic relatedness between each prime sentence and the picture it was to precede. For instance, one sentence set contained (5) and its two passive variants.

(5) De dokter onderzoekt de patient.
the doctor examines the patient

This sentence set was paired with a picture of a magnet attracting a coin (see the Appendix for a list of all stimulus materials).

The 30 dative pictures were paired with 30 sets of dative sentences. Each set consisted of three syntactic variants of the same sentence: A prepositional dative, a double-object dative and a frontal dative. The conditions of usage for prepositional datives and double-object datives in Dutch are comparable to English. In addition, Dutch has the possibility to topicalize the recipient by putting the prepositional phrase in front of the subject. All of the prime sentences had animate agents and recipients, and inanimate themes. Again, an attempt was made to minimize any semantic relatedness between sentences and pictures in a set, but in a small number of cases the action in both the sentence set and the corresponding picture involved handing over an object. However, the agent, recipient and theme in each sentence set were always different from the elements taking those roles in the corresponding pictures.

There were 45 filler sentences and three practice sentences comprising a wide range of syntactic structures. The filler sentences were comparable to experimental

sentences in length. In order to avoid peculiarities of experimental sentences drawing attention, we included fillers which resembled the experimental sentences in particular ways. Ten of the fillers contained the auxiliary verb 'worden' (be), that is used in passive sentences. Five fillers shared the preposition 'aan' (to) in first position with frontal datives.

List construction.

A 300-item master list was compiled in which all 60 experimental sentence sets and 60 experimental pictures appeared once, and all 45 filler sentences and 45 filler pictures appeared twice. The list was built up in a fixed format: First came three filler items (picture or sentence) followed by a transitive experimental trial (prime sentence set and picture), followed by three filler items and a dative experimental trial. The remainder of the list was constructed in the same manner. This way, there were always eight items between experimental trials of each type (including an experimental trial of the other type). Filler items were randomly assigned to the 180 positions available, with the constraint that no more than three pictures or sentences could follow each other. No constraints were placed on the distribution of trials that required a 'yes' or a 'no' response on the cover recognition task.

From the master list, nine experimental lists were derived, in such a manner that all three dative and transitive types of prime-sentences occurred ten times in each list, and that collapsed over the nine lists, each experimental picture was preceded three times by a prime sentence of each type.

Procedure

Subjects were tested in individual sessions lasting approximately 40 minutes. Sessions were recorded on audio tape. First, the subjects received a written instruction in which the experiment was introduced to them as a memory test. The purpose of this cover recognition task was to eliminate any strategies resulting from subjects being aware of the true nature of the task. Subjects had to respond 'yes' or 'no' to each item to indicate whether they had seen the item before or not. The instruction required that each sentence was read aloud, and that each picture was described with a single grammatically correct sentence, in order 'to help memorizing the sentences and pictures'. The instruction booklet contained a picture best described with an intransitive sentence. An example of a 'good' sentence was given, and of four 'bad' sentences. Items marked 'bad' were complex noun phrases, or had starter phrases, like 'I see a ...'

Before the experimental session, subjects were presented with ten practice items. These items consisted of three pictures and three sentences. Two of the pictures and two of the sentences occurred twice in the list. If subjects described a picture with an incorrect sentence according to the criteria stated above, they were given feedback

during the practice session. If subjects failed to supply a yes/no response, they were reminded to do so. During the experimental session, no feedback was given.

Each subject was presented with one of the nine lists. Each experimental list was given to four subjects. The task was self-paced: Participants could initiate presentation of the materials by pressing a button, and each item (sentence or picture) remained on the screen until the button was pressed again.

Scoring

Transcriptions of the audio tapes containing the sessions were made. Responses to experimental pictures were scored for syntactic structure. Transitive responses were classified as 'active' (AC), 'passive of type 1' (P1), 'passive of type 2' (P2) and 'others' (OT). Dative trials were classified as 'prepositional dative' (PP), 'double-object dative' (DO), 'frontal dative' (FR) and 'others' (OT). If subjects gave more than one response, only the first response was scored. An exception to this rule was made if the first response was clearly not meant as a description of the picture (e.g. 'Oh my... what is this?'). If subjects stuttered, made a restart or hesitated, the final form of the utterance was scored. If a syntactically incorrect sentence was produced, the response was scored as 'other'. An exception was made for omissions of articles (e.g. 'Dog bites man' is scored as active).

We used two different scoring criteria: Lenient and strict. If the prime and response did not consist of exactly the same constituents (for instance extra adjectives or adverbs, pronouns or proper names instead of nouns) the utterance was classified as the relevant dative or transitive structure with lenient scoring, but was scored as 'OT' with strict scoring. To be classified as an AC, P1, P2; PP, DO, FR, a sentence had to have an alternative in the other dative or transitive forms. For instance, (6) is not classified as an active because it cannot be passivized.

(6) De man ziet de lawine aankomen.
the man sees the avalanche approaching

The rationale for requiring the possibility to have alternatives of all tested syntactic structures, is that we can only assess an effect of priming when it is at least possible to produce all target structures.

A transitive sentence was classified as active when it contained the agent in subject position and the patient in direct object position. To be classified as a passive of either type, the patient had to be in subject position and the by-phrase had to contain the agent. If the 'by-phrase' followed the auxiliary 'worden' (be) or 'raken' (get) and the main verb, the response was classified as P1. A response was scored as P2 if the 'by-phrase' followed the auxiliary and preceded the main verb. Instrumental passives, locative

passives, static passives and truncated passives were classified as 'other'. Conjoined sentences were scored as actives or passives, if they adhered to the restrictions, e.g. (7) is classified as an active.

(7) De pijl vliegt en raakt de vogel.
the arrow flies and hits the bird

A dative utterance was classified as a prepositional dative if a dative verb was followed by the direct object and a prepositional phrase incorporating the indirect object. The preposition was required to be 'aan' (to). For dative verbs with a separable verbal complement (i.e. 'laten zien', to show, literally 'to let see'), two word orders were classified as prepositional dative - one with the verbal complement directly preceding the prepositional phrase, and one with a sentence-final verbal complement. In a double-object dative, there is no prepositional phrase, and the indirect object precedes the direct object. A frontal dative had to start with a prepositional phrase containing the indirect object, followed by the subject and direct object.

If the (in)direct object was a pronoun or a nominal constituent with an infinitive verb as head (Geerts, Haeseryn, De Rooij, & Van den Toorn, 1984), the sentence was scored as a dative (e.g. 'De zuster geeft de patient drinken.', 'The nurse gives the patient [something] to drink.'). However, if the direct object was a relative clause, like in (8), the utterance was classified as OT.

(8) Het kind laat zijn moeder zien dat hij zich gesneden heeft.
the child lets his mother see(inf) that he himself cut has
'The child shows his mother that he has cut himself.'

The reason is that all of the sentences where the direct object was a relative clause, had the direct object in sentence-final position.[4] Alternative word orders for these sentences sound unacceptable. Scoring these sentences as double-object datives would introduce a bias against prepositional datives. Conjoined dative sentences were scored as OT, if there was anaphoric reference to the (indirect) object with a pronoun (9).

(9) Het kind heeft een wond en laat dat aan zijn moeder zien.
the child has a wound and lets that to his mother see
'The child has a wound and shows it to his mother.'

[4]This observation agrees with recent findings by Stallings, MacDonald, & O'Seaghda (1995): speakers have a tendency to place 'heavy' constituents in sentence-final position.

The reason is that a double-object word order sounds unacceptable.

Design

Subjects were presented with all 30 transitive pictures and all 30 dative pictures. Prime type was a within-subjects factor: Subjects received ten prime sentences at each level of the transitive priming factor and ten prime sentences at each level of the dative priming factor.

Results

In Tables 1 and 2, the numbers of dative and transitive responses are listed per condition, using both strict and lenient scoring. As the tables show, the overall pattern of results with strict and lenient scoring are similar. However, especially in the case of datives, when applying the strict scoring rules few usable data points remain. The most important reason for that is that the dative items presented as primes often contained adjectives and possessive pronouns (See Appendix A). Repetition in strict sense required the subjects to use an adjective or pronoun as well in their picture description. In the remainder of this chapter we will only report results obtained with lenient scoring.[5]

Even when using a lenient scoring criterion we observed many responses classified as 'other' (OT-responses). This is an important difference with the experiments reported by Bock (1986b): Whereas we obtained proportions of OT-responses of a magnitude approximating 50% for transitives and 40% for datives, Bock (1986b; Experiment 1) observed proportions of only 15% for transitives and 20% for datives (however, the data are on par with the results in Bock et al. (1992), in which 47% of responses were classified as others). In Table 3, we divide utterances classified as 'others' into further subcategories, along with examples of each category. As Table 3 shows, this further categorization leads to an important decrease in the proportion of responses that cannot be classified.

Transitives

Transitive picture descriptions yielded 541 (50%) analyzable responses, i.e. responses not classified as 'others'. Thirty-four percent of analyzable responses occurred

[5]There are two additional reasons why the distinction was not made. firstly, as Bock(1989) showed, the persistence effect does not depend on prosodic similarity between prime and target description. Extra materials change the prosody, but not the syntactic structure beyond a reasonable level in the phrase structure tree. Secondly, it is implicit in Bock et al.'s work that this scoring rule was followed there. We found it desirable to score the utterances as much as possible in the same manner, in order to validly compare their results with ours.

in the condition with active primes, 34% in the condition with P1 primes and 32% in the condition with P2 primes. The number of actives, passives 1 and passives 2 in each prime condition are listed in Table 1, and depicted in Figure 1. ANOVA's were performed on the numbers of active responses, P1 responses and P2 responses, with prime category as a within-subjects variable. For each response type, there were two separate ANOVA's - one with subjects (F1) and one with items (F2) as a random factor.

TABLE 1

Response Frequencies for transitives in Experiment 1 (percentages in parentheses)

Prime[a]	*AC*	*P1*	*P2*	*OT*[b]
Strict Scoring				
AC	61 (16.9)	60 (16.7)	18 (5.0)	221 (61.4)
P1	61 (16.9)	58 (16.1)	15 (4.2)	226 (62.8)
P2	65 (18.1)	43 (11.9)	20 (5.6)	232 (64.4)
Lenient Scoring				
AC	87 (24.1)	71 (19.7)	28 (7.8)	174 (48.3)
P1	89 (24.7)	72 (20.0)	23 (6.4)	176 (48.9)
P2	94 (26.1)	51 (14.2)	26 (7.2)	189 (52.5)

a. Total number is 360 in each condition
b OT stands for 'Other' responses, i.e. responses not classified as Ac, P1, or P2.

In the ANOVA's on active and P2-responses, no significant effects of Prime type were found in the analysis with subjects as a random factor. The item analysis yielded similar results, $F2(2,58)<1$ for both active and P2 response.

The effect of Prime type was significant in the analysis on P1's for subjects ($F1(2, 70)=3.37$; $p<.05$), and marginally significant for items $F2(2,58)=3.13$; $p=.051$. However, planned comparisons revealed that the number of P1-responses following a P1-prime did not differ significantly from the mean number of P1-responses following the other two prime types: $F1(1,35) = 2.21$; $p=.146$; $F2(1,29)=1.93$; $p=.175$.

Datives

Of the dative picture descriptions, 617 responses were analyzable (57%). Of the analyzable responses, 34% occurred in the condition with PP-primes, 34% in the condition with DO-primes, and 32% in the condition with FR-primes. In Table 2 and Figure 2, the number of prepositional datives and double-object datives are given in each level of the Prime type factor.

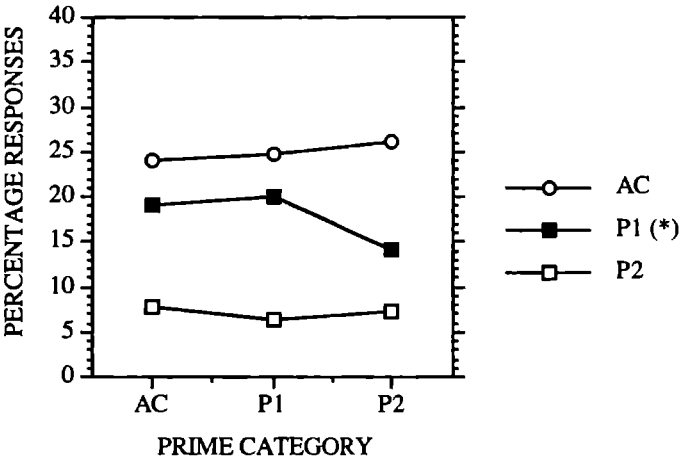

FIGURE 1. Active (AC), Passive 1 (P1), and Passive2 (P2) responses as a percentage of the total number of responses in each priming condition in Experiment 1.

TABLE 2

Response Frequencies for datives in Experiment 1 (percentages in parentheses)

Prime[a]	*PP*	*DO*	*FR*	*OT*[b]
Strict Scoring				
PP	35 (9.7)	19 (5.3)	1 (0.3)	305 (84.7)
DO	22 (6.1)	22 (6.1)	0 (0)	316 (87.8)
FR	29 (8 1)	18 (5.0)	0 (0)	313 (86 9)
Lenient Scoring				
PP	135 (37.5)	77 (21.4)	1 (0.3)	148 (41 1)
DO	104 (28.9)	104 (28.9)	0 (0)	151 (41 9)
FR	115 (31.9)	82 (22 8)	0 (0)	163 (45 3)

a Total number is 360 in each condition
b OT stands for 'Other' responses, i e responses not classified as PP, DO, or FR

As is clear from Table 2, an insufficient number of FR-responses was observed to permit a separate analysis on this response type. In the analysis with the number of PP-responses as the dependent variable, there was a significant main effect of Prime type ($F1(2,70)=5.17$; $p<.01$; $F2(2, 58)=3.22$; $p<.05$). Planned comparisons revealed that the number of PP-responses in the PP-prime condition was larger than the mean number of PP-responses in the other prime conditions ($F1(1, 35) = 10.25$; $p<.01$; $F2(1,29)=4.83$; $p<.05$).

In the analysis on the number of DO-responses, there was a significant main-effect of prime type ($F1(2,70)=3.86$; $p<.05$; $F2(2,58)=4.66$, $p<.02$). Planned

comparisons showed that the number of DO-responses in the DO-condition was significantly higher than the mean number of responses in the other conditions ($F1(1,35) = 9.80$; $p<.01$; $F2(1,29)=8.32$; $p<.01$).

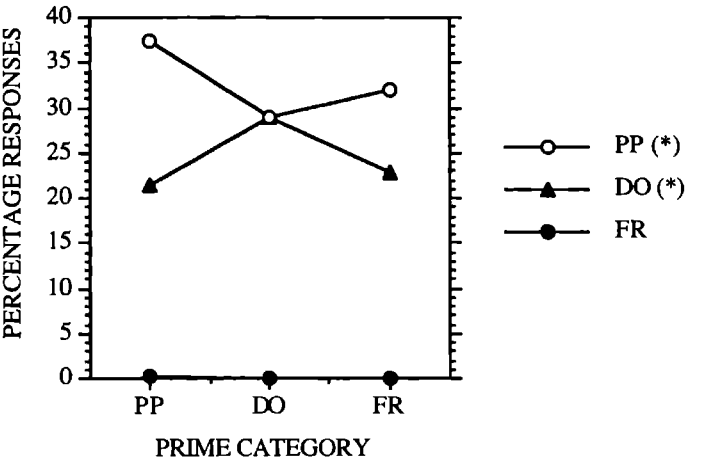

FIGURE 2. Prepositional phrase dative (PP), Double-object dative (DO) and Frontal datives (FR) responses as a percentage of the total number of responses in each priming condition in Experiment 1.

TABLE 3

Subdivision of OT-responses. Examples are followed by literal english translations.

Transitives	%	*Example*
Non-Reversable Active	12.7	De tank rijdt over de soldaat (The tank drives over the soldier)
Other Active	5.5	De skiërs zien een lawine aankomen (The skiers see an avalanche approaching)
Instrumental Passive	1	De bal wordt met de knuppel geslagen (The ball is with the bat hit)
Other Passive	6.9	Het bovenste deel van de fles wordt er afgeschoten (The top of the bottle is there shot off)
Not Classified	22.9	Er valt een steen op het hoofd van de jongen (There falls a rock on the boy's head)
Datives		
Nonreversable PP	4.1	De jongen gooit een bal naar het meisje (the boy throws a ball to the girl)
Other PP	7.8	De man geeft een brief in het postkantoor (The man gives a letter in the postoffice)
Other DO	.4	De jongen werpt de hond een bot toe (The boy throws the dog a bone to)
Medial dative	2.3	De jongen geeft aan het meisje een bal (The boy gives to the girl a ball)
Not Classified	27.3	De jongen geeft een brief (The boy gives a letter)

Discussion

The purpose of the experiment was to find evidence for repetition of syntactic structures for which this phenomenon has not been shown before. Therefore, a verb-final passive (P2) transitive was included, as well as a frontal dative (FR). We observed a fair number of P2's, but there was no priming effect. Frontal datives were almost never produced. This latter finding indicates that there are boundaries to the amount of influence a priming sentence can exert. Perhaps a frontal dative is only produced if there is a reason to topicalize the recipient. Such a reason is not offered in the experimental pictures (there may be such a reason if there were more than one potential recipient in the picture, and only one of them actually functions as such).

The results of Experiment 1 were surprising because we only managed to replicate part of Bock's (1986b) results: We found fair evidence for dative priming, but none for transitive priming. It is unclear why this is so.

One possible reason why transitive priming was not obtained, is that a number of items have a tendency to elicit primarily one of the two possible responses (active or passive). This bias might then be difficult to overcome by structure priming. However, 23 of the 30 transitive items yielded reasonable numbers of both actives and passives. The other seven items were almost exclusively described with non-analyzable sentences. (e.g. 'The tank bumps on the car'). In sum, there is no indication that such a bias interfered with the priming effect.

A second explanation is related to processing differences in the production of transitives and datives. Prepositional and double-object datives are syntactically the same up to and including the verb. This is not the case for actives and passives: These structures are different, from the first NP onwards. Suppose the effect of priming is not immediate, but somewhat delayed (e.g. Berg & Schade, 1992; MacKay, 1987). In MacKay's activation model, a syntactic structure may be represented by a node that has an activation level that is determined by events occurring in time. Prior to an experimental trial, the activation level is at resting level When the prime trial is presented, forcing the subject to produce a sentence with that particular structure, activation is fed to the node until its activation level exceeds a threshold. Then, this node is fed a 'jolt of activation' (cf. also Dell, 1986), and the node is selected. A sentence with that structure is now produced. Crucially, immediately following production, the node's activation first decreases below threshold: It is temporarily unavailable for selection. Following that period, activation bounces back. Activation is now above resting level. In fact, it is this latter period in which the node is said to be 'primed'. If, during that period, a target picture is presented, input fed to that node would bring its activation level much faster to threshold, and hence the probability of selection increases.

The MacKay (1987) model can explain the priming effect for datives and the lack of priming in the case of transitives if we assume the following. A priming effect is only observed if, at the moment a syntactic structure needs to be selected, the activation of the target structure is above resting level. If the activation level is still in the 'postselection inhibited state', no effect of priming will surface. If, on the other hand, the selection moment comes very late, activation of the target node has decayed to resting level. In other words, it is essential that the activation level is in the 'rebound' period. Because the two dative alternatives are syntactically the same much longer than the transitive alternatives, the moment of selection relative to picture presentation, comes about later for these structures. It is conceivable then, that selection of a transitive alternative takes place at the moment the target structure is still in the inhibited state, whereas selection of a dative alternative takes place when the target structure is already in the rebound period.

If this account is correct, increasing the temporal interval, separating prime and target, sufficiently should result in obtaining a priming effect for transitives. In Experiment 2, this explanation is tested.

A third explanation of the results concerns the way in which animacy was distributed within the priming sentences. In the Introduction we briefly mentioned the finding by Bock et al. (1992), that there is a persistence of assigning the grammatical role of subject and object to elements with a given animacy. For instance, following a prime with an inanimate subject and an animate direct object (e.g. 2b, repeated here as 10), one is more likely to describe a subsequent picture with a sentence having an inanimate subject and an animate object as well (e.g. 1b, repeated here as 11).

(10) The boat is being carried by five people.

(11) The alarm clock awakens the boy.

It is obvious that if the effects of this type of priming and of syntactic persistence are additive, which is exactly what Bock et al. claimed, than the two effects can counteract each other.

Such an additive effect may be responsible for the lack of transitive priming in Experiment 1: In the majority of the transitive trials, the distribution of animacy was such that the two types of priming would counteract each other. There were only five trials in which both types of persistence would have the same effect on syntactic structure: When considered separately, these trials yielded means in the predicted direction. In Experiments 2-4, the transitive materials are balanced with respect to the animacy of agent and patient in the prime sentences.

Two final explanations for the lack of transitive priming are related to methodological differences between our Experiment 1 and Bock et al.'s experiments.

First, we presented three types of transitive prime sentence, whereas they only used two. In addition, we used visual presentation of the prime sentence whereas they presented the sentences auditorily. These considerations are addressed in turn in Experiments 3 and 4.

Experiment 2

Experiment 2 had three main purposes. First, the question is addressed whether a transitive priming effect can be obtained. The hypothesis is tested that increasing the time separating prime and target will introduce a priming effect in transitives, but will leave dative priming intact. Therefore, ISI was manipulated experimentally. Because the task was self-paced, actual timing between the end of reading aloud the prime sentence and appearance of the target picture could vary. Therefore, we refer in this article with ISI to the time from the button press which brought about picture appearance to the actual appearance of the picture on the screen. In one condition, the picture appeared as soon as the refresh rate of the computer monitor allows (<20msec), in the other condition, there was a 1000 msec delay. These conditions are referred to as the ISI=0 and ISI=1000 conditions respectively. In addition, sentences and pictures were balanced with respect to the animacy of agents and patients. In this way, we controlled for the effects of a possible persistence of assigning elements with a certain animacy to subject and object positions.

The second purpose of the experiment was to demonstrate a priming effect for structures not tested before. In the transitive material, the same prime types as in Experiment 1 were presented: Actives, passives 1 and passives 2. Assuming that we will find transitive priming with a longer ISI, it is of interest to see whether it also occurs for P2. In the dative material, the set of prime structures was extended with a 'medial dative', a sentence type that consists of the same constituents as a prepositional dative, but has the word order of a double-object dative. An example is given in (12).

(12) De boer verkoopt aan zijn buurman een varken.
the farmer sells to his neighbor a pig
'The farmer sells a pig to his neighbor.'

The third purpose of the experiment was to collect baseline data. With a baseline, we are able to assess the relative contribution of facilitation and inhibition to the overall priming effect. Second, with these data, we will also have an indication of the relative frequency of the various structures. This will allow us to establish the extent to which syntactic priming is dependent upon frequency.

On a number of points, the methodology was improved in comparison with Experiment 1 First, the number of fillers between trials was increased This was done to eliminate as much as possible any interference from priming in previous trials Second, only filler pictures that elicit intransitive responses were included As a consequence, filler pictures were now as neutral as possible with respect to syntactic structures of experimental items Third, there was now complete balancing of animacy in prime and picture, and of position of agent and patient on the picture. In addition, pictures that elicited mainly 'other' responses were removed Finally, a number of new pictures were designed so that we no longer needed to include items that were mirror images of one another.

Method

Participants[6]

Participants were 84 students of Nijmegen University, who were paid for their participation or obtained course credits All were native speakers of Dutch All 84 participated in the transitive part of the experiment, but only 42 participated received the dative trials (See Footnote 6) None of them participated in Experiment 1.

Materials

There were 28 dative pictures and 28 transitive pictures Half of the transitive pictures had inanimate agents and animate patients, the other half had inanimate agents and patients Dative and transitive pictures were completely balanced for the position of agent and patient/recipient (left or right). In addition, there were 56 filler pictures These depicted events that could best be described with intransitive sentences, without any prepositional phrases. Pictures from the previous experiment, which tended to evoke responses with prepositional phrases were excluded. Five of the filler pictures reoccurred as their mirror image None of the experimental pictures were mirror images of other pictures

Each transitive picture was paired with a set containing six prime sentences A congruent and an incongruent sentence of the three tested syntactic structures (active, passive 1 and passive 2). For pictures with inanimate agents and patients (henceforward referred to as II-pictures), incongruent sentences had animate agents and patients For

[6]The 84 subjects were divided into two groups of 42 subjects, group 1 and group 2 Both groups were presented with the transitive materials However, only group 2 received the dative materials that are described above Group 1 received other dative and locative prime sentences, which are not relevant for our present purposes In all other respects, the experiments were the same for subjects in group 1 and group 2 In sum, the transitive data here reported are based on both groups The dative data are based on group 2 only

pictures with inanimate agents but animate patients (IA-pictures), incongruent sentences had animate agents and inanimate patients. Transitive sentences within a set had the same verb and were matched with respect to the frequencies of the agents and frequencies of the patients. A complete listing of the stimulus materials can be found in the Appendix.

Each dative picture was paired with a set of three priming sentences: A prepositional dative, a double-object dative and a 'medial' dative as in (12). In this article we will refer to 'medial dative' with 'MM'.

There were eight sentences serving as baseline sentences[7], and 56 filler sentences. The set of filler/baseline sentences contained intransitive sentences, clefts, reflexives, and various other syntactic structures.

A 336-item master list was created in which all 56 filler pictures and 56 filler sentences occurred twice. The list was randomized, with the constraint that no more than three pictures or three sentences could follow each other in a row. An experimental trial (prime sentence and picture) was presented, following every four filler items, with transitive and dative trials alternating. This way, the number of items between any two transitive or dative trials was always ten items (including one trial of the other type). The first four transitive trials and the first four dative trials served as the baseline condition: Experimental pictures were preceded by filler sentences.

From the master list, seven experimental lists were derived, in such a manner that across the lists, every experimental picture occurred once in the baseline condition (first eight trials) and twice in each level of the Prime type factor. Within each level of the Prime factor, each transitive picture was preceded once by a congruent prime and once by an incongruent prime. Within a particular list, there were always eight items in each transitive condition (4 II-pictures and 4 IA pictures), and eight in each dative condition.

Procedure

The procedure was the same as in Experiment 1.

Scoring

The same scoring rules were used as in Experiment 1, with one exception: Datives were categorized as PP, DO and as MM (this last category was treated as 'other' in Experiment 1). An MM-dative has agent in subject position, followed by the dative verb, a prepositional phrase incorporating the oblique object, followed by the direct object. FR-datives were scored as 'others'.

[7]It is possible that there was a bias to produce passives in the baseline condition, because three out of four transitive baseline trials had animate subjects. Because none of the pictures depicted animate agents, a persistence of having animate subjects would lead to a preference for passives.

Design

Transitives. ISI (0, 1000) was a between-subject variable and Prime (AC, P1, P2) was a within-subject variable. Forty-two subjects were presented with an ISI of 0, and 42 with an ISI of 1000. Eight trials were presented in each cell of the within-subject factor. Four of these trials were congruent in the distribution of agent and patient (i.e. the agent in the sentence had the same animacy as the agent in the picture, and ditto for the patients). The other four trials were incongruent in this distribution.

Datives. Forty-two of the subjects received the dative trials (see Footnote 6). Twenty-one subjects were presented with an ISI of 0, and 21 with an ISI of 1000. They received eight trials of each prime type (PP-dative, DO-dative, MM-dative).

Results

Transitives

In the experimental conditions, 1110 of the transitive responses were analyzable (55%). In the baseline condition, 122 transitive responses were analyzable (36%). Of the analyzable responses in the experimental conditions 33% occurred in the AC-condition, 34% occurred in the P1-condition and 33% occurred in the P2-condition. The number of actives, passives 1 and passives 2 in each level of the Prime and ISI factors are presented in Table 4. In Figure 3, the proportions of responses are depicted graphically, collapsed over ISI.

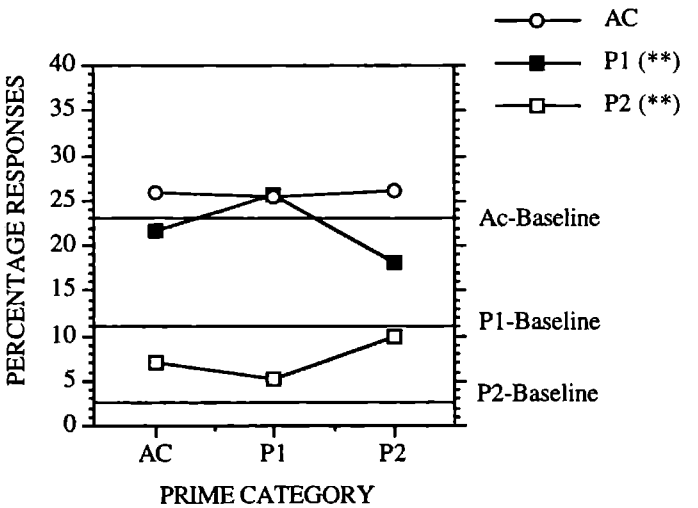

FIGURE 3. Active (AC) , Passive 1 (P1), and Passive 2 (P2) responses as a percentage of the total number of responses in each priming condition in Experiment 2, collapsed over ISI. Baselines indicate percentage of responses in control condition.

TABLE 4

Response Frequencies for transitives in Experiment 2 (percentages in parentheses).

Prime[a]	*AC*	*P1*	*P2*	*OT*
AC				
ISI=0	82 (24.4)	84 (25.0)	14 (4.2)	156 (46.4)
ISI=1000	93 (27.7)	61 (18.2)	33 (9.8)	149 (44.3)
Overall	175 (26.0)	145 (21.6)	47 (7.0)	305 (45.4)
P1				
ISI=0	93 (27.7)	93 (27.7)	13 (3.9)	137 (40.8)
ISI=1000	78 (23.2)	79 (23.5)	22 (6.5)	157 (46.7)
Overall	171 (25.4)	172 (25.6)	35 (5.2)	294 (43.8)
P2				
ISI=0	99 (29.5)	61 (18.2)	18 (5.4)	158 (47.0)
ISI=1000	77 (22.9)	61 (18.2)	49 (14.6)	149 (44.3)
Overall	176 (26.2)	122(18.2)	67 (10.0)	307 (45.7)
BA				
ISI=0	42 (25)	13 (7.8)	2 (1.2)	111 (66.1)
ISI=1000	36 (21.4)	23 (13.7)	6 (3.6)	103 (61.3)
Overall	78 (23.2)	36 (10.7)	8 (2.4)	214 (63.7)

a. Overall total number is 672 in the conditions AC, P1 and P2, and 336 in the baseline condition (BA).

We conducted ANOVA's on each response type with ISI as a between-subject variable and Prime type as a within-subject variable.

In the analysis with active responses as the dependent variable, there was no effect of Prime type. In the ANOVA on P1-responses, an effect of Prime type was obtained: ($F1(2,164) = 5.92$; $p<.01$; $F2(2,54)=4.95$; $p<.02$). Planned comparisons revealed that P1-primes were more likely to elicit P1-responses than other primes were ($F1(1, 82) = 8.74$; $p<.01$; $F2(1,27)=7.28$; $p<.02$). The ANOVA on P2-responses also yielded an effect of Prime type ($F1(2,164)=5.53$; $p<.01$; $F2(2,54)=4.53$; $p<.02$). Planned comparisons showed that P2-primes were more likely to elicit P2-responses than other primes were ($F1(1,82)=7.50$; $p<.01$; $F2(1,27)=6.40$; $p<.02$).

In none of the analyses did we find a significant main effect of ISI when subjects were treated as a random variable; in the item-tests, significant effects were obtained with passive responses (P1-responses: $F2(1,27)=5.45$; $p<.05$; P2-responses: $F2(1,27)=33.34$; $p<.001$).

If ISI is important for the occurrence of a priming effect, we should obtain a significant interaction between Prime type and ISI. However, the interactions were in general not significant. In the analysis on actives, the interaction was only significant in the item test: $F2(2,54)=3.64$; $p<.05$. In the analysis on P1-responses, the interaction was not significant. In the analysis on P2-responses, the interaction was marginally significant ($F1(2, 164)=2.57$; $p=.08$; $F2(2,54)=2.40$; $p=.10$). In sum, there is little statistical support for the hypothesis that ISI is important for obtaining a priming effect.

In Table 5, the priming effects are listed per animacy congruency condition. The table lists within each animacy congruency condition, for each response type, the proportion of responses in the condition with the same prime, minus the mean number of responses in the other conditions. For instance, the column labeled 'AC' stands for the proportion of AC-responses in the condition with active primes, minus the mean proportion of AC-responses in the other two prime conditions. This parameter thus indicates the magnitude of the priming effect in that condition. Inspection of the first row in Table 5 suggests that in the present experiment, animacy congruency is not important for a priming effect to occur. This informal observation is supported by analyses: Separate ANOVA's were conducted on each response type, with Prime type (AC, P1, P2), Picture type (IA, II) and Congruency (Congruent, Incongruent) as within-subject factors. The data were collapsed over ISI. If it is the case that animacy congruency is important for the occurrence of structure priming, a significant interaction should be obtained between the Prime type and Congruency factors. However, because animacy congruency is not likely to matter when Picture type is II, one would actually expect a significant three-way interaction between the factors. In contrast with these predictions, in none of the ANOVA's was either of the interactions significant.

TABLE 5

Priming effects for the Congruent (IA/IA) and Incongruent (AI/IA) conditions of Experiments 2-4.[a]

	AC		*P1*		*P2*	
	CON	*INC*	*CON*	*INC*	*CON*	*INC*
EXP2	-.9	.6	6.9	3.0	4.1	7.4
EXP3	.8	-4	4.8	0	-	-
EXP4	-1.2	4.7	2.4	-1.2	-	-

a. The priming effects are calculated by subtracting the percentage of responses in the other experimental conditions from the percentage of responses in the same condition.

Interestingly, the factor Picture type was significant in both the analyses on AC-responses ($F(1,83)=174.04$; $p<.001$ and P1-responses ($F(1,83)=5.95$; $p<.02$). II-pictures

tend to elicit more actives than IA-pictures do, and IA-pictures tend to elicit more passives than II-pictures do.

Datives

In the experimental conditions 637 dative picture descriptions were analyzable (63%). Of the analyzable responses, 34% occurred in the condition with PP-primes, 33% in the condition with DO-primes, and 32% in the condition with MM-primes. In the baseline condition, 80 responses were analyzable (48% of the responses). In Table 6, the number of prepositional datives, double-object datives and medial datives in each level of the Prime factor are shown. The proportions are depicted in Figure 4.

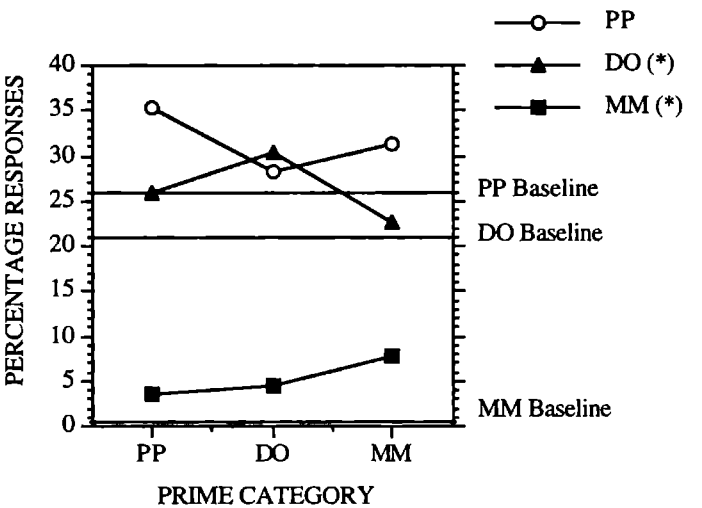

FIGURE 4. Prepositional phrase dative (PP), Double-object dative (DO) and Medial datives (MM) responses as a percentage of the total number of responses in each priming condition in Experiment 2, collapsed over ISI. Baselines indicate percentage of responses in control condition.

TABLE 6

Response frequencies for datives in Experiment 2, collapsed over ISI (percentages in parentheses)

Prime[a]	*PP*	*DO*	*MM*	*OT*
PP	119 (35.4)	87 (25.9)	12 (3.6)	118 (35.1)
DO	95 (28.3)	102 (30.4)	15 (4.5)	124 (36.9)
MM	105 (31.3)	76 (22.6)	26 (7.7)	129 (38.4)
BA	44 (26.2)	35 (20.8)	1 (0.6)	88 (52.4)

a. Total number is 336 in the conditions PP, DO, MM, and 168 in the baseline condition (BA).

In the analyses on dative responses, data were collapsed over the ISI factor, because first ISI was not a variable of interest with respect to datives, and second, visual inspection of separate tables for each ISI-condition revealed almost identical patterns of results.

In the ANOVA on the number of PP-responses, there was no effect of Prime type ($F1(2,82)=2.70$; $p=.073$; $F2(2,54)=2.4$; $p=.101$). Planned comparisons suggested that PP-primes are more effective in evoking PP-responses than the other primes: ($F1(1, 41)=3.96$; $p=.053$; $F2(1,27)=3.53$; $p=.071$. In the analysis with the number of DO-responses as the dependent variable, there was a main effect of Prime type ($F1(2,82)=3.42$; $p<.05$; $F2(2,54)=4.94$; $p<.02$). Planned comparisons revealed that the number of DO-responses was significantly larger following DO-primes, than following the other primes ($F1(1,41)=4.50$; $p< .05$). $F2(1,27)=7.47$; $p<.02$).

A significant effect of Prime type was also obtained in the analysis on MM-responses ($F1(2,82)=3.61$; $p<.05$; $F2(2,54)=5.04$; $p=.01$). Planned comparisons revealed that MM-responses occur significantly more often in the MM-prime condition than in the other two conditions ($F1(1, 41)=5.35$; $p<.05$; $F2(1,27)=9.62$; $p<.01$).

Discussion

The main purposes of this experiment were to examine the influence of ISI and animacy congruency on the occurrence of a transitive priming effect, to generalize the priming effect to structures not tested before (i.e. the MM-dative and the P2-transitive) and to collect baseline data.

In the experiment, priming effects were obtained for transitive structures: Both passives of type 1 and passives of type 2 were persistent, in contrast to the results of Experiment 1. Is the finding of transitive persistence for at least some structures due to the inclusion of a condition with a longer ISI? The data do not support this ISI-explanation: In general, the interactions between Prime type and ISI failed to reach significance. Comparing the ISI=0 and ISI=1000 rows in Table 4, we find this not surprising: The P1 responses and P2-responses are in the predicted direction in both ISI-conditions. An important difference between the results in the ISI=0 condition and those in the ISI=1000 condition, is the trend towards active persistence in the latter condition. We think it reasonable to consider the possibility that with a better controlled ISI-manipulation and with more levels of the ISI-factor, effects of ISI may arise. This is a question to be addressed in further research.

A second explanation for the occurrence of transitive effects in the present experiment as opposed to the previous experiment, is the better balancing of animacy congruency in the present experiment. Animacy plays an important role in the choice of syntactic structure. The results show that IA-pictures tend to elicit more passives, and

II-pictures more actives. However, congruency between animacy of agents and patients in prime and picture was not important for the occurrence of priming, as we hypothesized.

In sum, we do obtain transitive priming effects in this experiment, but not in Experiment 1. It does not appear to be the case that either the temporal characteristics of the priming effect, or interference by an effect of animacy congruency can explain this difference.

The second purpose of the experiment was to generalize the effect of structure priming to novel structures. In this we succeeded: We obtained a structure priming effect for the passive with clause-final verb (P2) and for the medial dative (MM). In addition, we replicated some of the dative effects of Experiment 1: We found a significant effect in the analysis on DO-responses. However, the effect was only marginally significant for PP-responses.

Third, we collected baseline data in the experiment. These were all based on the first four dative and transitive trials. A characteristic of the baseline proportions compared to the other proportions is immediately clear upon visual inspection of Figures 3 and 4. The proportion responses of each target structure are lower in the baseline condition than in any of the other conditions. That is, in the experimental conditions, more transitive and dative responses are produced, irrespective of prime type. Consider P1-responses. Whereas only 10.7% of responses in the baseline condition are P1, the proportions in the AC, P1 and P2 condition are, respectively, 21.6%. 25.6% and 18.2%. A similar difference between baseline and experimental conditions applies with respect to P2-transitives and to MM-datives.

This difference in response frequency between baseline and other conditions can be explained by assuming an effect of repeatedly priming the target structures in the experiment. As a consequence, the target structures are all more accessible than other structures, regardless of the particular prime structure most recently encountered (see also Bock & Loebell, 1990). In the remainder of this dissertation we will refer to this effect as Long Term Priming (LTP) because it results from many trials. Because the baseline trials all occur in the beginning of the experiment there is no effect of LTP there.

Unfortunately, the difference in response frequencies results in a problem of interpretation: It is impossible to reliably assess whether a prime of one structure inhibits or facilitates the response of a sentence of another structure.

Experiment 3

In the first two experiments, evidence for dative syntactic persistence was obtained. However, only in Experiment 2 did we find evidence for transitive priming,

and only for passives. In Experiment 3 we test whether the number of prime types presented can account for the lack of priming for actives in Experiment 2. The rationale is the following: When two structures are presented, a priming effect for one structure results in a priming effect for the other structure as well (assuming the same total number of analyzable responses in each condition). However, this is not the case when three structures are presented.

To clarify this, let us consider the case where there are two types of prime. Suppose that active primes exert no effect on the distribution of active and passive responses as compared to a baseline. Suppose furthermore that passive primes do exert an influence: They increase the number of passive responses, and ipso facto decrease the number of active responses. Then the number of active responses would be higher in the active condition than in the passive condition.

However, in the case where there are three types of prime, and consequently three types of response, an increase in the number of P1-responses in the P1-prime condition does not automatically lead to a decrease of active responses in that condition: It is possible that the number of P2-responses decreases instead. This explanation is illustrated graphically in Figure 5. Notice that the hypothetical data depicted therein are a fair approximation of the data in Experiment 2. In our opinion this explanation could offer a good account of the data.

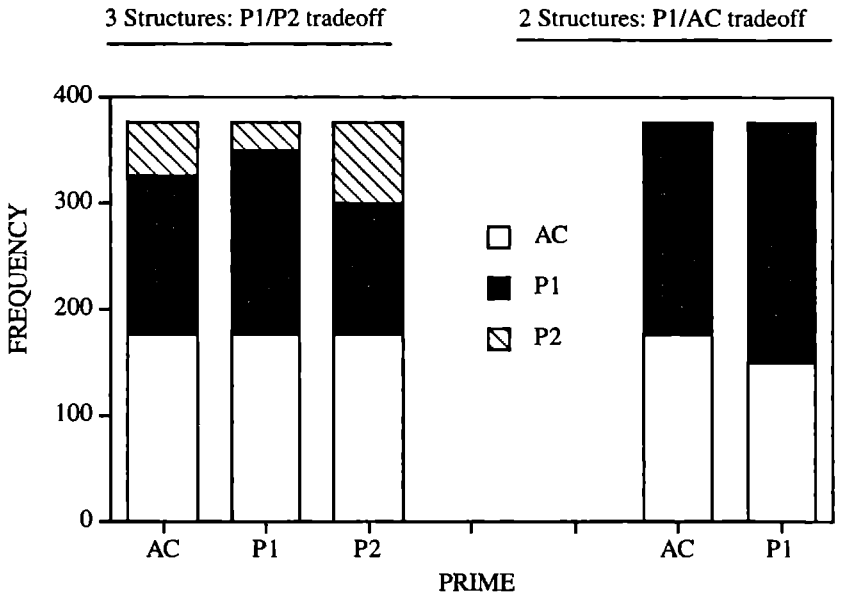

FIGURE 5. Idealized data of Experiment 2. When testing 3 structures: Whereas the total of active responses is the same in each condition, the frequencies of the two passive responses trade-off. When testing 2 structures: Assuming a fixed total of transitive responses and a passive priming effect, the number of actives is highest in the active condition.

The explanation put forward above is put to the test in Experiment 3. Instead of the three transitive prime types used previously, only two structures were presented: Actives and passives of type 1. In addition to the transitive materials, the same dative materials as in the previous experiment were presented.

Method

Participants

The participants were 42 undergraduate students of the University of Nijmegen. They were paid Dfl 8.50 for their services. None of the subjects participated in the other experiments reported here.

Materials

The same pictures and sentences as in Experiment 2 were used. However, each transitive prime set consisted only of four structures: An active and a passive 1, one animacy congruent and one animacy incongruent. The master list of Experiment 2 was used to derive seven new lists in which each of the 28 transitive pictures occurred. The first four pictures in each list were preceded by filler sentences: These served as the baseline. The remaining 24 pictures were preceded by 12 active and 12 passive primes. Across lists, each picture occurred once in the baseline condition, three times with an active prime and three times with a passive prime.

The dative sentences and pictures were the same as in the previous experiment. Their assignment to the seven lists was also the same, yielding Experiment 3 a direct replication of the previous experiment.

Procedure

The procedure was the same as in Experiments 1 and 2. ISI was kept constant at a value of 1000 msec.

Scoring

Scoring was performed in the same way as in Experiment 2 with the exception that responses previously classified as P2, were now classified as OT.

Design

Each subject received 12 trials in each of the two levels of the transitive Prime factor. Six of these were animacy congruent and six animacy incongruent. Each subject received 8 trials in each of the three levels of the dative Prime factor.

Results

Transitives

Of the transitive trials in the experimental conditions, 508 responses were analyzable (50%). Of the trials in the baseline condition 64 responses were analyzable (38% of the responses). Of the analyzable responses in the experimental conditions 48% occurred in the active condition and 52% occurred in the passive condition. The number of actives and passives 1 and passives 2 after each type of prime are presented in Table 7 and Figure 6. As Table 7 shows, the number of active responses following active primes (100) is lower than the number of actives following P1-primes (125), in contrast to our hypothesis.

In the ANOVA on active responses, the negative priming effect fell just short of conventional levels of significance in the analysis on participants ($F1(1,41)=3.21$; $p=.081$). However, this inhibition effect was significant in the item analysis ($F2(1,27)=4.99$; $p<.05$). No significant effects were obtained in the analyses with the number of P1-responses as the dependent variable.

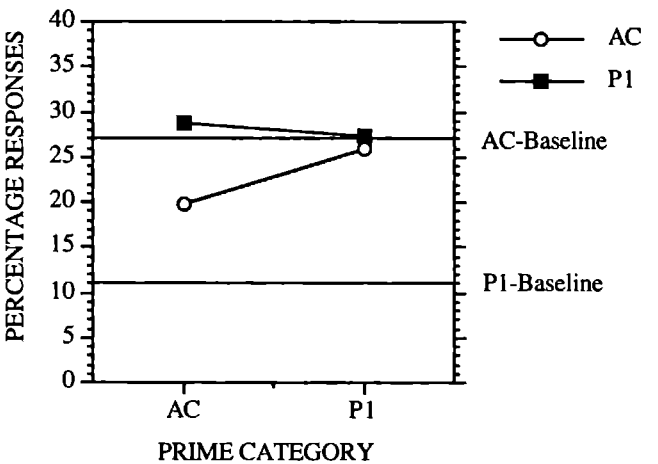

FIGURE 6. Active (AC) and Passive 1 (P1) responses as a percentage of the total number of responses in each priming condition in Experiment 3. Baselines indicate percentage of responses in control condition.

Because our materials were balanced with respect to animacy congruency, we were again able to determine whether there were priming effects in the animacy congruent condition and not in the incongruent condition. Inspection of the second row of Table 5 indicates that there indeed appears to be a positive priming effect for passives in the congruent condition, but not for actives.

TABLE 7

Response Frequencies for transitives in Experiment 3 (percentages in parentheses)

Prime[a]	*AC*	*PI*	*OT*
AC	100 (19.8)	145 (28.8)	259 (51.4)
PI	125 (24.8)	138 (27.4)	241 (47.8)
BA	45 (26.8)	19 (11.3)	104 (61.9)

a. Total number is 504 in the conditions AC, PI, and 168 in the baseline condition (BA)

Datives

Of the dative picture descriptions, 671 responses were analyzable (67%). Of the analyzable responses, 34% occurred in the condition with PP-primes, 32% in the condition with DO-primes, and 33% in the condition with MM-primes. In Table 8 and Figure 7, the number of prepositional datives, double-object datives and medial datives are given following each type of prime.

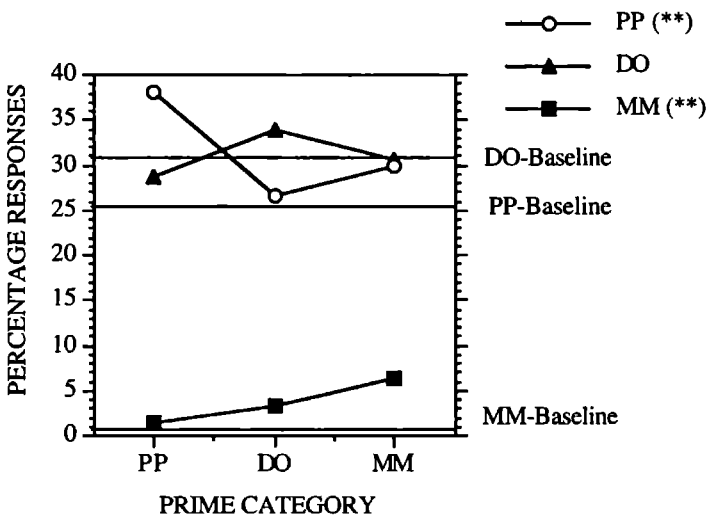

FIGURE 7. Prepositional phrase dative (PP), Double-object dative (DO) and Medial datives (MM) responses as a percentage of the total number of responses in each priming condition in Experiment 3. Baselines indicate percentage of responses in control condition.

In the analysis with the number of PP-responses as the dependent variable, there was a main effect of Prime type ($F1(2,82)=5.42$; $p<.01$; $F2(2,54)=5.19$; $p<.01$). Planned comparisons showed that the number of PP-responses was significantly larger when following PP-primes, than when following the other primes ($F1(1,41)=10.46$; $p< .01$; $F2(1,27)=12.06$; $p<.01$).

TABLE 8

Response frequencies for datives in Experiment 3

Prime[a]	*PP*	*DO*	*MM*	*OT*
PP	128 (38.1)	96 (28.6)	5 (1.5)	107 (31.8)
DO	93 (26.7)	114 (33.9)	11 (3.3)	118 (35.1)
MM	100 (29.8)	103 (30.6)	21 (6.3)	112 (33.3)
BA	43 (25.6)	52 (31.0)	2 (1.2)	71 (42.3)

a. Total number is 336 in the conditions PP, DO, MM, and 168 in the baseline condition (BA).

In the analysis on the number of DO-responses, there was no effect of Prime type ($F1(2,82)=1.30$; $p=.277$) $F2(2,54)=1.39$; $p<.257$).

Significant effects of Prime type were obtained in the analyses on MM-responses ($F1(2,82)=5.42$; $p<.01$; $F2(2,54)=4.97$; $p=.01$). Planned comparisons revealed that MM-responses occur reliably more often following MM-primes than following the other two primes ($F1(1,41)=6.12$; $p<.02$; $F2(1,27)=6.80$; $p<.02$).

Discussion

In Experiment 3 we tested the theory that attributes the lack of priming for actives obtained in Experiment 2 to the fact that we tested three structures, as opposed to two structures in the work of Bock and colleagues. According to this theory, a priming effect for both passives and actives should have been obtained in the present experiment. The results are clear cut in this respect: There is no evidence for a priming effect. Rather, there was a trend in the opposite direction for actives, and no effect at all for passives.

This finding does not necessarily falsify our explanation: It falls outside the domain to which the theory is applicable, because one implicit assumption of the explanation was that there is a priming effect for passives of type 1. This was not the case.[8]

The lack of transitive priming observed in this experiment, is in accordance with the results of Experiment 1. However, the findings are hard to reconcile with the priming effect for passives we obtained in Experiment 2. A final explanation for the lack of transitive priming is tested in Experiment 4.

In the present experiment we obtained almost exactly the same baseline data for actives and passives of type 1 as in Experiment 2. Again, the proportion of passives is

[8]Notice that the explanation would still hold if it were Passives of type 2 only that exerted a priming effect.

raised considerably from the baseline proportion, regardless of prime condition. The proportion of actives actually drops below the baseline in both prime conditions. In addition, the proportion of transitive (active or passive) responses is once again much lower in the baseline condition than in the other conditions.

Turning now to the datives, we replicated the priming effect for the MM-dative. In addition, PP-datives showed persistence. However, no significant effect was obtained for DO-datives, although the means were certainly in the predicted direction.

Experiment 4

In the present experiment, one final explanation is tested for the lack of transitive facilitation observed in the previous experiments. This explanation is based on one important methodological difference between the experiments of Bock et al., and our Experiments 1-3. In our experiments, we presented the prime sentences visually, and the prime sentence remained on the computer screen until the subject initiated the next trial. On the other hand, in Bock et al.'s experiments the auditory modality was used. It is conceivable that visual presentation of the prime sentence requires less profound syntactic planning. The subject would use the words available to him on the computer screen. It is conceivable that this results in a smaller memory demand, and hence less need to create so much structure.

On the other hand, the fact that we obtained priming effects for dative sentences in the previous experiments seems inconsistent with the notion outlined above. There is no obvious reason why there should be an interaction between mode of presentation and sentence type, such that there is a priming effect for datives with visual presentation, and a priming effect for both types of sentence with auditory presentation. However, a different argument can be made by referring to the magnitude of the priming effects. For instance, in Bock (1986b) the magnitude of the priming effect for datives was considerably larger than the one for transitives. If visual presentation requires less planning, and this reduces the priming effect, the effect for datives may be robust enough to still appear, whereas the effect for transitives, which is inherently weaker, would not surface. In the present experiment, this explanation is tested by using auditory presentation of the priming sentences.

Method

Participants

Eighty-four undergraduate students of Nijmegen University participated. They received course credit or were paid Dfl 7.50 for their participation.

Materials

We selected 12 transitive and 12 dative pictures that had shown to elicit a fair number of usable responses in the previous experiments. Each transitive prime set consisted of four sentences, an active and a passive, one animacy congruent and one animacy incongruent. There were six lists, in which each of the 12 transitive pictures occurred. The first four pictures in each list were preceded by intransitive sentences: These served as the baseline. The remaining eight pictures were preceded by four active and four passive primes. Across lists, each picture occurred twice in each condition (Baseline, Active prime, Passive prime). The lists were balanced with respect to (1) position of agent (left or right) (2) animacy of patient in picture (agents were all inanimate) (3) animacy congruency (agent (patient) has same animacy in prime as in picture or not).

Each dative prime set consisted of a double object and a prepositional dative alternate of the same sentence. There were six lists in each of which all 12 dative pictures occurred. The first four pictures were preceded by intransitives, serving as the baseline. The remaining eight pictures were preceded by four Double-Object and four Prepositional Phrase primes. Across lists, each picture occurred twice in each condition. The lists were balanced with respect to position of agent and recipient. Furthermore, care was taken that pictures that were to elicit a particular verb (e.g. 'give', 'show') occurred equally often in each condition.

Procedure

The procedure was the same as in the previous experiments, with one exception: The sentences were presented in the auditory modality. The subject initiated presentation of a trial by pressing a button. Sentences were presented from computer hard disk, using a single MacSpeaker. During presentation of the sentence, the Dutch translation equivalent of the word 'LISTEN' appeared on the screen. Following sentence presentation, the Dutch equivalent of 'REPEAT' appeared.

Scoring

The same scoring rules were used as in Experiment 3, with one exception: Medial datives were scored as 'OT'.

Design

In this experiment, the Baseline condition was regarded as a level of the Prime factor. Each subject received 4 trials in each of the three levels of the transitive Prime factor. Two of these were animacy congruent and two were animacy incongruent. In addition, each subject received four trials in each of the three levels of the dative Prime factor.

Results

Transitives

Of the transitive trials in the experimental conditions, 350 responses were analyzable (52.1%). Of the trials in the baseline condition, 146 responses were analyzable (43.5% of the responses). Of the analyzable responses in the experimental conditions, 49.4% occurred in the active condition and 50.6% occurred in the passive condition.

The number of actives and passives 1 after each type of prime are presented in Table 9 and Figure 8.

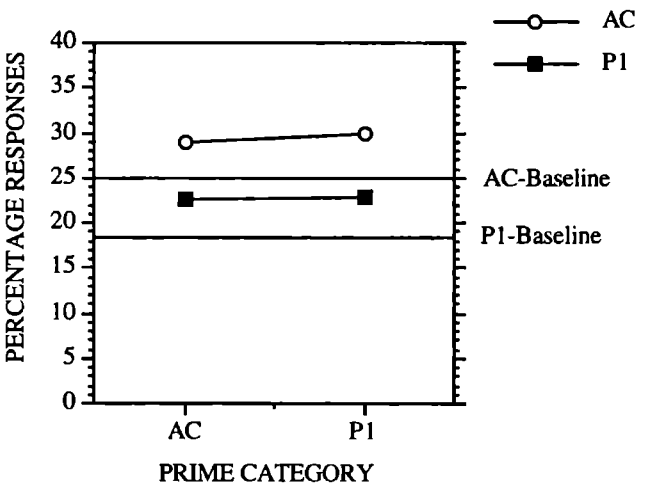

FIGURE 8. Active (AC) and Passive 1 (P1) responses as a percentage of the total number of responses in each priming condition in Experiment 4. Baselines indicate percentage of responses in control condition.

TABLE 9

Response Frequencies for transitives in Experiment 4

(percentages in parentheses)

Prime[a]	*AC*	*P1*	*OT*
AC	97 (28.9)	76 (22.6)	163 (48.5)
P1	100 (29.8)	77 (22.9)	159 (47.3)
BA	84 (25.0)	62 (18.5)	190 (56.5)

a. Total number is 336 in all conditions of Table 9

As the table shows, the distribution of responses following active or passive primes is virtually identical: There is not a trace of a priming effect. Furthermore, just as in the previous experiments, in the baseline condition the number of transitive responses is lower than in the experimental conditions, and consequently, the number of 'other' responses is higher in the baseline condition.

Because in this experiment the number of observations in the baseline condition was equal to the number of observations in each of the other conditions, and because across the six lists each item appeared equally often in all three conditions, we regarded the baseline condition as a level of the Prime factor (Active, Passive 1, Baseline). In subsequent planned comparisons, the effect of active primes was compared with that of passive primes, and in addition the effect of experimental primes (active and passive) was compared with the effect of baseline primes.

In the ANOVA on active responses there was no significant effect of Prime type ($F1(2,166)=1.36$; $p>.25$; $F2(2, 22)=2.93$; $p=.075$). The planned comparison between active and passive primes was not significant (both $F1<1$ and $F2<1$). The planned comparison between baseline and experimental trials was not significant for subjects ($F1(1,83)=2.59$; $p>.10$) but was significant in the item analysis ($F2(1,11)=6.71$; $p<.05$). The ANOVA on passive responses yielded a similar set of results. The effect of Prime Type was not significant ($F1(2,166)=1.27$; $p > .25$ $F2(2, 22) = 2.03$; $p>.15$). The planned comparison between active and passive primes was not significant (both $F1<1$ and $F2<1$). The planned comparison between baseline and experimental trials was not significant for subjects ($F1(1,83)=2.16$; $p > .10$) but was significant in the item analysis ($F2(1,11)=5.32$; $p <.05$). An ANOVA was also carried out on 'Other' responses. In that analysis, significant effects were obtained ($F1(2,166)=3.46$; $p<.05$; $F2(2,22)=5.01$; $p<.05$). The contrast between active and passive primes was not significant (both $F1<1$ and $F2<1$). On the other hand, the baseline condition differed reliably from the experimental conditions ($F1(1,83)=6.11$; $p<.02$; $F2(1,11)=12.97$; $p<.01$).

To summarize, in none of the analyses was there any indication that active and passive primes had differential effects on the distribution of responses. It is however clear that the baseline condition differed from the experimental conditions. This is most obvious in the analysis on 'Other' responses: In the baseline condition more 'other' responses, and ipso facto less transitive responses, were obtained than in either of the experimental conditions.

Again we determined whether there are priming effects in the animacy congruent condition and not in the incongruent condition. Inspection of the third row of Table 5 confirms the pattern of results from previous experiments. There are no priming effects for both actives and passives in the animacy congruent condition.

Datives

In the analysis on datives, two of the experimental items were discarded, because these had been accidentally substituted for each other in some of the experimental lists[9] Therefore, the results are based on a total of 840 trials, 280 in each condition.

Of the dative picture descriptions in the experimental conditions, 358 responses were analyzable (63.9%). Of the analyzable responses, 50 8% occurred in the condition with PP-primes, 49.2% in the condition with DO-primes. In the baseline condition, there were less analyzable responses (54.3 %)

In Table 10, the number of prepositional datives and double-object datives are given following each type of prime.

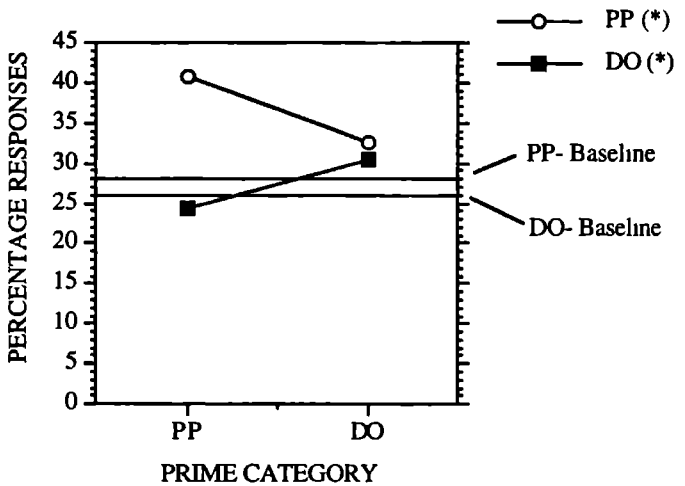

FIGURE 9. prepositional phrase dative (PP) and Double-object dative (DO) responses as a percentage of the total number of responses in each priming condition in Experiment 4. Baselines indicate percentage of responses in control condition.

TABLE 10

Response Frequencies for datives in Experiment 4 (percentages in parentheses)

Prime[a]	*PP*	*DO*	*OT*
PP	114 (40.7)	68 (24 3)	98 (35.0)
DO	91 (32 5)	85 (30.4)	104 (37.1)
BA	79 (28 2)	73 (26 1)	128(45 7)

a Total number is 280 in each condition

[9]Because of this, the number of items in a given condition was not the same for each subject Therefore, not the frequency of each response was the dependent variable, but the fraction, e g number of PP-responses in the PP-condition over total number of items in the PP-condition

Table 10 shows that the pattern of frequencies in the experimental conditions is according to prediction. The priming effect is of a similar magnitude as in the previous experiments.

In the analysis on PP-responses there was a main effect of Prime type ($F1(2,166)=7.48$; $p=.001$; $F2(2,18)=3.9$; $p<.05$). Planned comparisons showed that the number of PP-responses was significantly larger when following PP-primes, than when following DO-primes ($F1(1,83)=8.92$; $p<.01$; $F2(1,9)=8.19$; $p<.02$). The contrast between the experimental and Baseline conditions reached significance in the analysis on subjects ($F1(1,83)=6.56$; $p<.02$) but did not in the item analysis ($F2(1,9)= 2.83$; $p>.10$). In the analysis on DO-responses, there was no significant effect of Prime type ($F1(2,166)=2.09$; $p>.10$ $F2(2,18)=2.78$; $p=.089$). However, the contrast between PP-primes and DO-primes did reach significance ($F1(1,83)=4.40$; $p<.05$; $F2(1,9)=7.20$; $p<.05$). The contrast between Baseline and Experimental conditions was not significant (both $F1<1$ and $F2<1$). Finally, in the analysis of 'other'-responses, there was a significant effect ($F1(2,166)=6.80$; $p=.001$; $F2(2,18)=3.81$; $p<.05$). There were no differences between the PP and DO conditions ($F1(1,83)=1.10$; $p>.25$; $F2<1$). The difference between the experimental and baseline conditions, however, was reliable in the subject analysis ($F1(1,83)=9.84$; $p<.01$) and approached conventional levels of significance in the item analysis ($F2(1,9)=4.83$; $p=.056$).

To summarize, the dative results show a differential effect of PP-primes and DO-primes on both the distribution of PP-responses and the distribution of DO-responses, but not on the distribution of 'Other-responses'. In other words, consistent with Experiments 1-3, we observe a dative priming effect. In addition, again there is an indication that the frequency of 'Other' responses is highest in the baseline condition, and that ipso facto the frequency of dative responses is lowest in that condition. It appears, and the ANOVA's confirm this, that it is especially the frequency of PP-responses that is lower in the Baseline.

Discussion

This fourth and final experiment, although using a different mode of presentation of the prime sentences, yielded results that are very consistent with the findings in the previous experiments. We find a priming effect for datives. We find no priming for transitives. Furthermore, we find that the number of responses of the analyzable type is lower in the baseline condition than in the experimental conditions. Because of the design of Experiment 4 that observation is now supported by statistical evidence.

These results appear to refute any claims that the different pattern of results found in Bock et al.'s experiments with transitives is due to a different modality of presentation. Even when subjects have to repeat an auditorily presented sentence verbatim, and are therefore (ex hypothesi) required to carry out more syntactic planning, there is no structure priming for active and passive transitives in Dutch. Furthermore, it is not the case, as would be expected if that hypothesis were correct, that the magnitude of the dative priming effect is larger in the present experiment than in the previous experiments.

General Discussion

In the present study, we attempted to find structure priming for a larger number of syntactic structures than tested in previous studies, and to collect baseline data. The purposes of collecting the baseline frequencies were to examine the nature of structure priming effects (inhibitory, facilitatory or both), and to evaluate whether baseline frequency is an important determinant of the strength of the priming effect. In this section, we first turn to the question how successful we were in generalizing the priming effects to structures not tested before and in replicating the effects for 'old' structures. We note the possibility that differences in pragmatic impact of the tested structures contribute to the patterns of results we observed. Following that, we discuss how well the collecting of baseline data served its purposes. The baseline data allow us to make two empirical generalizations: (1) there appears to be long-term component to priming (2) priming is most effective when alternative responses have equivalent baseline frequencies. Finally, we argue that the second empirical generalization supports an explanation of our results in terms of competition between structures.

Generalization of the priming effect

We succeeded in generalizing the dative priming effect to another structure: The medial dative. There was a significant priming effect for this structure in Experiment 2, and we replicated that effect in Experiment 3. In addition, we succeeded in replicating the structure priming effects for datives that Bock et al. reported, in a different language and with different materials.

However, we found no priming effect for the topicalized dative, the FR-dative. In fact, the structure was hardly ever used as a response. In our opinion, this is due to the fact that fronting the dative serves a pragmatic goal in discourse (topicalization), and is not produced when such a goal is absent. In the pictures presented to our subjects, such a goal was absent indeed. In other words, structure priming can only be observed when pragmatic and semantic constraints allow a sentence with the same constituent

structure to be used. In our experiments, these constraints did not allow repetition of FR-dative structure.

We were, in general, unable to find priming effects for active and passive transitives. An exception is the effect of the P1 and P2 passives in Experiment 2. The lack of priming for transitive structures could not satisfactorily be accounted for by any of the four explanations put to the test in Experiments 2-4: (1) ISI was too short (2) repetition of assignment of animacy to subject and object interfered (3) the number of presented structures was too large (4) the visual modality was used instead of the auditory modality.

A plausible explanation for the mixed results needs to take into account two considerations. First, why do we find a transitive effect in Experiment 2, just as Bock et al. did, but not in the other experiments? Second, why is it that we do find, consistently, effects with dative sentences? One way in which an explanation could proceed, is by assuming that structure priming effects for transitives are very weak. The reason that they do show up in some conditions of Experiment 2 is caused by the greater power of this experiment, due to a larger number of observations.

Could it be the case that the effects of structure priming for transitives are so weak, that they are masked by noise, unless the experiment consists of a great many observations? The results from Bock et al.'s studies seem to support this notion. In the experiment reported in Bock et al. (1992), in which a transitive priming effect is obtained, the number of subjects was more than twice as large as in our largest experiment, Experiment 2. In addition, the magnitude of the priming effect in Bock et al. (1992) was only 5 percent. In Bock's (1986b) study, the priming effect for transitives is considerably smaller than the effect for datives (8 percent vs. 23 percent). In sum, the effect of transitive priming is either absent (this study) or of a relatively small magnitude (Bock et al.'s studies). If an effect does show up, this is due to the greater power of the particular experiment.

Given that interpretation, one question remains: Why are dative sentences more susceptible to priming than transitives? We think one variable that may contribute to the difference is the differential pragmatic impact of dative alternation as compared to passivization. It is conceivable that the decision to produce either an active or a passive is much more under the control of external, pragmatic factors than the decision to opt for one of the dative variants. That is, passivization serves a more important pragmatic goal than dative alternation. It is certainly the case that dative alternation serves some form of discourse function, be it to preserve the order given-new (Bock, 1977; Collins, 1995), to place 'dominant' constituents clause-finally (Erteshik-Shir, 1979), or to assign the pragmatic role of 'secondary topic' to the recipient (Givón, 1984). However, as Givón notes, the notion of secondary topic is far less important than the notion of primary topic. Therefore, subject assignment (in SVO-languages) is more important for

pragmatic purposes. Similar arguments may apply with respect to the other proposed discourse functions. Hence passivization could be dependent on pragmatic constraints to a stronger degree than dative alternation. However, although we certainly acknowledge the possible role of discourse factors, we believe its role to be limited in the present experiments. The method of the experiments deflected attention from language production, let alone production of discourse.

Establishing a baseline

The second aim of this study was to gather baseline data, for two purposes. First, we wanted to examine whether the direction of the structure priming effect was facilitatory or inhibitory. Second, we hoped to obtain an unbiased measure of the frequency of each tested structure in order to assess any relation between frequency and priming. Let us turn to these purposes in turn.

With respect to the first purpose, assessing the direction of the priming effect, our data are inconclusive. The reason is a rather unexpected finding: The trials in the baseline condition yielded less transitive and dative responses, and substantially more 'Other' responses. The statistical tests in Experiment 4 show these differences to be reliable. Because of the consistency of this finding and the statistical support for it in Experiment 4 (i.e. the experiment in which the difference was smallest) we regard it as the first of two empirical generalizations our data allow us to make.

Unfortunately, the difference between baseline and experimental conditions disallows assessment of the direction of priming effects (inhibitory, facilitatory or both). In order to establish the direction of the priming effect, one needs to have an equivalent number of analyzable responses in each condition. Why then are there more 'other' responses in the baseline? There are two obvious differences between experimental and baseline conditions: (1) The serial position in the list of trials, (2) The syntactic structure of the 'prime' sentence. Two possible explanations are based upon these differences. First, as was mentioned in the Discussion of Experiment 2, there could be Long Term Priming, increasing the probability of a structure being produced, regardless of the particular prime preceding the picture. This would entail a small increase in activation level, every time a prime sentence with a given structure is produced. This increase may be insufficient to override the preference for an alternative structure on a given trial, but does increase probability of using that structure in the long run. Because the baseline trials were always the first trials in the experiment, that condition was not influenced by LTP.

The second, highly speculative, explanation is that it is the syntactic structure of the baseline trials that is responsible for the difference. This would trivially be the case if the syntactic structure of baseline trials showed syntactic persistence. However,

informal inspection of the kinds of 'other' responses showed that this was not the case. Therefore, one would have to assume that transitive primes, be they active or passive, increase the probability of transitive responses. This would entail persistence of a more abstract unit than a configuration of constituents. This may be plausible when the point of view of some contemporary linguistic theories is taken: In linguistic theories, the mental lexicon is assigned an important role with respect to syntactic processing. In a theory such as Head-driven Phrase Structure Grammar (Pollard & Sag, 1994) there would be an entry for 'transitive verb' in the mental lexicon. Particular transitive verbs 'inherit' information from the more abstract entry. Within such a framework, one can speculate that repeated production of transitive verbs would prime the abstract 'transitive entry' in the mental lexicon.

Turning now to the second purpose of gathering baseline frequencies, what can we say about the effect of frequency on priming? In Table 11 we present a summary of the results of the experiments in which baseline data were gathered.

TABLE 11

The effect of baseline frequency on size of priming effect[a]

	EXP2			*EXP2*			*EXP2*		
	Prop.	*Priming*	*Bas*	*Prop.*	*Priming*	*Bas*	*Prop.*	*Priming*	*Bas*
AC	23.2	ns	<.01	26.8	ns	<.01	25.0	ns	.132
P1	10.7	<.01		11.3	ns		18.5	ns	
P2	2.4	<.02		-	-		-	-	
PP	26.2	ns	ns	25.6	<.01	ns	28.2	<.01	ns
DO	20.8	<.05		31.0	ns.		26.1	<.05	
MM	0.6	<.05		1.2	<.01		-	-	

a Prop. indicates baseline proportion, Priming indicates significance of priming effect, and Bas indicates significance of differences in baseline between AC/P1 and DO/PP.

Inspection of Table 11 suggests that low frequency structures are more susceptible to priming than high-frequent structures. So for instance, in Experiment 2 the baseline for PP-datives was highest, and we obtained no significant priming effect for that structure.

However, this observation is not supported by statistical analyses: We performed ANOVA's comparing baseline frequencies of Actives and Passives, and of PP and DO-datives in each experiment. Significance values are reported in Table 11. As is clear, the baseline values in the dative experiments did not differ significantly, whereas the baseline values in the transitive experiments did. It is hard to reconcile this

finding with a frequency attenuation effect such as reported in the literature on repetition priming (e.g. Forster & Davis, 1984). In fact, the pattern of results in Table 11 suggests a different empirical generalization, presented below: Only in experiments were baselines of alternative structures are of relatively equal magnitude does one obtain syntactic priming. Let us view the data in Table 11 from this perspective. To begin with, in all three experiments summarized in the table, the baselines for PP-datives and DO-datives did not differ significantly from each other. In all of these experiments, priming effects were observed (although in both Experiment 2 and Experiment 3 the effect for one of these structures failed to reach significance, the means were in the predicted direction in all experiments, and the structure not reaching significance in one experiment did reach significance in all the others).

Furthermore, there were large differences between the baselines of actives and passives in all three experiments. This difference was highly significant in Experiments 2 and 3, but fell short of conventional levels of significance in Experiment 4. In other words, there is a clear preference for the active transitive. If we take a priming effect to be an effect, where both actives and passives show differential frequencies based on the particular prime condition, we find no priming effect in any of the experiments with transitives.

In the next section, we will argue that this empirical generalization supports an account of our data in terms of competition.

An account of the priming results: Competition between structures

We believe one way of unifying the differential results with transitives on the one hand, and datives on the other hand, is related to the strength of competition. In the case of transitives there would be little competition between the two structures. In the case of datives there would be a strong competition.

Branigan et al. (1995) argue that syntactic priming is only effective when there is strong competition between alternative structures. They base this hypothesis on a number of syntactic priming studies in comprehension. It was shown there that processing a sentence with a certain syntactic structure facilitates reading times of a subsequent sentence with the same structure. However, this effect only occurred with sentences that strongly elicit 'garden paths'. In other words, the effect only occurred when the parser has to decide between two alternative syntactic structures, when a competition between these structures took place.

The hypothesis that differences in strength of competition are responsible for the different patterns of results in our experiments with transitives and datives (the Competition Hypothesis) is supported by the empirical generalization mentioned in the previous section: In the case of datives, baselines do not differ significantly (structures

compete), and we find priming effects. In the case of transitives, baselines differ significantly (structures do not compete), and we find no priming effects. The Competition Hypothesis entails that when two structures compete, presenting a prime disturbs a delicate balance between the two competing structures, allowing one of them to win the competition.

The Competition Hypothesis, however, leaves one aspect of our data unexplained: MM-datives and P2-passives were very infrequent in the baseline condition, yet we did observe priming effects for these structures (in Experiments 2 and 3 with MM-datives, in Experiment 2 with P2-passives). This is clearly in contrast with our hypothesis. We think there are two possible solutions to this problem.

First, the mechanism responsible for priming of very infrequent structures could be different from the competition mechanism sketched above. Priming very infrequent structures could be augmented by external sources of activation. For instance, it could be that due to their relative markedness, infrequent structures are brought into the focus of attention of the speaker. Attention to a marked structure may serve as a source of external input to the representation for that structure, anologous to 'attentional enhancement' in a visual cueing paradigm (cf. Posner & Raichle, 1994). A related account assumes mediation through episodic memory. As is proposed by students of repetition priming (e.g. Forster & Davis, 1984), processing a stimulus in a given context leaves a trace in episodic memory. When that stimulus is subsequently encountered, the episodic trace may facilitate access to that stimulus. However, in those conditions in which episodic trace formation is likely (that is, in conditions in which the first encounter of the stimulus is clearly visible and part of the relevant context) there is a greater benefit for low frequency items than for high frequency items. One explanation for this 'frequency attenuation' effect is that low frequency words form stronger episodic traces, as is attested to by the typical observation that recognition of low frequency words is better than for high frequency words (e.g. Shepard, 1967). Because low frequency items leave stronger traces, they influence processing of the repeated stimulus more than high frequency items do. Analogously, associating a certain conceptual structure with a syntactic structure in the syntactic priming experiments (when the prime sentence is produced) leaves an episodic trace. If the syntactic structure is very infrequent, i.e. marked, there is a strong episodic trace. When the conceptual structure is encountered a second time (when the target picture is presented), the strong episodic trace for marked syntactic structures facilitates access, i.e. it serves as an external source of activation.

Another solution to the problem of finding priming for very infrequent structures, in contrast to the competition account, follows from the observation that MM-datives and P2-datives share syntactic structure with more frequent alternatives: The MM-dative is a word order variant of the PP-dative, and the P2-passive is a word

order variant of the P1-passive. It is conceivable that syntactic priming entails two separate processes. First, there is a competition between two alternative syntactic structures. The competing structures are specified with respect to constituency and hierarchical relations, but not with respect to word order (cf. De Smedt, 1990). If an MM-dative is presented, a priming effect occurs at this level, as the DO-frame and the PP/MM-frame compete with each other. Then, once a structure is selected, word order has to be computed. The crucial assumption is that word order can be primed, independent of hierarchical relations, and furthermore, that this word order priming does not entail a competition process such as applies to the selection of structure. Therefore, word order priming would not be sensitive to baseline frequency differences.

Obviously, it is problematic to assume a priori different sensitivities to a variable such as frequency for different levels of processing. However, such an assumption is not without precedent. In fact, Jescheniak & Levelt (1994) studied word frequency effects in picture naming: They showed that there is no word frequency effect when participants had to determine the grammatical gender of the to-be-named picture. However, there was a word frequency effect when the pictures had to be named. They interpreted this as evidence for a two-stage theory of lexical access. First a 'lemma' is selected, and this process is not sensitive to frequency. Second, a word form is retrieved, and this process is sensitive to frequency.

Clearly, there remain a number of unsolved problems in the interpretation of the present data. However, that should not deflect attention from the central conclusions our data do allow us to draw: We have obtained evidence for the existence of a dative structure priming effect, in support of Bock et al.'s claims. We were able to extend this effect to a dative structure not tested before. Furthermore, collection of baseline data allowed two empirical generalizations. The first confirmed the existence of a Long Term Priming effect. The second empirical generalization suggests the existence of a competition between alternative syntactic structures in the production of sentences. This entails that syntactic structures can only be primed, if there is an equivalently strong alternative competing for being the eventual structure of the sentence.

Appendix: Stimulus materials in the four experiments

Experiment 1

Transitives[a]

1. De koffer houdt de deur open
   (The suitcase holds open the door)
   Lightning hits a church

2 De vader slaat het kind
   (The father hits the child)
   A truck tows a car

3 De zangeres zingt het lied
   (The singer-FEM sings the song)
   A rocket hits an aeroplane

4 De priester doopt het meisje
   (The priest baptizes the girl)
   A bat hits a ball

5 De wolk bedekt de zon
   (The cloud covers the sun)
   A bullet hits a bottle

6 De computer verslaat de schaker
   (The computer defeats the chessplayer)
   A bicycle tows a cart

7. De advokaat schrijft de brief
   (The attorney writes the letter)
   An avalanche buries skiers

8. Het lawaai verstoort de stilte
   (The noise disturbs the silence)
   An arrow hits a bird

9 De kachel verwarmt de huiskamer
   (The stove heats up the living room)
   An ambulance runs into a mailman

10 De brandweerman redt het slachtoffer
   (The fireman rescues the victim)
   A mosquito stings a man

11 De padvinder helpt de dame
   (The boy scout helps the lady)
   A wave hits a ship

12 De brandweer blust de brand
   (The firesquad extinguishes the fire)
   A tractor tows a car

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[a] Dutch sentence in active voice, English translation, and description of corresponding target picture. Passives are formed as follows. NP1 Vfin NP2 (particle) -> NP2 wordt {(particle)Vnonfin door NP} / {door NP (particle)Vnonfin}, e.g. "De koffer houdt de deur open" ->"De deur wordt opengehouden door de koffer".

13 De hoofdmeester straft de scholier
(The headmaster punishes the student)
An arrows hits an apple

14 De voetbalclub geeft het feest
(The soccerteam organizes the party)
A tennis ball hits a cup

15 De moeder verzorgt het kind
(The mother nurses the child)
An avalanche buries a house

16 De werkster maakt het huis schoon
(The cleaning lady cleans the house)
A tank runs over a car

17 De fabriek loost het afval
(The factory disposes of the waste)
Lightning hits a golf player

18 De machine pakt de koekjes in
(The machine packages the cookies)
A wave drowns a woman

19 De toerist boekt de reis
(The tourist books the journey)
A tank runs over a soldier

20 De regering ontkent het verhaal
(The government denies the story)
A dog bites a man

21 De dokter onderzoekt de patient
(The doctor examines the patient)
A magnet attracts a coin

22 Het meisje duwt de schommel
(The girl pushes the swing)
A train crashes into a bus

23 De kinderen plagen Kees
(The children tease Kees)
A stone destroys a window

24 De fietser passeert de voetganger
(The cyclist overtakes the pedestrian)
An avalanche destroys a barn

25 De timmerman maakt de kast
(The carpenter mends the cupboard)
A torpedo hits a ship

26 De garage repareert de auto
(The garage fixes the car)
A ball hits a boy on the head

27 De radio zendt de wedstrijd uit
(The radio broadcasts the game)
A bottle of syrup attracts a bee

28 De penningmeester bedriegt het bestuur
(The treasurer deceits the board)
A rock hits a boy

29 Het kind drinkt de melk op
(The child drinks the milk)
A snake bites a woman

30 De schilder verft de muur
(The painter paints the wall)
A rooster bites a man

Datives[b]

1 Opa vertelt het verhaal aan de jongen
(Grandpa tells the story to the boy)
A lawyer shows a letter to a judge

2 De burgemeester stelt de winnaar voor aan de koningin
(The mayor introduces the winner to the queen)
A boy gives a valentine to a girl

3 Het meisje toont het litteken aan haar klasgenootjes
(The girl shows the scar to her fellow students)
A girl gives another girl a plate

4 De student vraagt de sleutel aan de portier
(The students asks the key to the doorman)
A boy hands a guitar to a singer

5 De slager geeft een stuk worst aan het kind
(The butcher hands a piece of sausage to the child)
A boy reads a story to a girl

6 De postbode overhandigt de brief aan de oude dame
(The mailman hands the letter to the old lady)
A girl reads a story to a boy

7 De middenvelder bracht de overwinning aan ons elftal
(The midfielder brought the victory to our team)
A cowboy gives a hat to a clown

8 De hospita verhuurt de kamer aan de man
(The landlady lets a room to the man)
A boy throws a ball to another boy

9 De vrouw verkocht het autowrak aan de sloper
(The woman sold the car wreck to the demolisher)
A boy throws a ball to a girl

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[b] Dutch sentence in prepositional dative form, English translation and description of target picture Double object datives are formed as follows NP1 V NP2 (particle) aan NP3 -> NP1 V NP3 NP2 (particle)

10 De gokker betaalt de schuld aan de bank
(The gambler pays the debt to the bank)
A girl gives a boy a cup

11 De oude vrouw vertelt het nieuwtje aan de buurvrouw
(The old woman tells the news to the neighbor)
A girl throws a bone to a dog

12 De student stelt zijn vriendin voor aan zijn ouders
(The student introduces his girlfriend to his parents)
A man hands a bottle to a woman

13 Het kind toont het rapport aan zijn tante
(The child shows his grades to his aunt)
A child gives an apple to a teacher

14 De verrader verklapt het geheim aan de vijand
(The traitor reveals the secret to the enemy)
A boy gives a girl a valentine

15 De ongeruste vader overhandigt het losgeld aan de ontvoerders
(The worried father hands the ransom money to the kidnappers)
An old man reads a story to a child

16 De advokaat vraagt een lichte straf aan de rechter
(The lawyer asks a mild sentence to the judge)
A boy gives a plate to another boy

17 De man geeft het pakje aan het jarige meisje
(The man gives the parcel to the girl having her birthday)
A waitress presents drinks to some guests

18 De zeeman verhuurt een boot aan de toeristen
(The sailor rents a boat to the tourists)
A waitres gives the menu to a customer

19 De bakker verkoopt een taart aan de dame
(The baker sells a pie to the lady)
A police officer gives a ticket to a car driver

20 De arme man betaalt zijn laatste geld aan de huisbaas
(The poor man pays his last money to the landlord)
A girl gives a flower to her teacher

21 De kinderen vertellen het nieuws aan hun moeder
(The children tell the news to their mother)
A boy and a girl give flowers to a man

22 De meester stelt de nieuweling voor aan de klas
(The teacher introduces the newcomer to the class)
A girl hands a paintbrush to a boy

23 De man toont zijn gevoelens aan zijn echtgenote
(The man shows his feelings to his wife)
A girl gives a plate to a boy

24 De dokter geeft het medicijn aan het zieke jongetje
(The doctor gives the medicine to the sick boy)
A boy reads a story to a girl

25 De vrouw verklapt de verrassing aan haar zus
(The woman reveals the surprise to her sister)
A girl throws a ball to a boy

26 De buitenlander vraagt de weg aan de agent
(The foreigner asks (for) directions to the police officer)
A nurse gives a glass of water to a patient

27 De gemeente verhuurt het land aan de boer
(The city council rents the land to the farmer)
A boy throws a ball to a girl

28 De dief verkoopt het goud aan de heler
(The thief sells the gold to the fence)
Children show a drawing to their teacher

29 Het bedrijf betaalt een bonus aan het personeel
(The company pays a bonus to the employees)
A librarian gives a book to a boy

30 De reiziger overhandigt zijn paspoort aan de douane
(The traveller hands over his passport to the customs)
A girl reads a story to a boy

Experiments 2 and 3

Transitives[c]

Pictures with inanimate agent and animate patient.

1 Het lawaai / De journalist onderbreekt de spreker / het interview
(The noise / journalist interrupts the speaker / the interview)
The ambulance hits the mailman

2 De politieauto / straathond achtervolgt de overvaller / vuilniswagen
(The policecar / straydog chases the assailant / garbage truck)
A wave washes over a swimmer

3 Het maandblad / De cabaretier bespot de minister / het beleid
(The magazine / comedian mocks the minister / policy)
An avalanche buries the skiers

4 De sneltram / buschauffeur snijdt de fietser / de brommer
(The streetcar / busdriver cuts in the cyclist / the moped)
The pitch fork pricks the farmer

5 De microscoop / fotograaf vergroot de vlieg / afbeelding
(The microscope / photographer enlarges the fly / picture)
The lightning strikes a golf player

[c] Dutch sentence in active voice Two variants are listed, one with inanimate agent and animate patient, and the other with animate agent and inanimate patient

6 De dame / duisternis verbergt het juweel / de insluiper
(The lady / Darkness hides the juwel / burglar)
A bicycle hits a pedestrian

7 Het zeilschip / De toerist laat de matroos / het blikje achter
(The sailboat / tourist leaves the sailor / can behind)
A baseball hits a boy

8 De modder / boer bevuilt / vervuilt de wandelaar / sloot
(Mud / the farmer dirties / pollutes the walker / drain)
A tank runs over a soldier

9 De stewardess / het prikkeldraad houdt de bagage / stier tegen
(The stewardess / barbed wire stops the luggage / the bull)
A train runs over a woman

10 De archeoloog / bulldozer graaft de stadswallen / overlevenden uit
(The archeologists / bulldozer digs up the city walls / survivors)
The fly-swatter kills the fly

11 De zeurpiet / verkeersbord stuurt het voorgerecht / de automobilist terug
(The bore / traffic sign sends the starter / driver back)
An arrow hits a bird

12 De soldaten / takken camoufleren het terrein / de soldaat
(The soldiers / branches camouflage the terrain / the soldier)
A wirlwind lifts up a person

13 De verkeerstoren / verkeersleider roept de piloot / het vliegtuig op
(The control tower / traffic controller calls the pilot / airplane)
Smoke dazes a person

14 De politieauto / politieagent rijdt de autodief / vrachtwagen klem
(The police car / officer jams the carthief / truck)
An alarmclock awakens a boy

Pictures with inanimate agent and animate patient[d].

1 De vrachtwagen / ambtenaar hindert de bus / boer
(The lorry / civil servant hinders the bus / farmer)
An arrow perforates an apple

2 De vrachtauto / grootmoeder brengt de lading / het ventje weg
(The truck takes the load / the little boy away)
The bullet hit the bottle

3 Het lawaai / de kleuter verstoort de stilte / de vogel
(The noise / toddler disturbes the silence / bird)
Lightning hits the church

4 De stofzuiger / uitzendkracht stoort de radio / directeur
(The vacuum cleaner / temporary worker disturbs the radio / director)
An avalanche destroys a house

[d] Dutch sentence in active voice. Two variants are listed, one with inanimate agent and inanimate patient, and one with animate agent and patient.

5 Het gerucht /de zangeres brengt de effektenbeurs /de fans in beroering /vervoering
(The rumour/singer brings the stock exchange/fans in a state of turmoil/ecstasy)
A bicycle pulls a small cart

6 De transformator / leeuwin voedt de apparaten / welpen
(The transformer / lioness feeds the appliances / cubs)
A tennisbal hits a vase

7 De locomotief / pestkop duwt de trein / het jongetje
(The engine / bully pushes the train / little boy)
A torpedo hits a freighter

8 De auto / jongen spat het reclamebord / de grijsaard nat
(The car / boy splashes the billboard / old man)
A bat hits a ball

9 De hagelsteen / bokser treft de ruit / tegenstander
(The hailstone / boxer hits the window pane / opponent)
A tractor pulls a car

10 De wielen / jagers raken de landingsbaan / fazant
(The weels / hunters hit the runway / pheasant)
A magnet attracts a coin

11 De dam/ brigadier houdt de zee / menigte tegen
(The dam / police sergeant stops the sea / crowd)
A truck pulls a car

12 De deur / moeder houdt de warmte / het meisje binnen
(The door / mother keeps the warmth / girl inside)
A missile shoots down an airplane

13 De bom / militair maakt de raketbasis / verzetstrijder onschadelijk
(The bomb / soldier renders the rocket base / resistence fighter harmless)
A ball hits a stack of cans

14 De bowlingbal / rugbyspeler gooit de kegel / scheidsrechter omver
(The bowlingball / rugby player throws the pin / referee around)
A wave washes over a ship

Datives

1 De grijsaard vertelt een oorlogsverhaal aan de jongen
(The old man tell a war story to the boy)
A girl hands a present to another girl

2 De burgemeester stelt de winnaar voor aan de koningin
(The mayor introduces the winner to the queen)
A policeman hands a ticket to the driver

3 Het meisje laat een Greenpeace-button aan haar zus zien
(The girl shows a Greenpeace button to her sister)
The child hands a flower to the teacher

4 De studente vraagt de sleutel aan de portier
(The student aks the key to the doorman)
Children give flowers to a man

5 De hospita verhuurt een zolderkamer aan de student
(The landlady lets an attic to the student)
A woman hands a book to the boy

6 De Chinees geeft een nasi-goreng aan de klant
(The Chinaman hands a fried rice to the customer)
Children show a drawing to the teacher

7 Sinterklaas geeft een banketletter aan mijn broer
(Santa Claus gives a sweet to my brother)
The lawyer hands a letter to the judge

8 De gokker betaalt duizend gulden aan de kassier
(The gambler pays thousand guilders to the cashier)
A waitress serves drinks to customers

9 De scholier laat het spiekbriefje zien aan zijn vriend
(The student shows the crib to his friend)
The boy hands a guitar to the artist

10 De boekhouder vertelt een schuine mop aan zijn collega
(The accountant tells a dirty joke to his colleague)
A boy hands over a hammer to another boy

11 De journalist vraagt een reactie aan de getuige
(The journalist asks a comment from the witness)
A boy gives a candy heart to a girl

12 De zakenman overhandigt een belastingformulier aan de boekhouder
(The businessman hands a taxform to the accountant)
A child shows his mother his wounded arm

13 De zakenman betaalt een enorm bedrag aan de afpersers
(The businessman pays an enormous amount to the extorters)
A cowboy shows his hat to a clown

14 De vrouw laat een oude foto zien aan de bezoeker
(The woman shows an old picture to the visitor)
A boy gives a baseball to another boy

15 De slager geeft een stuk leverworst aan het kind
(The butcher gives a piece of liver sausage to the child)
A woman shows a dress to a man

16 De makelaar verkoopt het grachtenpand aan de prins
(The broker sells the old house by the canal to the prince)
A girl gives a mug to a boy

17 De dame vraagt een likeurtje aan de kelner
(The lady asks a liqueur to the waiter)
A girl hands a paintbrush to a boy

18 De kunstenaar liet een meesterwerk na aan de mensheid
(The artist left a masterpiece to mankind)
The waitress shows the menu to the customer

19 De campinghouder verkoopt een nieuwe gasfles aan de kampeerder
(The camping owner sells a new gas bottle to the camper)
A small boy gives a candy heart to a small girl

20 De soldaat laat het geweer zien aan de recruut
(The soldier shows the rifle to the recruit)
A girl gives a plant to a boy

21 De jongen geeft een armband aan zijn vriendin
(The boy gives a bracelet to his girlfriend)
A girl gives a ball to the tennisplayer

22 De zeeman schrijft een lange brief aan zijn vriendin
(The sailor writes a long letter to his girlfriend)
The child gives a pear to the teacher

23 De zwerver vraagt een kwartje aan de voorbijganger
(The tramp asks the passerby for a quarter)
The nurse gives the patient a glass of water

24 De fietsenmaker verkoopt een speciaal stuur aan de wielrenner
(The bicycle repair person sells a special handlebar to the cyclist)
The girl gives a present to the boy

25 De klant geeft een grote fooi aan de ober
(The customer gives a large tip to the waiter)
A girl shows her report card to a boy

26 De boer verkoopt een varken aan zijn buurman
(The farmer sells a pig to his neighbor)
A girl gives a bone to the dog

27 De bejaarde geeft wel een rijksdaalder aan de collectant
(The senior citizen gives as much as Dfl 2.50 to the collector)
A girl gives a flower to another girl

28 De vakantiegangers vragen een retourbiljet aan de loketist
(The holiday goers ask the clerk for a round-trip ticket)
A man hands a bottle of wine to a woman

Experiment 4

Transitives

1 De lak / leeuwin beschermt het hout / de welpen
(The paint / lionesse protects the wood / cubs)
A wave hits a ship

2. De dam / agent houdt de zee / mensen tegen
(The dam / police officer stops the sea / people)
A magnet attracts a coin

3 De politieauto / straathond achtervolgt de overvaller / vuilniswagen
(The police car / street dog chases the assailant / garbage truck)
A fly swatter kills an insect

4 De caberetier / het maandblad bespot het beleid / de minister
(The comic / monthly magazine mocks the policy / minister)
A tank runs over a soldier

5 De koster / haardvuur verwarmt de kapel / reiziger.
(The sexton / hearth fire warms up the chapel / traveler)
An ambulance runs over a mailman

6 De buschauffeur / sneltram snijdt de auto / fietser
(The bus driver / street car cuts in the car / bicyclist)
A tripod hits a farmer

7 De bom / soldaat schakelt het kanon / de spion uit.
(The bomb / soldier eliminates the canon / the spy)
A tennisball shoots boxes of a table

8 De ton / spin vangt het water op / de mug
(The barrel / spider catches the water / the mosquito)
An avalanche destroys a house

9 De stuurman / radar ziet de duikboot / albatros
(The navigating officer / radar sees the submarine / albatros)
A tornado lifts up a girl

10 De bus / kat haalt de fiets / muis in
(The bus / cat overtakes the bicycle / mouse)
A bullet hits a bottle

11 Het zeilschip / de toerist laat de matroos / het blikje achter
(The sailing-vessel / tourist leaves the sailor / can behind)
Lightning hits a golfplayer

12 De bromfiets / ambtenaar hindert de bus / boer
(The moped / civil servant hinders the bus / farmer)
An arrow hits an apple

Datives

1 De burgemeester stelt de winnaar voor aan de koningin
(The mayor introduces the winner to the queen)
A lawyer shows a letter to a judge

2 De studente vraagt de sleutel aan de portier
(The student asks the key to the doorman)
A boy gives a hammer to another boy

3 Sinterklaas geeft een banketletter aan mijn broer
(Santa Claus gives a pastry-letter to my brother)
A girl gives a bone to a dog

4 De slager geeft een stuk leverworst aan het kind
(The butcher gives a piece (of) liver sausage to the child)
A girl shows her grades to a boy

5 De gokker betaalt duizend gulden aan de cassière
(The gambler pays thousand guilders to the cashier)
A boy hands a candy heart to a girl

6 De grijsaard vertelt een oorlogsverhaal aan de jongen
(The old man tells a war story to the boy)
A girl gives a tulip to another girl

7 De hospita verhuurt een zolderkamer aan de student
(The landlady lets an attic room to the student)
Children show a drawing to their teacher

8 De scholier laat het spiekbriefje zien aan zijn vriend
(The student shows the crib to his friend)
A woman shows a dress to a man

9 Het meisje laat een GreenPeace-button aan haar zus zien
(The girl shows a GreenPeach button to her sister)
A waitress shows the menu to a customer

10 De boer verkoopt een varken aan zijn buurman
(The farmer sells a pig to his neighbor)
A girl gives a plant to a boy

11 De journalist vraagt een reactie aan de getuige
(The journalist asks a comment from the witness)
A boy gives a cup to a girl

12 De klant geeft een grote fooi aan de ober
(The customer gives a large tip to the waiter)
A child shows his wounded arm to his mother

Chapter 2
Priming word order in sentence production[1]

Abstract

When producing a sentence, the speaker needs to place words in linear order. We hypothesized that there exists a *linearization* process which imposes order on a constituent structure. This structure is specified with respect to hierarchical relations between constituents but not with respect to word order. We tested this hypothesis in a primed picture description experiment. Speakers of Dutch repeated prime sentences and described target pictures. Word order of prime sentences was manipulated (e.g. 'On the table is a ball' vs. 'A ball is on the table'). Both alternatives could be used in the description of unrelated target pictures. In support of our hypothesis, word order was 'persistent': Speakers were more likely to use a given word order, when the prime sentence had that same word order. We argue that our results support the notion of a linearization process, and reject the alternative explanation that the results should be attributed to persistent selection of a fully specified syntactic frame.

Introduction

Theories of sentence production, the process with which an intention is translated into an utterance, typically distinguish separate stages of processing (Bock & Levelt, 1994; Dell, 1986; De Smedt, 1990; Garrett, 1975; 1980 ; Kempen & Hoenkamp, 1987; Levelt, 1989). The motivation for these different levels mainly comes from the analysis of speech error corpora (Dell, 1990; Fromkin, 1971; Garrett, 1975, Stemberger, 1982) but, as we will discuss below, also from controlled experiments. One of the processing stages so distinguished is called 'grammatical encoding' (Bock & Levelt, 1994; Levelt, 1989). The task of grammatical encoding is to take the conceptual representation of the to-be-uttered sentence, and translate this into an ordered, hierarchical structure containing all constituents and words. Various theories differ with respect to the actual output of this process: For instance the terminal elements of the structure may or may not be specified for phonological form. Furthermore they differ with respect to the way this process operates. In particular, grammatical encoding is sometimes considered to be 'encapsulated' from other processes, such as phonological encoding and

[1]The data reported in this chapter were presented at the 1996 meeting of the CUNY conference on Sentence Processing as Hartsuiker, R.J. & Huiskamp, Ph. (1996). Priming Word Order in Sentence Production: Locatives and Subordinate Clauses in Dutch. New York. A modified version of this chapter will be submitted, under authorship of Hartsuiker, R.J., Kolk, H.H.J., & Huiskamp, Ph.

conceptualizing, whereas other theories assume continuous interaction between these components. However, psycholinguistic theories of sentence production in general agree upon the necessity to construct a constituent structure during speech (an exception is Ward, 1992, who presents a connectionist model of sentence production in which constituent structure constraints 'emerge' from the interactions of simultaneously active representational elements).

How is constituent structure constructed? According to Bock & Levelt (1994), basically following Garrett (1975; 1980), grammatical encoding can be divided into two levels, called the functional level and the positional level. The task of functional level processing is to select lexical items that appropriately express conceptual content. These lexical items, called lemma's (cf. Kempen & Huijbers, 1983), are not specified for phonological form, but are abstract units which contain semantic and syntactic information. A further task of functional processing is to assign grammatical functions, such as subject and direct object, to these lemma's. The functional representation drives positional processing, which also has two tasks: The construction of a constituent structure which specifies hierarchical and linear relations between constituents, and determination of inflections. Eventual structure is highly predictable from the functional representation, but not isomorphous to it. The reason for that is that the same kind of functional relations can be expressed with a number of word orders, even in a relatively fixed word order language such as English. An important job of positional processing is thus to place words in linear order. In this study, we test the hypothesis that there exists a process of linearization in sentence production, that operates on a constituent structure. That structure specifies hierarchical relations between constituents, but not word order; word order is determined by linearization.

The notion of a linearization process is not new: In fact, Kempen & Hoenkamp (1987) and De Smedt (1990) proposed computational models of grammatical encoding, which assume such a linearization process[2]. An important characteristic of these models, which motivates the assumption of that process, is incremental processing. The speaker does not wait until a sentence is encoded in its entirety before commencing to articulate it (Von Kleist, 1805). Instead, production is piecemeal: As soon as a higher level of processing has encoded part of its output representation, a lower level can begin to work on it. In De Smedt's model, the order at which parts of sentences are encoded depends on the order with which lemma's are selected. Lemma's, which are assigned syntactic relations such as subject and object, are then placed in a representation called 'f-structure'. This representation specifies constituency, but not word order. Word order is determined in the mapping from f-structure to another structure called c-structure. The c-structure contains sequences of slots for each constituent, in which daughter

[2]These models are certainly in the spirit of the Bock & Levelt theory, and focus on the process of constituent structure building.

constituents can be placed. Placement of constituents in slots is guided by grammatical constraints, such as the constraint that in Dutch the verb occupies the second position of a main clause, or that a determiner precedes a noun in a noun phrase. In addition, the principle of incrementality dictates that a constituent is placed in a slot as far to the left as grammatical constraints allow, so that phonological encoding of that part of the sentence can proceed as soon as possible.

The linearization process thus allows for incremental processing: Depending on temporal availability of pieces of f-structure, one word order or another will be placed in a certain linear position. However, experimental evidence for this process is scarce. Some indirect evidence was obtained by Vigliocco, Butterworth, & Garrett (in press) and Vigliocco & Nicol (submitted). They elicited errors of subject-verb agreement in a constrained production experiment, using a paradigm introduced by Bock & Miller (1991). In that paradigm, participants are presented sentence preambles with a subject head noun and a modifier of the subject, containing a 'local noun' (i.e. the final noun of the modifier) such as (1) and (2).

(1a) The report of the destructive fire
(1b) The report of the destructive fires

(2a) The report that they controlled the fire
(2b) The report that they controlled the fires

Participants had to repeat each preamble and then complete it to a full sentence. This naturally leads to the elicitation of a verb, and the number of wrongly inflected verbs is the dependent variable. Bock & Miller (1991) showed that the number of agreement errors is highest when a head noun mismatches in number with a local noun (especially when the head noun is singular). Following Quirck, Greenbaum, Leech, & Svartvik (1972) this effect has been dubbed an attraction effect (the verb inflection is 'attracted' by the number of the local noun).

Vigliocco & Nicol (submitted) tested the effect of a number mismatching local noun, in a question formation variant of the subject-verb agreement paradigm. For instance, participants were presented with (3).

(3) SAFE the flight of the helicopters

Participants had to turn this adjective/preamble pair into a question such as 'Was the flight of the helicopters safe?' An attraction effect was obtained in that experiment, even though a relatively large distance separated the verb and the local noun. Vigliocco et al. (in press) obtained similar results. The finding of an attraction effect in the production

of utterances with position of verb and subject noun phrase (NP) reversed suggests that linear distance between verb and mismatching local noun is unimportant for an attraction effect to occur. This finding implies that it is syntactic distance, the number of intervening phrasal nodes, that is crucial. These results support the hypothesis that first a structure is generated containing hierarchical relations between constituents but not word order, that subsequently agreement is determined, and that finally constituents are assigned to linear position.

Given the scarcity of the evidence for a linearization process, it seems desirable to obtain more direct evidence for it. The approach pursued in this study is to test whether the output of linearization, word order, is 'persistent'. Is there a tendency to reuse the word order of a previously produced sentence? If the answer is yes, that would support the notion that a linearization process exists.

Persistence effects in grammatical encoding have been observed earlier, especially in the work of Bock and colleagues (Bock, 1986b; 1989; Bock & Loebell, 1990; Bock, Loebell, & Morey, 1992) which was followed inter alia by Branigan, Pickering, Leversedge, Stewart, & Urbach (1995) and Hartsuiker & Kolk (submitted), and has some earlier precursors (Kempen, 1977; Levelt & Kelter, 1982; Tannenbaum & Williams, 1968; Wiener & Labov, 1983). These experiments all demonstrated some forms of repetition effect in speaking: Speakers tend to reuse recently produced words, phrases, or syntactic structures.

Bock et al. (e.g. 1990) showed that participants in a priming experiment, tended to reuse the syntactic structure of a prime sentence in a subsequent picture description. Pictures could be described with a sentence having the same structure as the prime sentence, but also with a syntactic variant of that structure. The experiments showed that constituent structure is 'persistent', e.g. following the production of prime sentence (4) the incidence of sentences such as (5a) increased, whereas the incidence of sentences such as (5b) decreased.

(4) The cheerleader offered a seat to her friend.
(5a) The girl is handing a paintbrush to the man.
(5b) The girl is handing the man a paintbrush.

Such effects were reported with active and passive transitives as well as with prepositional datives (5a) and double object datives (5b).

Crucially, these effects were obtained in the absence of lexical, thematic, or prosodic correspondences between prime sentence and picture description. For instance, Bock (1989) showed that 'to-dative' responses were equally well primed by 'to-dative' primes and by 'for-dative' primes, thus excluding the possibility that the results are an

artifact of lexical priming Furthermore, Bock & Loebell (1990) showed that priming is not an artifact of persistent thematic role assignment For instance, a sentence with a locative complement, such as (6) which has the same phrasal configuration as a prepositional dative, but different thematic roles, primes the prepositional dative equally well as the prepositional dative itself

(6) The wealthy widow drove her Mercedes to the church

In addition, a locative sentence with a by-phrase, having the same phrasal configuration as a passive, but different thematic roles, such as (7), primes the passive equally strong as a passive prime [3]

(7) The minister was praying by the broken stained glass window.

Furthermore, a prime sentence with the same prosody and almost the same lexical items as a prepositional dative, but with a different constituent structure (8a) does not facilitate prepositional dative responses, whereas a prepositional dative prime (8b) does

(8a) Susan brought a book to study [4]
(8b) Susan brought a book to Stella

Finally, Bock, Loebell, & Morey (1992) reported an experiment that provides evidence for a distinction between conceptual and syntactic effects on construction of constituent structure In a syntactic persistence experiment with active and passive transitives, they showed additive effects of constituent structure on the one hand, and a conceptual feature (i.e animacy) of subject and object on the other hand They did this by orthogonally varying (i) constituent structure of prime sentence (active or passive) (ii) animacy of subject and object in prime sentence (animate subject, inanimate object or the reverse) Target pictures could all be described with an active or a passive Furthermore, target pictures all had inanimate agents and animate patients Therefore, a target description in the active voice would contain an inanimate subject and an animate object To begin with, there was a priming effect of animacy Following a prime sentence with an inanimate subject and an animate object (9a), subjects were likely to repeat that assignment in their description of the target picture (9b)

[3]Notice however that all locative complements were headed by the preposition 'by', thus allowing for an explanation in terms of lexical priming
[4]Notice that in (8a), 'to study' is a node of category S, modifying the direct object NP 'a book' In (8b) 'to Stella is an argument of the verb

(9a) The boat was carried by five people

(9b) The alarm clock awakened the boy

Furthermore, there was a priming effect of constituent structure. These two main effects were additive. According to Bock et al. (1992) this shows that the syntactic persistence effect can be isolated from levels of processing at which conceptual features exert an influence.

It thus appears that these persistence effects reflect the construction of constituent structure: The effects can not be attributed to conceptual, thematic, lexical, or prosodic factors. That makes the paradigm a good candidate for the investigation of a linearization process. If such a process exists, we expect persistence of word order: Speakers would tend to reuse the word order of a prime sentence. It should be emphasized that the models proposed by De Smedt (1990) and Kempen & Hoenkamp (1987) assumed that linearization operates on a constituent structure which specifies functional and hierarchical relations, but not word order. In order to restrict our manipulation to the relevant syntactic aspect, word order, we need to keep those other relations constant. Notice that syntactic contrasts tested in earlier experiments, such as the one between the active and passive transitive, differed with respect to functional relations, hierarchical relations between constituents, and word order. If our hypothesis is correct, sentences with the same functional relations, same hierarchical relations, but different word orders should have different impacts on picture description, such that word order tends to be repeated.

A syntactic contrast that allows the manipulation we intend is that between two variants of the locative sentence in Dutch. These variants consist of a subject NP, a locative verb and a prepositional phrase (PP). The PP is either placed sentence-final, as in (10a) or sentence-initial, as in (10b). (See Figure 1).

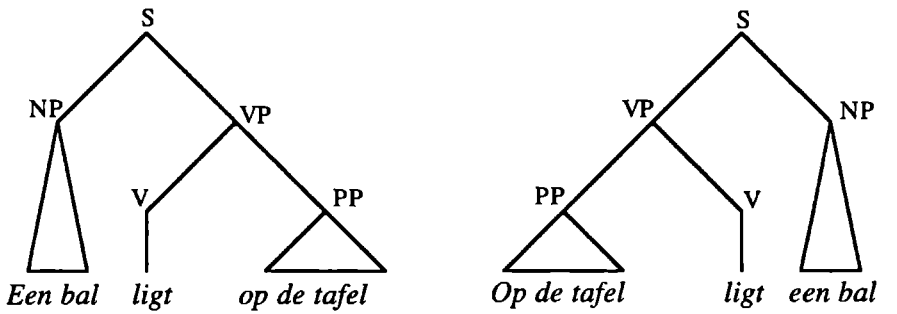

FIGURE 1. Syntactic stucture of the Locative State (LS) sentence 'Een bal ligt op de tafel' (A ball lies on the table') and its Frontal Locative (FL) alternate. Notice that there are alternative syntactic theories that, for instance, do not postulate a VP-node but assume the V-node is immediately dominated by S. We feel this to be unproblematic for the hypothesis at hand.

(10a) Een boek ligt op de plank.
(A book lies on the shelf.)

(10b) Op de plank ligt een boek.
(On the shelf lies a book.)

The construction illustrated in (10a) is called the Locative State sentence (Bloom & LaHey, 1978). We dub the construction in (10b) the Frontal Locative. In the remainder of this chapter we will abbreviate these constructions as LS (Locative state) and FL (Frontal Locative). Notice that it can be argued from the point of view of Government and Binding theory, that the hierarchical relations of constituents in these sentences differ (e.g. 10b would be derived from 10a by move-α). In fact, in early transformational literature there has been some debate on the analysis of sentences with a preposed prepositional phrase (Klein & Van den Toorn, 1978; Kooij & Wiers, 1977). However, with Bock et al. (1992) we assume a non-transformational approach to formulating. First, because Bock et al. (1992) provided evidence against the psychological reality of D-structure subjects and objects, and second because of the non-locality of transformations: It would require the construction of large portions of syntactic trees, and this seems to violate the principle of incrementality (De Smedt, 1990; Kempen & Hoenkamp, 1987; Levelt, 1989; Von Kleist, 1805).

Before conducting the experiment reported below, we required 40 participants to describe experimental pictures and to supply acceptability ratings for prime sentences. None of these subjects participated in the main experiment. From the pretest it became clear that the LS-sentence is highly dominant: Few or none FL-sentences were produced. It also became clear that one important condition of usage for the non-canonical form, the FL-sentence, is the definiteness of the elements fulfilling the thematic roles of theme and location. In particular, we observed an increase in the incidence of FL-sentences when the prepositional object was definite, and the subject was indefinite, as in (10). A similar pattern of results emanated from the collection of acceptability judgments: When the distribution of definiteness was as stated above, FL-sentences were judged as more acceptable than with any other distribution. In addition, with that distribution FL- and LS-sentences were judged as equally acceptable. This effect of definiteness is probably related to the given-new distinction (Haviland & Clarck, 1974). Bock (1977) showed how for a variety of syntactic alternations, speakers had a tendency to preserve the order given-new. Similar results with respect to the dative alternation were reported by Collins (1995). With a definite location and an indefinite theme, the frontal locative construction allows a speaker to place 'given' material sentence-initial and new material sentence-final. In order to ensure a fair

number of FL-responses in our experiment, we decided to require participants to use the distribution of definiteness as outlined above (see Method section for details).

In our experiment, the primed sentence production task of Bock et al. is used. We presented three types of primes to our subjects: LS-primes, FL-primes, and furthermore, baseline-'primes'. The rationale for having a baseline is to assess whether any priming effects are facilitatory for both constructions or not (see Hartsuiker & Kolk, submitted, for an extensive discussion about baselines in these kinds of experiment).

Method

Participants

Eighty-four undergraduate students of the University of Nijmegen participated. All were native speakers of Dutch. They were paid Dfl 7.50 or obtained course credits.

Materials

There were 12 locative pictures which were paired to 12 sets of locative prime sentences. Each picture had shown to elicit a fair number of locative state and frontal locative responses in pretests. All of the picture material depicted a scene with a location and a theme. Next to each element, a two-word label was printed. Labels were simple noun phrases (NP's). Noun phrases next to locations contained an indefinite determiner ('een', 'a'); NP's next to themes contained a definite determiner ('de' or 'het', 'the'[5]). The set of pictures was completely balanced with respect to left/right position of theme and location.

Each sentence set contained three sentences: A locative state and a frontal locative alternate of the same sentence and a baseline sentence. The baseline sentences were all Wh-questions, i.e. they had a structure that was not feasible for subsequent reuse in picture description. A complete list of experimental materials is provided in the Appendix. An example of a target picture is presented in Figure 2.

In addition, there were 24 filler pictures and 24 filler sentences. Filler pictures had all been shown to elicit intransitive responses in earlier experiments. All picture elements were labeled with NP's. There were 18 pictures with only one picture label. Of those 18, the determiner was definite in nine cases, and indefinite in the remaining nine. The six pictures with two picture elements, had two definite or two indefinite determiners in three cases, and one definite, one indefinite element in the remaining three. Filler sentences comprised a range of constructions, including WH-questions, imperatives, intransitives, and transitives with preposed objects. All filler materials occurred twice. Furthermore, there were ten practice sentences and pictures.

[5]The gender-system in Dutch is basically restricted to a distinction between neuter and non-neuter. The definite determiner 'de' precedes non-neuter nouns, whereas 'het' precedes neuter nouns.

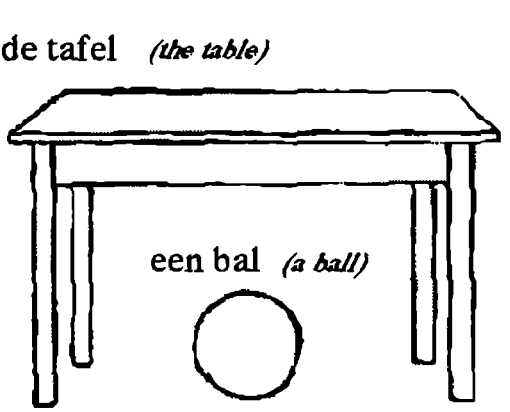

FIGURE 2. Example of target picture in the experiment.

Three 108-items lists were constructed, such that in each list occurred an equal number of pictures (four) in each condition of the Prime factor, and that across the lists, each picture occurred once in each condition. The lists were built up in a quasi-random fashion with the following constraints (i) each list started with eight fillers, followed by an experimental trial (prime and picture), followed again by eight fillers and so on (ii) the first four experimental trials were all baseline trials (iii) there were never more than three pictures or sentences in a row.

All pictures were available on computer disk. They were edited for clarity if necessary, and picture elements were provided with labels using an image enhancement software package. All sentences were recorded on analog audio tape. They were digitized and stored on computer hard disk.

Procedure

Participants were tested in individual sessions, lasting approximately 20 minutes. They received written instructions, in which the task was explained to them as a memory task: Following sentence repetition or picture description, they had to indicate with 'yes' or 'no' whether they had run into the item before or not. Sentences were presented from computer hard disk, using a single MacSpeaker. During sentence presentation, the Dutch equivalent of 'LISTEN' appeared on the screen. Following that, the equivalent of 'REPEAT' appeared. Pictures had to be described with a single, grammatically correct Dutch sentence. Participants were required to use the labels that were provided next to the picture elements, including the determiner. The task was self-paced: Following sentence repetition or picture description and the yes/no-response, participants initiated the next trial by pressing a button. Before the actual experiment started, participants were presented with ten practice items. The experimenter corrected

any inadequate responses (incomplete sentences, wrong determiners, etc.) during practice, but not during the actual experiment.

Each participant was presented with one of the three lists, and each list was presented to 28 participants. The experimental sessions were recorded on audio cassette.

Scoring

The audio cassettes containing the sessions were transcribed. Descriptions of experimental pictures were scored for syntactic structures. Responses were divided into one of the following three categories: Locative State (LS), Frontal Locative (FL), and Others (OT). An utterance was scored as LS if the sentence started with a subject noun phrase (NP) incorporating the theme, followed by a locative verb, which is followed by a prepositional phrase (PP) incorporating the location. An utterance was scored as FL, if it started with a PP incorporating the location, followed by the locative verb, followed by the subject NP. A sentence was only scored as FL or LS if an alternative in the other form was syntactically correct. The rationale for requiring the possibility to have both alternatives is that we can only assess an effect of priming when it is at least possible to produce both target structures. All responses not adhering to the criteria for LS or FL, were scored as OT. These were mainly sentences containing extra modifiers such as past participles or infinitives e.g.(12-13), and responses that had starter phrases such as 'there is'.

(12) Een pleister zit op de voet geplakt.
(a plaster sits on the foot stuck)
(A plaster is stuck on the foot.)

(13) Aan de waslijn hangt een was te drogen.
(on the clothes-line hangs a laundry to dry)
(Laundry is drying on the clothes line.)

Design

Participants were each presented with 12 locative pictures. Prime type was a within-subject factor. The baseline condition was regarded as one level of this factor. Subjects received four trials in each of the three levels of the Prime type factor.

Results

Scoring according to our criteria yielded a total of 1008 responses. There were 765 LS responses (75.9%), 160 FL-responses (15.9%), and 83 responses classified as OT (8.2%). Of these OT-responses, 34.9% occurred in the Baseline condition, 27.7% in

the LS-condition, and 37.3% in the FL-condition. The number of LS-, FL-, and OT-responses in each prime condition are listed in Table 1. In Figure 3, we list the proportion of FL-responses in each condition. The proportion of LS-responses follows a complementary distribution.

TABLE 1

Response frequencies (percentages in parentheses)

Prime[a]	*LS*	*FL*	*OT*
LS	260 (77)	53 (16)	23 (7)
FL	230 (68)	75 (22)	31 (9)
BA	275 (82)	32(10)	29 (9)

a. Total number is 336 in each condition.

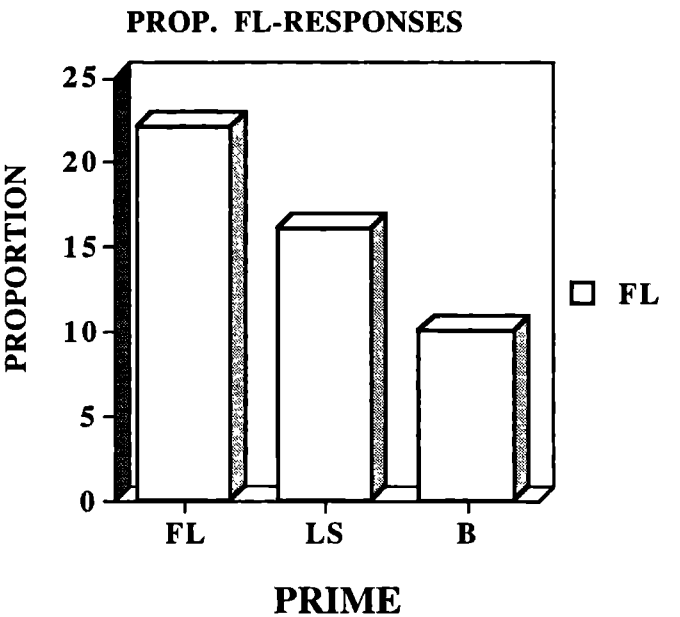

FIGURE 3. Barcharts indicate the proportion Frontal Locative (FL) responses following each type of prime (FL, LS, and baseline). The proportion of Locative State responses follows a complementary distribution.

The pattern of results listed in the table shows that there is syntactic persistence for the two tested locative alternatives in Dutch. The frequency of FL-responses is highest in the condition with FL-primes, followed by the condition with LS-primes, followed by the baseline condition. The frequency of LS-responses is higher in the LS

condition than in the FL-condition, but interestingly, the frequency is highest in the baseline. Finally, the frequency of OT-responses is approximately equal in all conditions.

ANOVA 's were performed on the numbers of LS-, FL-, and OT-responses, with Prime type as a three-level within subject factor. For each response type, there were separate ANOVA's, one with subjects (F1) and one with items (F2) as a random factor.

In the ANOVA on LS-responses the effect of Prime was significant [F1(2,166)=8.88; p<.001; F2(2,22)=12.58; p<.001]. Post-hoc comparisons revealed that both the difference between FL- and LS-primes was significant [F1(1,83)=6.99; p=.01; F2(1,11)=33.00; p<.001] and the difference between the experimental primes and the baseline was reliable [F1(1,83)=11.15; p=.001; F2(1,11)=8.59; p<.02].

A similar set of results was obtained in the analysis with the number of FL-responses as the dependent variable. The effect of Prime was significant [F1(2,166)=11.19; p<.001; F2(2,22)=23.80; p<.001]. Post-hoc comparisons revealed that both the difference between FL- and LS-primes was significant [F1(1,83)=5.07; p<.05; F2(1,11)=20.48; p=.001] and the difference between the experimental conditions on the one hand and the baseline on the other hand was reliable [F1(1,83)=19.53; p<.001; F2(1,11)=25.26; p<.001].

No significant effects were obtained in the analysis on OT-responses.

Finally, we noticed that the syntactic structure used to describe target pictures was influenced by position of picture elements as well as by structure of prime sentence (cf. Flores d'Arcais, 1975). In fact, if the data are split according to this variable, there appears a strong position effect on the total number of FL-responses (124 when location is on the left, 36 when location is on the right). However, in both of these item sets (each containing 50% of the materials), responses of each type were most frequent following a prime of the same type.

Discussion

The experiment presented here allows us to generalize the claim that syntactic structure shows persistence to structures not tested before: Locative sentences in Dutch. In fact, following a prime sentence with an initial prepositional phrase, one is more likely to use the same structure in a subsequent picture description than following a prime sentence with a final prepositional phrase. The latter type of sentence is more frequent when preceded by a prime of that type. Because the alternatives serving as prime sentences differed with respect to word order, but were the same with respect to functional relations and hierarchical relations between constituents, this is evidence for a persistence effect at the level of constituent structure linearization.

There are two characteristics of our data that merit further elaboration. Following discussion of these characteristics, we will turn to the implications of our findings for theories of grammatical encoding. In particular, we will deal with an alternative interpretation of our results. That interpretation entails that we have provided evidence for persistence of constituent structure selection, and that these constituent structures are specified for word order as well as for hierarchical relations between constituents. We will argue that such an interpretation runs into trouble because of the *overspecification* of the functional representation with respect to constituency. We will conclude by proposing some additional principles that guide linearization.

The first finding that merits discussion is the following. Although we observe a clear-cut facilitation effect in the case of frontal locatives, this is not the case for locative state sentences. In fact, there are more locative state utterances in the baseline condition than in either of the two prime conditions. Why is this the case? We believe that the same explanation holds as the one suggested in Hartsuiker & Kolk (submitted). In the four experiments with active and passive transitives reported there, there was a consistent finding: The number of target utterances (actives and passives) was much lower in the baseline condition than in either of the experimental conditions.

Hartsuiker & Kolk accounted for this by assuming that syntactic persistence has a relatively long duration. Repeated exposure to several priming trials with a given structure increases availability of that structure. This entails that producing a prime sentence leads to a small increase in the activation level of the relevant mental representation. This in itself may increase the probability of producing a description having the same structure on a subsequent picture description. However, there is also a combined effect of repeatedly producing prime sentences of a given structure, such that the activation level of the relevant representation increases (Long Term Priming). Because the baseline trials were always the first trials in the experiment, they were not influenced by Long Term Priming.

We believe that the present result with the baseline condition can be accounted for in a similar way: In principle the locative state response is highly dominant. This is reflected by the baseline data, collected in the first four trials of the experiment. In fact, the incidence of the locative state has reached a ceiling. Long Term Priming cannot increase the availability of that structure anymore. However, Long Term Priming does increase the activation level of the frontal locative. This increases the likelihood of that structure being produced on any experimental trial, and especially on trials with a frontal locative prime. Because the overall likelihood of a frontal locative increases, the overall likelihood of a locative state decreases.

We now turn to an important feature of the data: The pictures with the location on the left elicited more than three times as many FL-responses as pictures with

locations on the right. Notice that FL-sentences begin with a PP incorporating the location. This points to left-to-right processing in either scanning the picture, or reading the labels next to the picture elements. Order of mention would then, to a strong degree be determined by the relative accessibility of the concepts to be uttered. Bock (1982) argued that variables such as (lexical) accessibility codetermine syntactic structure. Moreover, evidence for effects of lexical and conceptual accessibility was found, inter alia, by Bock (1977, 1986a). A counterexample is a study by Levelt & Maassen (1981) who found no effect of conceptual accessibility in the production of noun phrase conjunctions. However, it is argued by Levelt (1989) that this experiment probably tested phonological accessibility, not conceptual accessibility.

Therefore, it seems safe to assume that indeed order of mentioning concepts is determined by their accessibility. The question arises at what level of processing such conceptual accessibility effects occur. McDonald, Bock, & Kelly (1992) proposed that it is the assignment of grammatical functions that is sensitive to conceptual features. There is a tendency, for instance, to assign the role of grammatical function to animate entities. Because grammatical subjects tend to occur in the beginning of sentences, speakers prefer to start sentences with animate entities. On the other hand, quite consistent with the line of reasoning in the present experiment, Prat-Sala et al. (1996) provided tentative evidence for a tendency to begin utterances with animate entities, regardless of subjecthood, in languages which allow more freedom of word order than English (i.e. Catalan and Spanish). This points to a different level of processing in the system that is influenced by conceptual factors: Linearization. The tendency to begin with conceptually more accessible elements would then be explained as follows: Because the lemma's of the conceptually more accessible elements are retrieved earlier, assignment of grammatical functions to lemma's has a temporal advantage. Because of that, construction of the local syntactic environment around those lemma's has a high probability of being completed earlier. Therefore, the linearization process begins earliest with these elements and places them in a sentence-initial position. It should be noted that similar explanations, referring to the time course of incremental sentence production, can also account for the phenomenon of 'heavy-NP shift' (Stallings, MacDonald, & O'Seaghda, 1995, Haanstra, 1995). Speakers have the tendency to place a long complex NP sentence-finally. That may be accounted for by assuming that it takes longer to construct the phrase-structure of a long, complex NP than that of remaining constituents. Because these remaining constituents thus have a temporal advantage, they are placed in a slot farther to the left.

We now turn to an alternative interpretation of the present results. Instead of persistence of a linearization process, the results could be taken as evidence for persistence of a hierarchy of phrasal nodes which is fully specified for constituent order.

One way in which positional processing could construct an ordered, hierarchical frame, is by selecting it in one go. Indeed, the priming experiments reported by Bock and colleagues (Bock, 1986b; 1989; Bock & Loebell, 1990; Bock et al., 1992) seem to imply that selection of a constituent structure can be primed.

However, obviously, persistence of constituent structure assembly is only possible to the extent that there is a choice between alternative syntactic frames. In other words, priming that level is only possible as long as the syntactic frame is not predetermined by functional level processing. Unfortunately, Bock & Levelt's (1994) theory seems to imply that constituent structure is largely determined by functional relations: The functional level representation is *overspecified*, leading to a highly predictable syntactic structure. Consider the description of an event like a man hitting a child. That scene will only be described in the passive voice, if during functional integration, the role of subject is assigned to 'child' and the role of by-phrase object to 'man'. Since functional integration precedes constituent assembly, and since, furthermore, the theory assumes a feedforward flow of information only, there is no obvious way how, once a commitment has been made to functional relations (restricting the utterance to be, for instance, a passive), a previously produced alternative constituent structure (say, an active) can be facilitated. The same would apply to priming of datives: Once functional integration has determined the subject, direct object, and prepositional object, the resulting phrase structure is restricted to be a prepositional dative, regardless of any advantage given to a different phrase structure by priming.

It thus seems untenable to ascribe the priming effects in the present experiment to reuse of a constituent structure specified for hierarchical relations as well as word order. Instead, we ascribe the effect to persistence of linearization. However, we would not want to go as far as to claim that *all* syntactic persistence effects reported in the literature can be explained in this way. Consider again Bock et al. (1992). They ascribed the tendency to repeat the assignment of animacy to subject and object to processes at functional integration, and the tendency to repeat syntactic structure to positional processing. However, they admit that there is another possibility: The possibility that the animacy effects occur at an earlier level, that of conceptualizing and that priming of constituent structure is located at the stage of functional integration. That would solve the problem of overspecification we alluded to above: Priming cannot take place at the level of constituent structure building, because that process is predetermined by functional integration. A more likely locus for priming effects is the process of functional integration itself.

However, it might be argued that a similar problem of overspecification applies to the conceptual representation, which serves as input for functional integration. We do not think this is the case. The reason is that in order for the speaker and listener to know the communality of different constructions that express the same state of affairs, there

must be a processing level at which these different constructions share a common representation. With Bock et al. (1992) we assume that this communality lies in the conceptual representation. Therefore, a single conceptual representation can be expressed with different kinds of constituent structures. This is not to say we deny the role of a semantic/pragmatic component in the decision to produce, for instance, a passive and not an active. However, we conceive of these higher level cues as 'gentle forces': They may bias the system in one direction or another, but they do not predetermine the outcome. In other words, it seems plausible that the conceptual representation is underspecificied with respect to eventual syntactic structure. On the other hand, the functional representation is overspecified with respect to syntactic structure.

A possible objection to the localization of structural priming effects at the level of functional integration follows from the results of Bock and Loebell (1990), mentioned above: A locative such as (6), repeated here, primes a prepositional dative, even though thematic role assignment is different (the last noun phrase has the role of recipient in a dative, and the role of location in a locative).

(6) The wealthy widow drove her Mercedes to the church

However, as mentioned in Footnote 3, it is possible that these results can be accounted for in terms of lexical priming. In addition, it is important to distinguish thematic role assignment from functional relation assignment. It may be the case that thematic roles are important for functional integration, and that locatives and datives differ with respect to this aspect of functional integration. However, that does not preclude the possibility that datives and locatives share other aspects of functional integration that are more important for the occurrence of a priming effect. For instance, if we assume, with Bock et al. (1992, p.166), that functional assignment involves subcategorization properties of the selected verb form, both locative and dative verbs would specify the need to assign a function like 'object of prepositional phrase'. Thus, the shared subcategorization properties may well be the representation that is primed.

In sum, the syntactic persistence experiments reported in the literature can be taken to show priming of function assignment. Moreover, the alternative interpretation that constituent structure is primed, runs into trouble because the functional representation is overspecified with respect to constituent structure. On the other hand, constituent structure as we envisage it, is underspecified with respect to word order. Therefore, the results of the present experiment can best be taken to show priming of constituent structure linearization. This conclusion is also supported by the effect of position, mentioned before: Because picture elements on the left side of the picture are available earlier, their linguistic encoding is available sooner to the linearization

process. Therefore, they are placed in an earlier linear position and hence are articulated earlier.

Given our conclusion, that constituent structure is underspecified with respect to linear order, the process of linearization seems a good candidate for the explanation of a number of effects. For instance, although a language may have free word order, some word orders are more canonical than others. Therefore, it is likely that in a predominantly SVO-language there is a bias to place grammatical subjects in first position. Such a bias could be implemented during linearization. Furthermore, an 'instruction to topicalize' may be implemented at that stage (De Smedt, 1990), or the instruction to form a question (Vigliocco & Nicol, submitted). If linearization then is conceived as an interplay of 'gentle forces', such as accessibility, canonicity of word order, pragmatic constraints, and the need to ensure fluency of speech, it seems a likely candidate indeed for a process that is sensitive to priming.

Appendix: Experimental sentence sets and pictures[a]

1.	Een doek ligt op het aanrecht.	(a cloth lies on the sink)
	Welke flessen kan ik meenemen?	(which bottles can I take?)
	Een hond zit naast het hok.	*(A dog sits besides the kennel.)*
2	Een bal ligt onder de auto.	(a ball lies under the car)
	Waar kun je die planten kopen?	(where can you those plants buy?)
	Een schilderij staat op de tafel.	*(A painting stands on the table.)*
3	Een beker staat op het dienblad.	(a cup stands on the tray)
	Wat is de reden van zijn bezoek?	(what is the reason of his visit?)
	Een was hangt aan de waslijn.	*(A laundry hangs on the landry line.)*
4	Een knikker ligt onder de kast.	(a marble lies under the cupboard)
	Wie is die man?	(who is that man?)
	Een tuinslang ligt op de boomstronk.	*(A garden hose lies on the treetrunk.)*
5	Een lamp hangt boven de tafel.	(a lamp hangs above the table)
	Waar is de vergadering?	(where is the meeting?)
	Een boek staat op de plank.	*(A book stands on the shelves)*
6	Een handdoek ligt in de wasmand.	(a towel lies in the the laundry-basket)
	Waarbij vind je deze kleur passen?	(where by find you this color fit?)
	Een pleister zit op de voet.	*(A plaster sits on the foot.)*
7	Een kunstwerk hangt aan de muur.	(a work of art hangs on the wall)
	Waarom staan die mensen daar?	(why stand those people there?)
	Een kop en schotel staat op de tafel.	*(A cup and saucer stand on the table.)*

[a] Prime sentence in the LS-form, baseline sentence, and LS-target picture description in italics. Sentences are followed by word-by-word literal English translation. Translations of compound Wh-words, e.g. 'waarop', meaning 'on what' are provided morpheme-by-morpheme, i.e. 'where on'.
Frontal locative is derived from Locative State as follows: NP V PP -> PP V NP.

8	Een kwast ligt op de verfpot.	(a brush lies on the paint pot)
	Waarom doe jij zo vervelend?	(why do you so annoying?)
	Een poes zit onder de tafel.	*(A cat sits under the table.)*
9	Een kussen ligt op de bank.	(a pillow lies on the couch)
	Welke oen heeft dat gedaan?	(which fool has that done?)
	Een boom staat voor de kerk.	*(A tree stands before the church.)*
10	Een struik staat naast de deur.	(a bush stands besides the door)
	Wie kan er vandaag nog komen helpen?	(who can there today yet come help?)
	Een hond zit in het hok.	*(A dog sits in the kennel.)*
11	Een fiets staat tegen de muur.	(a bicycle stands against the wall)
	Waarop is dit gebaseerd?	(what on is this based?)
	Een bal ligt onder de tafel.	*(A ball lies under the table.)*
12	Een dweil ligt op de grond.	(a floorcloth lies on the floor)
	Wie gaat er mee?	(who goes there along?)
	Een appel ligt in de kom.	*(An apple lies in the bowl.)*

Chapter 3
Syntactic facilitation in agrammatic sentence production[1]

Abstract

Recently, proposals have been made to relate processing difficulties in aphasic language performance to limitations in resources for grammatical processing (Carpenter, Miyake, & Just, 1994; Hagiwara, 1995; Kolk, 1995; Martin & Romani, 1994). Such proposals may account for a defining characteristic of agrammatic sentence production: Reduced syntactic complexity. Syntactic structures that require deep hierarchical processing or reversals of canonical word order make demands exceeding limited resources. In the present study, we investigate the possibility of counteracting hypothesized resource limitations by increasing the availability of relatively complex sentences (i.e. datives and passives). The phenomenon of 'syntactic priming' has been observed in a number of studies with healthy adults (e.g. Bock, 1986). With respect to Broca's aphasics, we hypothesized that increased availability of a syntactic structure, due to syntactic priming, results in a lesser demand on (limited) resources for sentence production. We elicited speech from 12 Broca's aphasics and 12 control subjects in three different conditions: Spontaneous speech, picture description without priming, and picture description with priming. In addition, we varied instructions, in order to determine the role of strategies. Main findings were (a) Broca's aphasics show stronger syntactic priming effects than controls (b) The effects are automatic rather than strategic (c) In conditions with priming, Broca's aphasics produce relatively complex sentences. We discuss these results in relation to capacity theories.

Introduction

A defining symptom of Broca's aphasia is a reduced complexity of syntactic structure (e.g. Caplan, 1987; Caplan & Hanna, in press; Gleason, Goodglass, Green, Ackerman, & Hyde, 1975; Goodglass, Christianson, & Gallagher, 1994; Menn & Obler, 1990). Menn & Obler (1990), in the concluding chapter of a large crosslinguistic study, state that 'syntax (in agrammatic sentence production) is simplified, both within and

[1]Hartsuiker, R.J. & Kolk, H.H.J. (Submitted). *Brain and Language.* Parts of the data were presented at the Cognitive Neuroscience Society, San Francisco, 1995 and at the Academy of Aphasia, London, 1996, both presentations authored by Hartsuiker, R.J. & Kolk, H.H.J. The conference abstract for the Academy of Aphasia presentation will appear in *Brain and Language.*

across clauses' (p.1370, material in brackets ours). What can account for this syntactic simplification?

A recent theory, within the framework of Chomsky's minimalist program (Chomsky, 1995) was put forward by Hagiwara (1995). That theory is one of the first attempts to explain differential sensitivity for different closed class items to be omitted by agrammatic speakers (cf. Haarmann & Kolk, 1992). In addition, the theory makes predictions concerning complexity of syntactic structure. The theory claims that for agrammatic speakers, difficulties exist in the projection of functional categories, such as C (complementizer), T (tense), and AGRS (Subject agreement). Each of these categories has its own position in the functional hierarchy. Turning to agrammatism, every agrammatic patient can be characterized with respect to a particular level in this hierarchy. Functional categories below this level are spared, but categories higher in the hierarchy are inaccessible. This theory accounts for Hagiwara's Japanese data, where patients would never omit negations (dependent upon the relatively low NEG-node) but would often omit complementizers (dependent upon the much higher C-node) Furthermore, if an agrammatic speaker is unable to create the projection of a node as high as the C-node, he is also unable to produce subordinate clauses introduced by a complementizer. Indeed, structures with embeddings ranked among the most difficult for agrammatics to produce in a study with 14 different constructions (Gleason et al., 1975).

Crucially with respect to the present study, Hagiwara relates the functional level that is still accessible to *processing capacity*. The more capacity one has, the more often a 'Merge Operation' (Chomsky, 1995) can take place, resulting in higher functional projections. If one has little capacity, only small, i.e. more economical structures can be created: Structures that make less demand on capacity.

The notion of limitations in capacity for syntactic processing is not new (Caplan, Baker, & Dehaut, 1985; Caplan & Hildebrandt, 1988; Frazier & Friederici, 1991; Haarmann, Just, & Carpenter, in press; Just & Carpenter, 1992; Kolk, 1995; Kolk & Van Grunsven, 1985; Martin & Romani, 1994; Martin, Shelton, & Yaffee, 1994; Miyake, Carpenter, & Just, 1994, 1995), both in the study of individual differences in capacity among the normal population, and in the study of aphasic comprehension as an instance of a severe capacity reduction. Although in a number of these studies, especially in the work of Just et al., detailed assumptions are made about the relation between the language processor and processing capacity, important questions remain unanswered. For instance, there is considerable debate about the specificity of these resources: Separate resources for semantic, syntactic, and phonological processing (e.g. Caplan & Waters, 1995; Martin, 1995; Martin & Romani, 1994; Waters & Caplan, in press) or a general verbal working memory, involved in all of these components of the language processor (e.g. Just & Carpenter, 1992; Miyake, Carpenter, & Just, 1994; 1995). Furthermore, it is unclear whether the same resources are being used both in production

and comprehension (but see Daneman & Green, 1986, for tentative evidence that the amounts of resources available for producing and comprehending language are not the same). Although previous research has mostly focused on comprehension, we think the same importance of resource limitations for the study of individual differences in verbal skills, and of aphasia, applies to production (whether that involves the same resources or not).

In the present study we will argue that the output deficit underlying agrammatic aphasia consists of, at least in part, a limitation in mental 'resources' for syntactic processing. The main question we address is the following: Assuming that agrammatic speakers suffer from a limitation of resources for syntactic processing, resulting in an inability to produce complex sentences, can we counteract the results of this limitation by temporarily increasing the availability of the relevant syntactic structures? If we can decrease the demands complex sentences make of limited resources, we may be able to elicit them from agrammatic speakers.

However, is it possible to increase availability of a syntactic structure? A series of studies on the phenomenon of 'syntactic priming' in healthy adults shows it is (Bock, 1986, 1989; Bock & Loebell, 1990; Bock, Loebell, & Morey, 1992; Branigan, Pickering, Liversedge, Stewart, & Urbach, 1995; Hartsuiker & Huiskamp, 1996; Hartsuiker & Kolk, 1995). In these studies, the syntactic structure of a 'prime' sentence affects the way a subsequent target picture is described[2]. For instance, a picture showing a man giving a brush to a woman, is more often described with a prepositional dative sentence (2) if it is preceded by a seemingly unrelated sentence with the same structure (1a) than if it is preceded with the alternate syntactic structure, the double object dative (1b).

(1a) The sailor buys a present for his girlfriend.
(1b) The sailor buys his girlfriend a present.
(2) The man gives a brush to the woman.

In addition to priming of double-object and prepositional datives (Bock, 1986; 1989; Bock & Loebell, 1990; Braningan et al, 1995; Hartsuiker & Kolk, 1995), effects are reported with active and passive transitives (Bock, 1986; Bock et al., 1992), with fronted or canonical locatives (Hartsuiker & Huiskamp, 1996) and with different word orders in Dutch subordinate clauses (Hartsuiker & Huiskamp, 1996). Interestingly, although Hartsuiker & Kolk (1995) tested the active/passive contrast in a number of

[2]or in the case of Branigan et al. (1995), and Hartsuiker & Huiskamp (1996), how a sentence fragment is completed.

experiments with large groups of Dutch speaking subjects, they were unable to find a transitive priming effect.

This syntactic persistence, the tendency to reuse the syntactic structure of a previously produced sentence, could not be ascribed to thematic, lexical or prosodic factors (e.g. Bock & Loebell, 1990). The most obvious interpretation is that speakers, when constructing a sentence, have a mental representation of the sentence's phrase structure, and the availability of this phrase structure can be increased through priming.

In a pilot study with three Broca's aphasics, Saffran & Martin (1990) showed that patients who produced no passives in a pretest, did provide picture descriptions in the passive voice, when they were first primed with a passive sentence to repeat. This finding is in good agreement with the hypothesis that the surface syntactic level is impaired: Broca's aphasics manage to produce a relatively difficult sentence type, following an intervention that has been shown to affect the syntactic level of processing and not the metrical, lexical, or thematic domains. Furthermore, those findings support the prediction that syntactic facilitation diminishes demands on limited resources, thus enabling the patient to produce a relatively complex sentence.

However, there are at least three problems with this pilot study, which disallow us to draw any firm conclusions. First, the results were limited to a very small group of patients. Second, there was no control group with agematched healthy subjects. In addition, the procedure followed by Saffran & Martin departed from that followed by Bock (1989); Bock & Loebell (1990); Bock, Loebell, & Morey (1992); and Hartsuiker & Kolk (1995). These authors, in contrast to Saffran & Martin, disguised their task as a recognition task. The experimental items were embedded in a long list of filler pictures and sentences, some of which occurred twice in the course of the experiment. Subjects were instructed to respond with 'yes' or 'no' following sentence repetition or picture description in order to indicate whether that item had occurred previously or not. In this way, subjects attention was diverted from the sentence production component of the task, in order to eliminate any strategies on the subjects side.

Because Saffran & Martin's task was not covered up, the possibility of strategic involvement can not be excluded. For instance, subjects may realize that a good way of describing an experimental picture is to reuse the previous sentence and substitute the content words for different ones.

In the present experiment, we try to disentangle the contributions of automatic, facilitatory effects and strategic involvement with respect to higher incidence of target syntactic structures in primed conditions. We attempt to remedy the shortcomings of Saffran & Martin's pilot study, by testing a relatively large groups of Broca's aphasics, by testing a group of agematched control subjects, and by varying task instructions across sessions, in order to assess any strategic effects. We present our subjects with prepositional and double-object datives, and active and passive transitives. In addition to

experimental pictures preceded by a prime sentence, we have baseline conditions, containing the same pictures but preceded by sentence types not feasible for subsequent reuse.

The questions we address are the following: First, are Broca's aphasics susceptible to syntactic priming, and if so, are they susceptible to syntactic priming to the same extent as normal controls? A priming effect for Broca's aphasics, especially for more complex sentence structures, would support the hypothesis that priming can overcome a resource limitation.

Second, is it true that Broca's aphasics show syntactic simplification as compared with control subjects with respect to the target structures in our experiment? In order to assess that question, we conduct interviews with all our subjects, and determine the incidence of passives and datives. Because there may be important differences between spontaneous speech and a picture description task (Hofstede & Kolk, 1994) we also establish baselines for the target pictures. If we do not find any of the target structures in spontaneous speech and in the baseline conditions, this would be a clear indication that the structure is so resource demanding that the subject either does not succeed in producing it, when he attempts to, or avoids the structure altogether, given the high probability of failure. A high incidence of the target structure in the conditions with primes would be particularly enlightening in that case.

Unfortunately, that in itself would still not be sufficient evidence for a resource limitation account, as the possibility of strategic involvement in performing the priming experiment remains. In order to deal with that, we test our subjects in three separate sessions, and we vary instructions across sessions. In the first session, we employ the procedure Bock et al. (1992) and Hartsuiker & Kolk (1995) used in the studies with healthy adults: We disguise the experiment as a recognition task. In Session 2, we remove the recognition instructions and tell participants to simply describe pictures and repeat sentences. We supply no further information about the purpose of the task. These task instructions match those of Saffran & Martin (1990). Finally, in the third session, we supply explicit instructions to reuse the syntactic form of the previously presented sentence. We reason that if subjects are unable to use this 'strategy' on our request, they were unable to use any strategy of that sort themselves in earlier sessions. In that case, priming effects have to be ascribed to an automatic, facilitatory process, reducing the results of resource limitations in the case of complex sentence types.

Method

Participants

Participants were 12 aphasic patients (9 males, 3 females) diagnosed as Broca's aphasic on the Dutch version of the Aachener Aphasie Test (AAT), and 12 healthy control participants (7 males, 5 females), who were matched in age and educational level with the group of aphasics. Mean age was 47 for the Broca's aphasics and 53 for the control group. All participants were native speakers of Dutch. In Table 1, demographic information on the participants with aphasia is given. In Table 2, scores on a number of AAT-scales are presented: Syntactic structure in spontaneous speech, token test, repetition, repetition of sentences, naming, naming pictures with sentences. Table 2 shows that the group of Broca's aphasics selected for the experiment had severe problems in constructing well-formed, complex sentences in spontaneous speech production but had, in general, relatively spared repetition and naming abilities. This is important, because the experimental procedure required participants to repeat sentences and describe visually displayed scenes with sentences.

TABLE 1
Demographic information on the group of Broca's Aphasics

Subject	*Age*	*Sex*	*Onset*[a]	*(former) Profession*	*Etiology*
NU	65	m	12	Municipal worker	CVA
BO	38	f	2	Housewife	CVA
FR	28	m	5	Truckdriver	CVA
GE	67	m	16	Mechanic	CVA
HA	47	m	7	Bricklayer	Trauma
LA	40	f	17	Secretary	Aneurism
KL	64	f	?	Hairdresser	CVA
LO	44	m	7	Accountant	CVA
WI	30	m	14	Student	Encephalitis
TH	36	m	3	Mover	Meningitis
PE	40	m	1	Railroad worker	CVA
HO	61	m	1	Planner	CVA

a Years since onset.

TABLE 2
Scores on subset of AAT scales

Subject	*Spont. Speech*[a] *(0-5)*	*Token Test (50-0)*	*Repetition (0-150)*	*Repetition sentences (0-30)*	*Naming (0-120)*	*Naming sentences (0-30)*
NU	1	5	?	?	97	21
BO	2	19	84	11	79	9
FR	2	13	122	24	107	22
GE	2	17	127	25	100	26
HA	2	24	115	21	96	19
LA	2	31	111	12	84	16
KL	2	11	120	24	108	27
LO	2	33	112	17	66	14
WI	2	24	124	15	101	24
TH	3	10	129	19	94	14
PE	2	21	119	15	111	22
HO	2	32	118	23	78	20

a.the score on Spontaneous Speech indicates, on a scale from 0 (very severe disturbance) to 5 (no or minimal disturbance) the syntactic structure of utterances Scores of 1 and 2 indicate that no complex sentence structures were observed and that functionwords and inflections were missing.

Materials

In total there were 27 pictures designed to elicit transitive sentences and 27 pictures designed to elicit dative sentences. In order to avoid word finding problems, next to the relevant picture elements the name was printed, in large letters. Transitive pictures all had inanimate agents, but animacy of patient was balanced (48% inanimate, 52% animate). The motivation for selecting pictures with inanimate agents only, was the extremely low frequency of passives expected with animate agents (see Bock, 1986; Harris, 1978). Dative pictures all had animate agents and recipients, and inanimate themes. In both dative and transitive pictures, agents occurred almost as often on the left side of the picture (48%) as on the right side (52%). The motivation to balance for that factor was a study by Flores d'Arcais (1975), showing effects of perceptual variables like position of agent on syntactic structure. In addition to experimental pictures, there were 54 filler pictures depicting scenes that in our opinion are best described with an intransitive sentence (e.g. a bottle is tumbling, a man is listening). Most of these pictures contained only one picture element with its name printed next to it. However, in order to avoid drawing attention to experimental pictures, that contained two words next to the

relevant picture elements (transitives) or three words (datives), nine filler pictures also contained two or three words (e.g. 'one *piece* of the *puzzle* is missing').

In addition, there were 27 pairs of dative prime sentences and 27 foursomes of transitive sentences, 27 locative sentences and 27 intransitive sentences[3]. Furthermore, there were 54 filler sentences comprising a wide range of syntactic constructions.

To each transitive picture corresponded a set of four prime sentences and one locative control sentence (see Table 3; for a complete listing of materials, see the appendix).

TABLE 3
Example of a set of transitive prime sentences

Condition	*Example followed by literal English translation*
AC, congruent	Het lawaai onderbreekt de spreker.
	(the noise interrupts the speaker)
PI, congruent	De spreker wordt onderbroken door het lawaai.
	(the speaker is interrupted by the noise)
AC, incongruent	De journalist onderbreekt het gesprek.
	(the speaker is interrupted by the noise)
PI, incongruent	Het gesprek wordt onderbroken door de journalist.
	(the interview is interrupted by the journalist)
LOC, control	De jongen loopt op de stoep.
	(the boy walks on the sidewalk)

We tested two transitive sentence types: The active, and its passive counterpart. In addition, there were two variants of each syntactic structure. One variant had the same distribution of animacy over agent and patient in prime sentence and target picture, and one had the opposite distribution. For instance, a picture of lightning (inanimate agent) hitting a golf player (animate patient) was paired to the sentence set in Table 3, that is, with an active and a passive sentence also having inanimate agents and animate patients (first two rows of Table 3) and sentences with the opposite distribution, animate agents and inanimate patients (last two rows of the table). Each of the four sentences in a set were presented equally often. This ensured controlling for any tendency to reuse the distribution of animacy on subject and object in the prime sentence for subsequent picture description (cf. Bock et al., 1992).

[3]We thank Eleanor Saffran for suggesting to us to use locatives and intransitives as 'baseline' sentences.

The sentences in a set had the same main verb. In addition, frequencies of subject and object nouns were matched.

To each dative picture corresponded a set of three prime sentences (see Table 4). We presented two types of dative: A prepositional dative, and its double-object counterpart. An intransitive served as a control.

TABLE 4
Example of a set of dative prime sentences

Condition	*Example followed by english translation*
PP	De klant betaalt tien gulden aan de verkoper.
	(the customer pays ten guilders to the salesman)
DO	De klant betaalt de verkoper tien gulden.
	(the customer pays the salesman ten guilders)
INT, control	De vrouw rookt te veel.
	(the woman smokes too much)

The materials were divided into three blocks. Each block contained nine transitive sentences and pictures, nine dative sentences and pictures, and 72 filler items. Across blocks, filler items all occurred twice, with the constraint that each block contained at least 30 new items. Furthermore, across blocks, the pictures were matched with respect to the proportions of unclassifiable responses they elicited in previous studies with healthy adults (Hartsuiker & Kolk, 1995). Each block was built up in a fixed format: First came 4 fillers, than came a dative trial (prime sentence followed by a target picture), then came 4 fillers, then came a transitive trial, and so on. In this way, each block consisted of 108 items. The order of items within this format was random, with the constraint that no more than three pictures or sentences followed each other.

There were three sessions. In each session, each subject received three blocks, with a pause separating the blocks. There were three different orders in which the blocks were presented. A different order of blocks was presented to each subject in each session. In addition, each block was randomized separately for each subject. Furthermore, in each session, a different pairing of prime sentences to target pictures was made, ensuring that there were no semantic or phonological similarities between prime sentence and target utterances.

Procedure

The experiment consisted of an interview and three experimental sessions, that were separated by at least three weeks.

Each interview, lasting about 10 minutes, was recorded on audio tape. Broca's aphasics were encouraged to tell as extensively as possible about their illness history, former occupation, family, and daily activities. Control subjects were requested to tell about their occupation, motivation to pursue that vocation, and if there remained time, about their family. Interviews were transcribed in Dutch, and the incidence of passives and datives was counted, as well as the total number of narrative words (see 'Scoring' section, below).

Session 1.

The participant was told that he took part in a memory experiment. A number of pictures and sentences appeared, and he had to indicate whether each item had appeared earlier or not. To 'facilitate his recognition', he had to repeat the sentences out loud and to describe the pictures with one correct sentence. After reading the instructions to the participant, ten practice trials were presented. Each prime sentence was presented bimodally: It appeared visually on the computer screen and was also read aloud by the experimenter. The participant was instructed to repeat the sentence. There were three blocks. The first of these consisted of baseline trials and fillers only. In the baseline, transitive pictures were preceded by locative sentences, and dative pictures were preceded by intransitives. Blocks 2 and 3 contained experimental trials and fillers. Recognition instructions applied to one block at a time. The session consisted of two subsessions, generally in the same week.

Session 2.

Session 2 consisted of three blocks. In the first block, which consisted of baseline trials, the memory instructions of Session 1 were used. On the following two blocks however, the instructions were changed: Subjects no longer had to indicate whether items had appeared before. They were told that this time we wanted to know how well repetition of sentences and describing pictures went, without having to remember these materials. No further information about the purpose of the experiment was supplied. The session consisted of two subsessions, generally in the same week.

Session 3.

Session 3 consisted of three blocks. Again, the first block consisted of baseline trials and fillers only. The same instructions as in Session 2 were used for this block. On the following block however, the instructions were changed. The subject was explicitly instructed to reuse the grammatical form of the prime sentence. This was indicated by accompanying the prime sentence with a tone. The new instructions were practiced by offering several practice trials. Following such a trial, the target utterance was presented

as well If necessary, the practice trials were presented twice. There were two blocks to which these instructions applied, but in some cases, when the patient showed signs of fatigue or stress in trying to comply with the (difficult) task demands, only one of those blocks was carried out.

Scoring

Audio tapes containing interviews, and picture descriptions in the priming experiment, were transcribed. Long pauses, hesitation marks, restarts and the like were all explicitly scored. Words that the transcriber did not recognize and neologisms were transcribed using Dutch orthography, whenever possible. When several attempts were made at describing pictures, only the final attempt was used for further scoring

Utterances were divided into the following categories. A dative was either classified as a prepositional phrase dative (PP), a double-object dative (DO), or 'other' (OT) For transitives, a response was either classified as a canonical active (AC), an active with the word order Object Verb Subject (OVS), a full passive with sentence-final by-phrase (P1), a full passive with a sentence-final passive participle (P2), or 'other' (OT). Although verb-final passives (P2) and non-canonical actives (OVS) were thus explicitly scored, for all analyses examining the effect of prime type they counted as OT In order to be scored an active or a passive, a double-object or a prepositional dative, the syntactic alternate had to be possible.

A dative utterance was classified as a prepositional dative if a dative verb was followed by the direct object and a prepositional phrase incorporating the indirect object. In principle, the preposition was required to be 'aan' (to) However, Broca's aphasics made a lot of errors in selecting prepositions (as one patient, WI, put it 'voorzetsels vreselijk', 'prepositions terrible') Therefore, in those cases where Broca's aphasics supplied a different preposition then 'aan', but where it was unambiguously clear, that this was a paragrammatism with 'aan' being the correct target, we accepted the utterance as a prepositional dative[4]. For dative verbs containing an auxiliary and an infinitival complement (i e. 'laten zien', 'to show', literally 'to let see'), two word orders were classified as prepositional dative: One with the infinitival complement directly preceding the prepositional phrase, and one with a sentence-final infinitival complement, on the assumption that both alternatives are equally distinct from a dative with only one, finite, verb[5] In a double-object dative, there is no prepositional phrase, and the indirect object precedes the direct object.

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[4]Note that we did not allow any for paragrammatisms in the 'by-phrase' of passives The reason is that many other prepositions are acceptable in this construction, changing the interpretation into for instance a locative passive (e g 'het huis wordt bedolven onder een lawine' 'the house is buried under an avalanche')

[5] Note that leaving out a construction such as 'laten zien' would result in the loss of much data, as it is much more frequent than the synonimous verb 'tonen' (to show)

In order to be counted as an active, a transitive picture description needed to contain a subject-noun (N), a transitive verb (V), and an object-noun. Utterances containing a locative preposition ('de ambulance rijdt over de man ' 'the ambulance drives over the man') or an auxiliary and an infinitive complement ('de bliksem doet de kerk raken', 'the lightning does the church to hit') were scored as 'others'.

For passives, two scoring regimes were applied: Strict scoring and lenient scoring. The most important motivation to apply a more lenient criterion for this assessment is the low frequency with which structures such as the full passive have been observed to occur in corpora of Dutch (Kirsner, 1976). However, many sentence types resemble a full passive in various respects, and these are included in the lenient scoring regime.

Strict scoring. In order to be counted as P1, a transitive picture description needed to contain a subject-noun, the auxiliary 'worden' (to be), a passive participle, and a by-phrase incorporating an object noun. In addition, the by-phrase needed to be placed sentence-final, e.g. 'de man wordt getroffen door de bliksem' ' the man is (being) hit by the lightning'). The same restrictions applied for a score of P2, with the exception that the passive participle, instead of the by-phrase, was placed sentence-final (e.g. 'de man wordt door de bliksem getroffen', 'the man is by the lightning (being) hit'). An attempt at a passive utterance missing any of these required elements was scored as 'others'.

Lenient Scoring. The criteria for counting an utterance as a passive with lenient scoring were that there had to be a passive auxiliary ('wordt' in Dutch) and a passive participle. This included full passives (P1 and P2), agentless passives (without a by-phrase), instrumental passives, and locative passives. However, 'static' passives, containing the auxiliary 'is' instead of the passive auxiliary 'wordt', e.g. literally, 'the house is hit by the avalanche' were not included in the count, as it is often difficult to determine whether these structures really are passive. This is because in Dutch passive participles can often not be distinguished from adjectives. We also allowed utterances that adhered to all criteria for a full passive, except for lacking either the preposition 'door' (by) or the auxiliary 'wordt'. However, when both the preposition and the auxiliary were missing, or when the utterance lacked a passive participle, the utterance was not included in the passive count.

The category of 'others' (OT) included any response having a syntactic structure different from that of any of the target structures. Furthermore, it included any response where the experimenter gave linguistic help, any unrecognizable response, any response interrupted by loud external sounds, computer error, any trial where the participant failed to correctly repeat the prime, and any response where the participant failed to supply a response or gave up after several attempts.

With respect to the interviews, we marked and counted any dative and passive utterance in the transcriptions (for passives, according to 'lenient' criteria). In order to

control for any differences in the total amount of speech produced in the interviews, we counted the total number of *narrative words* (Saffran, Berndt, & Schwartz, 1989). In determining this number, we followed the procedure suggested by Saffran et al. (1989), that is, we discarded from the transcript all neologisms, direct responses to examiners questions, comments the subject made on the narrative, habitually used starter phrases, conjunctions joining complete sentences, direct discourse markers, and materials that were subsequently repaired. The remaining words were counted (see Saffran et al., 1989 for further details on this procedure).

Design

In each session, each subject received nine trials per transitive and dative condition: Nine intransitives preceding dative pictures, and nine locatives preceding transitive pictures (presented in Block I of each session), nine prepositional datives and nine double-object datives preceding dative pictures; nine actives and nine passives preceding transitive pictures (distributed across Block 2 and Block 3 of each session).

Separate ANOVA's were performed for each Group (Broca or Control) on the proportion responses of each target syntactic structure (active, passive; double-object and prepositional dative), with Prime type (same structure, different structure) and Session (1,2,3) the independent variables. In addition, whenever there was an interaction between the two independent variables, there were separate analyses for each session.

In addition, whenever there appeared to be a difference between baseline and experimental conditions, with respect to the incidence of a target structure, those conditions were compared.

Results

We divide our presentation of results into three separate parts. First, we present the results of syntactic priming in Sessions 1 through 3. We test the effects of Session and Prime type (same or alternate syntactic structure) on the proportion of double-object and prepositional datives, and active and passive transitives. The dependent variables are the numbers of responses of each type in each condition, divided by the total number of presentations in that condition. We took that proportion, rather than the absolute frequencies, in order to compensate for slight differences in the total numbers of trials presented per condition. We only report ANOVA's with participants as a random factor (F1), because there were too few observations per item to justify an item-analysis.

Following the evaluation of priming effects, we list the incidence of target structures in spontaneous speech and in the baseline conditions of the priming experiment, and compare that with the incidence in primed conditions. Finally, for

transitives, we present ANOVA's, testing effects of variables such as position of agent on the picture and animacy.

TABLE 5
Response frequencies for transitives

Prime	*AC*	*PI*	*OT*	*TOTAL*
Broca's aphasics, Session 1 (N=12)				
AC	40 (37)	2 (2)	66 (61)	108
PI	37 (34)	13 (12)	58 (54)	108
B	37 (34)	1 (1)	70 (65)	108
Broca's aphasics, Session 2 (N=11)				
AC	39 (39)	5 (5)	56 (56)	100
PI	30 (31)	9 (9)	59 (60)	98
B	28 (28)	2 (2)	69 (70)	99
Broca's aphasics, Session 3[a] (N=11)				
AC	25 (35)	6 (8)	41 (57)	72
PI	22 (31)	14 (19)	36 (50)	72
B	48 (48)	2 (2)	49 (50)	99
Normals, Session 1 (N=12)				
AC	37 (34)	21 (19)	50 (46)	108
PI	46 (43)	20 (19)	42 (39)	108
B	30 (28)	24 (22)	54 (50)	108
Normals, Session 2 (N=11)				
AC	22 (22)	29 (29)	49 (49)	100
PI	32 (33)	26 (27)	40 (41)	98
B	22 (22)	23 (23)	54 (55)	99
Normals, Session 3 (N=11)				
AC	68 (69)	11 (11)	20 (20)	99
PI	3 (3)	87 (88)	9 (9)	99
B	29 (29)	24 (24)	46 (46)	99

a Some subjects not tested on all blocks

Syntactic Persistence

Transitives. Application of scoring criteria yielded, 130 responses classified as active or passive (P1) for Broca's aphasics in Session 1 (40%), 113 (38%) in Session 2, and 117 (48%) in Session 3. For normal controls there were 178 responses classified as active or passive in Session 1 (55%) 154 (52%) in Session 2, and 222 (75%) in Session 3. Obviously, there were quite a number of responses classified as 'others'. A substantial part of these responses consisted of passive sentences with a clause-final participle, the P2-passive, (for Broca's aphasics 3% across sessions, for normal controls 12%) and of active sentences with the word order OVS (for Broca's aphasics 4%, but for normal controls less than 1%). The number of active, passive, and other responses in the different transitive conditions are listed for each session in Table 5.

As is clear from Table 5, in all sessions, Broca's aphasics produced more passives in the passive prime condition than in the active prime condition. Smaller differences, although in the predicted direction, are observed with respect to active responses. Normal controls on the other hand showed no priming effects for passives and small negative priming effects for actives in Sessions 1 and 2. In Session 3, however, response type corresponded strongly to prime type, as predicted.

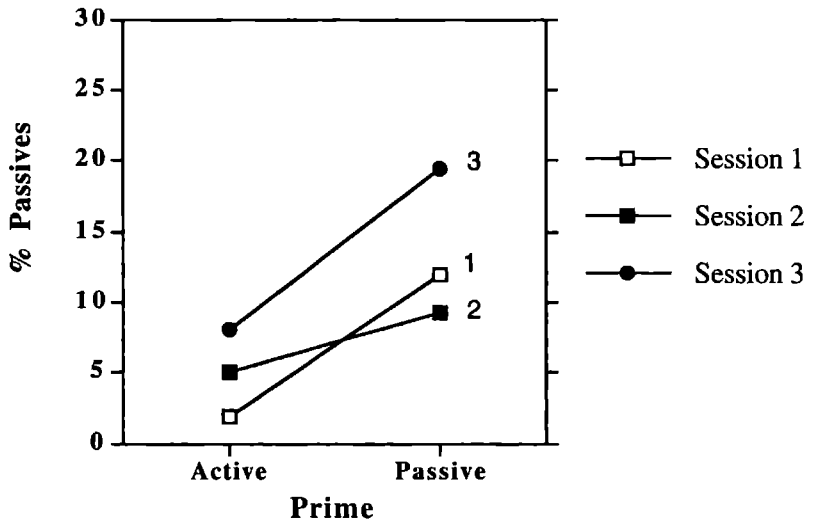


FIGURE 1. Proportion of passives in each session for Broca's aphasics.

In Figure 1, we depict the proportion of passives in each condition for Broca's aphasics. Visual inspection of this figure suggests a priming effect, and no effects of Session. Indeed, for Broca's aphasics, the ANOVA's revealed a significant effect of Prime type on passives ($F(1,10)=7.10$; $p<.03$) but there was no significant effect on

actives (F(1,10)=1.01; p>.3). For neither response type did we obtain significant effects of Session. The interaction between Prime type and Session did not reach significance either.

The proportions of passives for normal controls in every session are depicted in Figure 2. The figure clearly shows negative priming effects in the first two sessions, and a much stronger positive priming effect in the third session. ANOVA's on the proportions of actives and passives revealed highly significant effects of Prime type (in the analysis on active responses: F(1,10)=26.20; p<.001. In the analysis on passives: F(1,10) =49.98; p <.001). There was a significant effect of Session for passives (F(2,20)=15.42; p <.001), but not for actives (F(2,20)=1.23; p=.315). The interaction of Prime type and Session was highly significant (actives: F(2,20)=41.88; p<.001; passives: F(2,20)=38.94; p<.001).

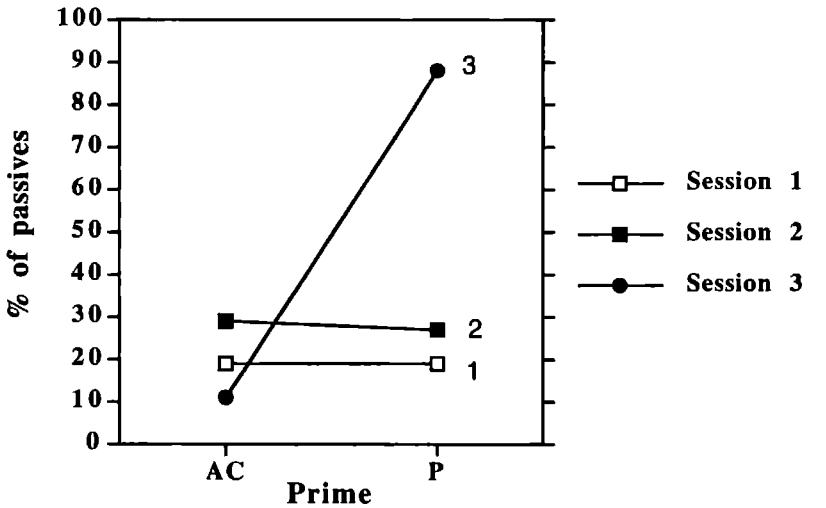


FIGURE 2. Proportion of passives in each session for normal controls.

Because inspection of Figure 2 and Table 5 shows obviously that the effect of Prime type and the interaction between Prime type and Session are due to strong priming effects in Session 3, but no or negative priming in the other sessions, we performed additional analyses: One in which data from Sessions 1 and 2 were collapsed, and one in which Session 3 was analyzed separately. The analysis with data from Sessions 1 and 2 together yielded a significant effect of Prime type in the analysis on actives (F(1,10)=12.02; p <.01). It is important to realize that this is a *negative* priming effect: Collapsed over these sessions there are 59 active responses in the condition with active primes and 78 actives in the condition with passive primes. There was no significant

effect of Prime type in the analysis on passives ($F(1,10)<1$). In addition, there were no significant effects of Session, and the interaction between Prime type and Session was not significant (all p's > .10).

The analysis of the data from Session 3 yielded significant effects of Prime type for active responses ($F(1,10)=75.46$; $p<.001$] and for passive responses ($F(1,10)=81.88$; $p<.001$).

TABLE 6

Response frequencies for datives

Prime	*PP*	*DO*	*OT*	*TOTAL*
Broca's aphasics, Session 1 (N=12)				
PP	43 (40)	20 (19)	45 (42)	108
DO	37 (34)	29 (27)	42 (39)	108
B	28 (26)	26 (24)	54 (50)	108
Broca's aphasics, Session 2 (N=11)				
PP	51 (52)	15 (15)	33 (33)	99
DO	30 (30)	23 (23)	46 (46)	99
B	28 (28)	20 (20)	51 (52)	99
Broca's aphasics, Session 3[a] (N=11)				
PP	40 (55)	11 (15)	22 (30)	73
DO	25 (35)	16 (23)	30 (42)	71
B	32 (32)	28 (28)	39 (39)	99
Normals, Session 1 (N=12)				
PP	71 (66)	24 (22)	13 (12)	108
DO	67 (62)	23 (21)	18 (17)	108
B	43 (40)	42 (39)	23 (21)	108
Normals, Session 2 (N=11)				
PP	55 (55)	22 (22)	22 (22)	99
DO	51 (52)	26 (26)	22 (22)	99
B	60 (61)	27 (27)	12 (12)	99
Normals, Session 3 (N=11)				
PP	75 (76)	15 (15)	9 (9)	99
DO	31 (30)	63 (64)	5 (5)	99
B	56 (57)	28 (28)	15 (15)	99

a. Some subjects were not tested on all blocks.

Datives. For Broca's aphasics application of our scoring criteria yielded 183 (56%) analyzable responses in Session 1, 167 (56%) in Session 2, and 152 (63%) in Session 3.

Normal controls produced 270 (83%) prepositional and double-object datives in Session 1, 241 (81%) analyzable responses in Session 2, and 268 (90%) in Session 3. The numbers of prepositional and double-object datives in the different conditions of each session are listed in Table 6.

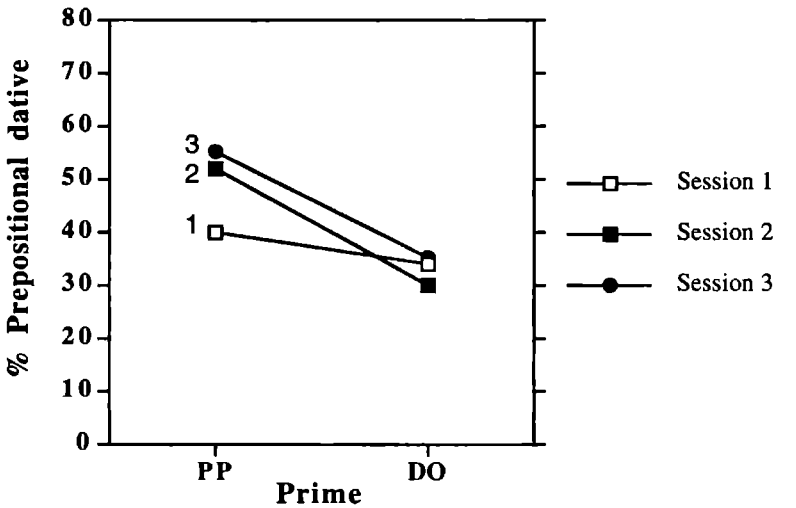


FIGURE 3. Proportion of prepositional datives in each session for Broca's aphasics.

The proportion of prepositional datives in the three sessions for Broca's aphasics are depicted in Figure 3. As the number of 'other' responses was roughly equal in each condition, the proportion of double-object datives follows a complementary distribution. The results are clear cut. First, there appears to be a priming effect in every session. Second, there does not seem to be a difference between the sessions with respect to the magnitude of priming. These observations are supported by statistical testing. ANOVA's on prepositional dative responses and double object responses of Broca's aphasics, treating Prime type (double-object dative, prepositional dative) and Session (1, 2, or 3) as within-subject factors, revealed significant effects of Prime Type (double-object datives: $F(1,10)=5.69$; $p<.05$; prepositional datives: $F(1,10)=31.64$; $p<.001$), a marginally significant effect of Session (double-object datives: $F(2,20)=2.62$; $p=.097$; prepositional datives $F(2,20)=3.37$;$p=.055$), and no interaction between these variables (double-object datives: $F(2,20)<1$; prepositional datives: $F(2,20)=1.11$; $p=.348$).

As is clear from Table 6, there is hardly any priming effect for normal controls in Sessions 1 and 2. However, as predicted, response type corresponded to a very strong extent with prime type in Session 3. We depict the proportion of prepositional datives for normal controls in Figure 4. As the number of 'other' responses was roughly equal in each condition, the proportion of double-object datives follows a complementary distribution.

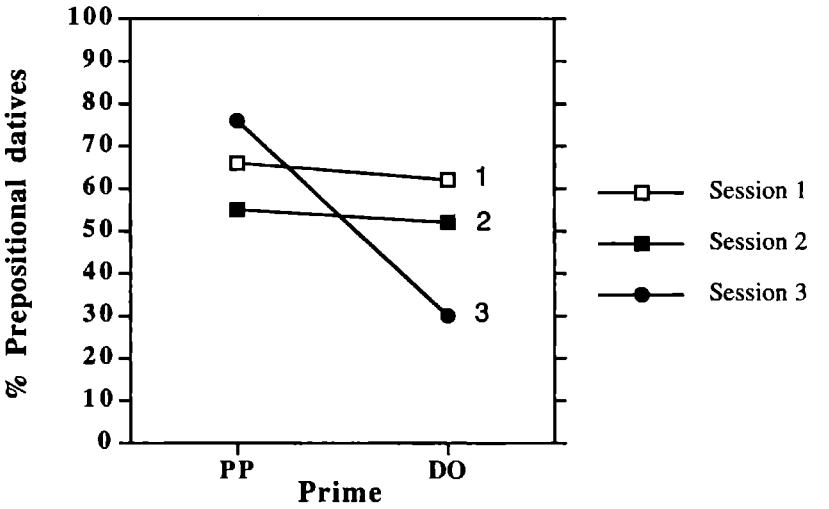


FIGURE 4. Proportion of prepositional datives in each session for normal controls.

ANOVA's on the dative responses produced by normal controls revealed significant effects of Prime type (double-object datives: $F(1,10)=22.12$; $p<.005$; prepositional datives: $F(1,10)=26.11$;$p<.001$), significant interactions between Prime type and Session (double-object datives: $F(2,20)=21.69$; $p<.001$; prepositional datives: $F(2,20)=6.88$; $p<.01$), and a significant effect of Session for double-object datives ($F(2,20)=7.83$; $p<.005$) but not for prepositional datives ($F(2,20) = 1.68$; $p =.168$).

Because visual inspection of Figure 4 makes it obvious that the effect of Prime type, and the significant interaction between Session and Prime type should be indeed ascribed to the occurrence of a priming effect in Session 3, but not in Sessions 1 and 2, we conducted additional analyses. We performed ANOVA's on double-object and prepositional datives with Sessions 1 and 2 collapsed, and in Session 3 only. In the analysis on responses in Sessions 1 and 2, there was no effect of Prime type, no effect of Session, and no interaction between these variables, both in the analysis on prepositional datives and in the analysis on double-object datives (all p's>.10). However, in Session

3, there were highly significant effects of Prime type (double-object datives: $F(1,10)=31.84$; $p<.001$; prepositional datives: $F(1,10)=14.67$; $p<.005$).

In conclusion, we find dative and transitive priming effects in three out of four tested structures for Broca's aphasics. For normal controls, we only find an effect on one structure, the active transitive, and in the opposite direction from what was predicted. For normal controls, but not for Broca's aphasics, we find an effect of Session. In particular, normal controls show no (or negative) priming in Sessions 1 and 2, but show a strong effect of 'priming' in Session 3, where participants were explicitly instructed to reuse previous sentence form. Two points concerning Session 3 should be noted though. First, although normal controls were in general able to follow the instructions, many of them complained about how difficult this task was. Indeed, they still made many errors. Second, a listing of error rate per individual revealed that there was a considerable overlap between the two groups: At least one Broca's aphasic scored in the normal range, and at least one normal control in the aphasic range.

Production of target structures

We consider production of target structures in three conditions: Spontaneous speech, baseline conditions, and conditions containing primes. In spontaneous speech, we observed no dative utterances, neither in interviews with normal controls, nor in interviews with patients. However, in both groups substantial number of actives were observed. In Table 7, we list the number of passives and the number of narrative words for each participant.

As is clear from the table, only 1/12 Broca's aphasics produced any passive at all. Normal controls, on the other hand, produced many passives, with an average of 3.5 per interview (range 0-9). However, normal controls produced many more narrative words to begin with (Controls: Median=894, Broca's aphasics: Median=239). In order to compensate for that difference, we randomly[6] selected for each control subject, fragments of the transcripts containing 239 narrative words and determined the incidence of passives. It is important to realize that this procedure works against the hypothesis of finding more passives in normal control subjects, because it results in a smaller number of *clauses* being considered for normal controls. This is due to the fact that clauses produced by normal controls consist of more words than clauses produced by Broca's aphasics. Nevertheless, even with such a procedure, we observed passives in eight out of 11 normal controls subjects (average 1.1, range 0-3).

[6]With the constraint that the fragment started no later than the 152nd word.

TABLE 7

Incidence of passives in spontaneous speech

Broca's Aphasics			*Normal Controls*			
Subject	*#Passive*	*#Words*	*Subject*	*#Passive (Total)*	*#Passive (Sample[a])*	*#Words*
NU	2	190	*JJ*	4	1	1111
BO	0	188	*HB*	9	1	1028
FR	0	302	*MB*	0	0	697
GE	0	484	*BVD*	5	3	920
HA	0	271	*THJ*	1	0	772
LA	0	338	*OO*	1	1	496
KL	0	172	*HK*	4	1	894
LO	0	166	*WO*	n a [b]	n a	n a
WI	0	206	*TV*	3	3	391
TH	0	899	*KK*	5	1	991
PE	0	108	*BS*	2	0	907
HO	0	371	*DE*	4	1	619
		M = 308		*M = 3 5*	*M= 1 1*	*M = 802*
		Md = 239				*Md = 894*

a Random sample of 239 (narrative) words
b n a denotes 'not available"

What about production of passives and datives in baseline and experimental conditions? Datives, both prepositional datives and double-object datives were frequently observed in both baseline and experimental conditions of Broca's aphasics and controls In the baselines of Sessions 1, 2 and 3 respectively, 10/12, 10/11 and 10/11 Broca's aphasics produced prepositional datives, and 9/12, 9/11 and 9/11 Broca's aphasics produced double-object datives Across sessions, 12/12 Broca's aphasics produced these structures

Table 8 lists the incidence of passives in each baseline and experimental condition, for passives separately marking scoring according to lenient and strict criteria The table shows, as is particularly clear from the baseline of Session 1, that passives are almost never produced in unprimed conditions, but occur more often in those blocks in which passive primes were presented. Across experimental sessions, 10/12 Broca's aphasics were observed to produce full passives

TABLE 8

Conditions in which Broca's aphasics produced one ore more passives[a]: Spontaneous speech, Baseline, and Priming blocks

	Spon.[a]	*Experimental*					
		Session 1		*Session 2*		*Session 3*	
Subject		*Baseline*	*Priming*	*Baseline*	*Priming*	*Baseline*	*Priming*
NU	(+)		+	(+)			+
BO			+	n.t.[c]	n.t.	n.t.	n.t.
FR				+			+
GE			+	+	+	+	+
HA			+				+
LA							
KL		(+)	+	+	+	+	+
LO		+	+	+	+	(+)	+
WI		(+)					+
TH							
PE		(+)	+	(+)	+		+
HO			+		+		

a. Occurrence of full passives, irrespective of placement of 'by-phrase' (sentence-finally, or sentence-medially) is marked with '+', occurrence of other kinds of passive (according to lenient scoring criterion) is marked with a '(+)'.
b. Spontaneous speech.
c. Subject BO was not tested (n.t.) in Sessions 2 and 3.

Interestingly, for Broca's aphasics, passive responses were most frequent in the passive prime condition but were not restricted to that condition. Across sessions, there were 12 passives in the condition with active primes and only five in the locative baseline condition (when P2-passives are included, these numbers increase to 20 in the active condition and 11 in the locative condition). We statistically compared the number of passives (P1) in the active and locative conditions with an ANOVA with Prime (active, locative) and Session (1, 2, or 3) as independent variables. There was a significant effect of prime ($F(1,10)=5.08$; $p<.05$). There was no main effect of Session, nor was the interaction significant. The effect of finding more passives in the active condition was consistent across participants: Every participant producing passives in the locative condition, produced more passives in the active condition.

Hence, the conclusion is justified that in the conditions with priming trials, active or passive, there are more passives than in the baseline condition. These results are in agreement with results of Hartsuiker & Kolk (1995), who obtained evidence for a relatively long-lasting influence of a prime (Long-term Priming). This refers to an

increased activation level of a primed structure, even after a number of other sentences have been produced. In that way, a prime on trial n, can influence the outcome on trial n+1, even if these trials are separated by a number of fillers. Similar results were obtained by Bock & Loebell (1990), who obtained a stronger priming effect (i.e. less carry-over) when more fillers separated prime-target pairs.

Effects of position and of animacy

Two variables that have been shown to determine syntactic structure of picture descriptions, in particular for pictures requiring transitive responses, are animacy (Bock, 1986; Harris, 1978) and left/right position of agent and patient on the picture (Flores d'Arcais, 1975). An important question is whether Broca's aphasics show similar effects of these variables or not, especially given proposals by Saffran, Schwartz, & Marin (1980) that Broca's aphasics make strong use of animacy in order to determine order of nouns in noun-verb-noun sequences (see also Caplan, 1983). It is important to consider variables like animacy and position, because it may be the case that in performing the present task, Broca's aphasics make use of certain strategies to a stronger extent than normals, e.g. a strategy to always start a sentence with the animate participant, or with the participant on the left side of the picture.

We compared numbers of actives and passives (collapsed over full passives with a sentence-final by-phrase, and full passives with a sentence-final passive participle) in the different position and animacy conditions. Because visual inspection of the data suggested effects on 'other' responses, we also conducted an ANOVA on that response category. In order to obtain the most unbiased measure of the dependent variables, we decided to consider the baseline conditions only. These data are listed in Table 9.

TABLE 9

Proportion of different transitive responses for different animacy and position conditions

		Agent on Left Side			*Agent on Right Side*		
Group	*Animacy*	*AC*	*PI*	*OT*	*AC*	*PI*	*OT*
Broca's Aphasics	*II*	56	3	41	38	5	58
	IA	31	3	66	24	5	71
Controls	*II*	48	33	18	25	48	27
	IA	21	47	32	11	39	50

The table shows that both Broca's aphasics and normal controls show additive effects of the variables animacy and position. Broca's aphasics produced more actives and less 'other' responses when the patient was inanimate (actives: F1(1,10)=8.35; p<.02; 'others': F(1,10)=8.79; p<.02). When the agent is depicted on the left side of the picture, Broca's aphasics produce more actives (F(1,10)=6.94; p<.03), and less 'others' (F(1,10)=6.04; p<.05). The interaction between animacy and position was not significant (actives: F(1,10)=1.34; p=.274; others: F(1,10)=1.45; p=.256). No main effects or interaction in the analysis on passives (which were extremely infrequent in the baseline condition considered here) was observed.

Normal controls also have additive effects of the variables Animacy (thematic role of 'patient' animate or inanimate) and Position (agent left, agent right) on production of actives, but not on production of passives. Opposite additive effects are found on 'other responses'. In particular, if the patient is inanimate, more actives are observed (F(1,10)=75.01; p <.001)and less 'other responses' are observed (F1(1,10)=54.84; p <.001). If the agent is on the left side of the picture, more actives are observed (F(1,10)=7.93; p<.02) and less other responses (F(1,10)=11.87; p<.01). The interaction between animacy and position was not significant in the analysis on active responses (F1(1,10)=2.06; p =.182), and the same applies to 'other' responses (F1(1,10)=2.03; p=.185). No significant effects of position and animacy were found in the analysis on passive responses, but the interaction was marginally significant (F(1,11)=4.26; p=.066).

Because the proportion of actives is so dependent on the variables of animacy and position, but there is no effect on the proportion of passives, the question arises what kind of responses are produced in the conditions that infrequently elicited actives. Inspection of the aphasic responses revealed that in the condition with animate patients, and with the agent depicted on the left side, the first NP produced usually incorporated the thematic role of patient (in 73% of the cases). This often led to a sentence which gave a somewhat different interpretation to the visual scene than intended by the experimenter. For instance, a picture of a woman being run over by a train, was described as 'the woman ... commits suicide'. In addition, in the baseline, 100% of 'actives' with the word order OVS occurred in the condition with the agent on the right side. There were 13 of those, eight in pictures with animate patients, and the remaining five in the condition with inanimate patients.

To summarize, both Broca's aphasics and normal controls tend to produce more actives when the patient is inanimate instead of animate, and more actives when the agent is on the left side than when it is on the right side of the picture. These effects are additive. Exactly the reverse pattern is found for 'other' responses. The frequency of passives is not sensitive to these two variables. When patients were depicted on the right side, Broca's aphasics often resorted into producing non-canonical actives.

Discussion

The present experiment, investigating the impact of activation processes on production of syntactic structure in Broca's aphasics, allows for three main conclusions with respect to our initial hypotheses. In addition, an important unexpected result surfaced: Broca's aphasics show stronger syntactic priming effects than normals. In this section, we will first outline the three main conclusions. Then we will briefly address the issue of animacy and position effects in picture description. We will end by proposing a mechanism which could be responsible for the stronger priming effects for Broca's aphasics.

First, we showed that Broca's aphasics show syntactic priming effects, for both tested sentence types, transitives (with the exception of actives) and datives. This in itself is an impressive finding, especially given the relatively small group of subjects (12 Broca's aphasics, with one failing to complete all sessions). These results are consistent with the view that availability of syntactic structure can be increased by priming, as a result of which participants produce that structure more readily. The results are inconsistent with the view that knowledge or procedures for producing complex sentences like passives, or relatively complex sentences like datives[7], are deleted from the Broca's aphasics language processor, as could be derived by proposals such as Grodzinsky's (1986) trace-deletion hypothesis.

Second, we obtained evidence for a lack of strategic involvement in priming effects for Broca's aphasics. We varied task instructions, from disguising the task (Session 1) or not (Session 2) to explicitly instructing subjects to reuse primed syntactic structure. For neither group did we see important differences between Sessions 1 and 2: For Broca's aphasics, means were in the predicted direction for all structures in both of these sessions. For normal controls, we saw small negative priming effect for actives in both sessions, no passive priming effect in either session, and no dative priming effects in either session. In other words, given the lack of a significant difference between the results of Sessions 1 and 2, we can discard our concern that strategic involvement somehow influenced the priming effects in Saffran & Martin's (1990) pilot study. That point is strengthened by our findings in Session 3, where normal controls were able to follow a 'strategy' on our request, but Broca's aphasics were not. It seems a reasonable assumption that a strategy is only possible when the subject consciously notices the feasibility of reusing structure of the previous sentence, and has no problems in parsing

[7]Note that in a study with Broca's aphasics by Gleason et al. (1975), datives ranged among the most complex of 14 tested structures. In fact, datives were more difficult than transitive passives there, but that may be due to experimental procedure (i.e. the subject NP was provided, and a by-phrase was not required). Interestingly, in the current experiment all Broca's aphasics produced both prepositional and double-object datives. That finding sharply contrasts with Caplan and Futter's (1986) case study, in which it was claimed that in comprehension the prepositional dative is more difficult.

the sentence, subsequent recall of its structure, and adapting content words to the event depicted on the target picture. Our data indicate that there must be considerable problems in either parsing of the prime sentence, recalling it, or adapting it to a novel situation. Even normal controls must have had some problems in one or more of these task components. Hence, we are forced to conclude that the priming effects we observe must be the result of an unconscious, automatic, facilitatory process rather than of a strategy.

Third, analysis of produced sentence types in spontaneous speech and in baseline conditions was informative. We showed that passives were virtually absent from spontaneous speech of Broca's aphasics, but not in that of control subjects. Similar remarks apply to the baseline conditions. Datives on the other hand were absent in spontaneous speech of both groups. However, they occurred frequently in baseline conditions for both groups. Those results indicate (1) How careful one has to be in drawing any strong conclusions from analyses of spontaneous speech with respect to Broca's aphasics syntactic repertoire , especially in the absence of a control group, (2) Broca's aphasics are able to produce sentences as complex as datives, both in the prepositional and in the double-object form. The fact that these structures are not observed in their spontaneous speech is hardly remarkable, because normal controlsdo not produce them either. Probably, the dative sentence type is restricted to a very small subset of propositions out of all the propositional content one would like to convey in speech production, (3) Broca's aphasics either avoid to produce passives or are not able to: Whereas normal controls regularly produce passives, both in spontaneous speech and in baseline conditions, Broca's aphasics do not. Given the higher incidence of passives in primed conditions, and given the lack of strategic involvement, these results make it very likely that passives are too complex for Broca's aphasics to produce. They lack the computational resources to produce a sentence of such complexity, but this limitation can be overcome by an automatic facilitatory process, syntactic priming. We are not aware of any other theory of aphasic language performance that can offer a better account of the present results.

Before turning to the important issue of having obtained stronger priming effects in Broca's aphasics, we will address the issue of semantic and perceptual cues in picture description. Both Broca's aphasics and normal controls show effects of these variables, such that actives are more frequent when the agent is depicted on the left side of the picture, and when the patient is inanimate. These effects are additive. Those findings are consistent with the results of earlier studies. Caplan (1983) distinguished three strategies[8] in agrammatic sentence production that could account for the results of Saffran, Schwartz, & Marin (1980) with respect to word ordering in Noun Verb Noun sequences:

[8] Notice that 'strategy' is used here in a different sense from that of a conscious 'task strategy' as investigated in the current study with respect to priming effects Rather, Caplan's use of the term refers to automatic use of perceptual and semantic cues in language produciton.

(1) Produce sentences in the active voice
(2) Put the agent left of the verb
(3) Put the animate entity left of the verb[9]

In normal picture description, this set of strategies should be extended with an additional one (Flores d'Arcais, 1975):

(4) Start the response with the element on the left side of the picture

It is important to note that strategies (2) and (3), and perhaps also (1), apply to normal sentence production as well as to agrammatic production (for a review of the relationship between agenthood, animacy, and subjecthood, see Bock, Loebell, & Morey, 1992). These strategies combined, account for the additive effects of position and animacy: Strategies (1) and (2) lead to actives in all conditions. Strategy (3) works against actives in the case of pictures with animate patients, and strategy (4) works against actives in pictures with agents on the right side. The present experiment shows that strategy (4) also applies to agrammatic sentence production. Furthermore, both groups showed animacy and position effects of a similar magnitude, in contrast to the hypothesis that Broca's aphasics rely to a stronger extent on these strategies.

Interestingly, for Broca's aphasics, proportion of structures with the word order OVS, e.g. 'the golf player hits the lightning', also depended on position. In fact, all of these occurred when the agent (lightning) was depicted on the right side, and hence the patient (golf player), which is assigned the grammatical function of subject, on the left side. In that case, strategies (3) and (4) conspire to begin with the patient, and hence produce OVS sentences. Whether strategy (1) and (2) apply is not so clear, however. That depends on whether (i) OVS-sentences have the same syntactic structure as canonical actives (ii) whether OVS should be really interpreted as such, or whether these utterances should be considered as canonical actives containing word exchanges. This latter possibility seems likely, especially given the fact that normal controls produced hardly any OVS-sentence. We think this issue needs further investigation. However, the findings are compatible with both the account in terms of the strategies outlined above, and with a resource limitation account, given the assumption that an OVS sentence is syntactically simple.

[9]There are actually two possibilities here: one could have a preference for assigning the grammatical function of subject to animate entities, which, it seems likely, are conceptually more accessible (e.g. Bock & Warren, 1985) or one could have a preference for simply starting a sentence with animate entities. Some evidence for the latter claim was presented by Prat-Sala, Branigan, Pickering, & Shillcock (1996).

Enhanced priming effects in Broca's aphasics

The present experiment yielded another unexpected result. The remarkable fact is that Broca's aphasics show syntactic priming, whereas normal controls fail to do so. We should repeat here that Hartsuiker & Kolk (1995) observed priming effect for datives, but not for transitives, testing relatively large groups of college students. So, it seems plausible that priming effects, at least for datives, would have surfaced if only we had tested larger groups of elderly controls. It seems unlikely that the finding of priming effects in college students and no such finding with elderly controls can be attributed to the different group characteristics (age and educational level) since, elderly controls obviously resembled the group of Broca's aphasics much more in that respect. A further issue is whether Broca's aphasics have a larger priming effect or a more reliable priming effect. In the case of passives there clearly is a larger effect, since there was no priming effect for passives at all for elderly controls, but also no such effect in the Hartsuiker and Kolk (1995) study with college students. However, it is conceivable that the effect with datives is of equal magnitude, but simply more reliable with Broca's aphasics than with controls. In whatever way that matter may be resolved, the fact remains that we observe priming effects with a relatively small group of Broca's aphasics. We tentatively conclude that Broca's aphasics are more susceptible to priming than normal controls. Why is this so?

We had no initial hypotheses about a difference between Broca's aphasics and controls concerning the magnitude of priming effects. It seemed to us that resource theories, as they currently stand, especially when stated in verbal form only, may predict both weaker and stronger priming for Broca's aphasics. Indeed, in previous studies examining other forms of priming in pathological populations (i.e. lexical priming), both stronger and weaker than normal effects have been observed. For instance, Haarmann & Kolk (1991), in a lexical decision task, examined the influence of a starter phrase which was syntactically congruent or incongruent with a target item for lexical decision ('the man ...WALKS' vs. 'the man ... NOSE'). They also varied the temporal interval between starter phrase and target item (SOA). Whereas normal controls showed priming effects in every SOA-condition, Broca's aphasics only showed an effect at the longest SOA. That effect was comparable in magnitude to that of normal controls.

On the other hand, Chertkow, Bub, & Seidenberg (1989) obtained quite different results with semantic priming in a group of patients with Alzheimer's disease. Surprisingly, they found that these patients showed stronger priming than normal controls. One account Chertkow et al. (1989) present for these results is that the locus of that effect lies in semantic memory, that patients with Alzheimer's disease have degraded representations in semantic memory, and that degraded representations benefit more from priming than intact representations. With respect to the present results, an analogous explanation has the advantage that it not only accounts for more priming in Broca's

aphasics than in normals, but also for the fact that we obtain priming for passives in Broca's aphasics, but not for actives. However, this explanation depends critically on the assumption that degraded representations would benefit more from priming.

A different account of the finding that Broca's aphasics are more susceptible to priming than normal controls follows from the observation that Broca's aphasics have a reduced variety of grammatical form. This entails that when the language processor recruits syntactic structures in order to describe a picture (see Bock, 1982, for a theory of language production that encompasses such a recruitment process), Broca's aphasics only select a few structures and normal controls select many. As a result, in the case of Broca's aphasics the primed syntactic structure has few competitors and can easily win the competition. However, in the case of normal controls, there are many other structures competing with the primed structure, decreasing the likelihood that it will be selected. Effects of the number of competitors are predicted by interactive activation models such as McClelland & Rumelhart's (1981) model of letter perception. In that model, the target node is inhibited by competing nodes. If there are many competitors, the target node will be more strongly inhibited.

However, a subdivision of the 'other' responses produced by Broca's aphasics shows that agrammatic participants responded with a relatively large variety of sentence types, including locatives, intransitives, constructions with infinitives, constructions with past participles, datives with medial 'to-phrase', sentences containing verbs like 'receive' instead of dative verbs, etc. This shows at least that in the case of describing dative or transitive sentences, the number of constructions being produced by Broca's aphasics is not limited to the target structures only. Nevertheless, the possibility cannot be excluded that upon encountering a picture to be described, normal control subjects activate a much broader range of syntactic structures (regardless of whether we actually observe all of them), and show weaker priming effects as a result of having to select a structure from more competing items.

Finally, another explanation of the priming effect follows from the hypothesis that the amount of priming is inversely related to the amount of verbal working memory resources. The rationale for this hypothesis is the following. Initially both structures in competition (the active and the passive) have resting activation levels. However, because of having produced a prime (e.g. the passive) the activation level of the primed structure increases substantially. When subsequently a target picture is presented, the language processor recruits both competing structures and attempts to raise their activation levels above threshold. This results in a high demand for working memory resources. This demand may well exceed available capacity in the case of Broca's aphasics, who have, ex hypothesi, limitations of these resources. Because of that, a scaling operation proceeds (Haarmann, Just, & Carpenter, in press; Just & Carpenter, 1992). As a result of this scaling operation, activation levels of both competing structures decrease. However, this

decrease has more radical consequences for the structure that is lowest in activation: The 'unprimed' structure. Because that structure had less activation to begin with, further decreasing activation results in it 'falling' out of working memory (the activation level drops below a lower threshold). This effectively results in Broca's aphasics being unable to simultaneously maintain two competing structures. Normal controls on the other hand, having many more working memory resources, are able to maintain both alternatives, resulting in a smaller probability of finding priming effects. Note that an analogous reasoning was applied by MacDonald, Just, & Carpenter (1992), with respect to maintenance of different parse trees of structural ambiguous sentences by subjects with low and high spans of verbal working memory in comprehension. They obtained evidence from eye-movement studies showing that initially both parse trees are available to both groups of subjects, but that for low-span subjects the dispreferred parse tree rapidly becomes unavailable, whereas high-span subjects maintain both.

It remains to be seen whether any of the proposed accounts can really explain the present data: In order to do so, detailed assumptions need to be made about (i) the consequences the presentation of a prime sentence has for the activation level of the target structure, and whether 'weak' representations benefit most from priming (ii) the consequences of changes in this activation level for demand of working memory resources (iii) the consequences the presentation of a target picture has for the recruitment of syntactic structures and whether recruitment of many competing structures diminishes the advantage of the primed structure (iv) the consequences of demand for maintenance and processing exceeding capacity for the final activation levels of the competing structures. However if, given well-motivated assumptions, an implemented model can simulate our data, that would strongly support the model's validity, as well as the general theoretical framework.

Whatever the final explanation of the hyper priming effect may be, the current study clearly supports the hypothesis that Broca's aphasics' deficits in syntactic construction can, at least partially, be accounted for in terms of a resource limitation. This limitation can be temporarily remediated by syntactic priming.

Appendix: Materials

Target Pictures

Transitives	*Datives*
a tractor pulling a car	a boy handing another boy a hammer
a bullet hitting a bottle	a child showing his wounded arm to his mother

Transitives	*Transitives*
lightning hitting a golf player	a girl handing flowers to a teacher
a bycicle pulling a cart	children handing flowers to a man
a flyswatter killing an insect	a girl giving a tulip to another girl
a tripod hitting a farmer	a police officer handing a ticket to a car driver
a wave flushing a ship	a girl handing a paintbrush to a boy
smoke dazing a man	a girl handing a plant to a boy
an avalanche destroying a house	a boy handing a ball to a girl
a magnet attracting a coin	a waitress showing the menu to a customer
a ball hitting a vase	a little boy giving a valentine to a girl
an arrow hitting an apple	a woman showing a dress to a man
lightning hitting a church	a boy giving a ball to another boy
a tank killing a soldier	a lawyer showing a letter to a judge
a ball hitting some cans	children showing a drawing to their teacher
a wave flushing a girl	a girl handing a cup to a boy
a bicycle bumping into a pedestrian	a waitress presenting drinks to some men
a train killing a woman	a boy giving a valentine to a girl
an ambulance bumping into a mailman	a cowboy showing his hat to a clown
a rocket destroying an airplane	a nurse handing a glass of water to a patient
a torpedo hitting a ship	a child handing a pear to her teacher
a tow truck pulling a car	a boy handing a guitar to a singer
a bat hitting a ball	a girl showing a report card to a boy
a tornado lifting up a girl	a girl giving a present to a boy
a ball hitting a boy	a girl handing a ball to a boy
an arrow hitting a bird	a girl handing a bone to a dog
an avalanche burying skiers	a librarian handing a book to a boy

Transitive prime sentences in different animacy conditions[a]

agent inanimate/animate patient animate/inanimate.

1 Het lawaai/journalist onderbreekt de spreker/het gesprek
the noise/journalist interrupts the speaker/the conversation

2 De krant/komiek bespot de minister/het beleid
the newspaper/comedian mocks the minister/the policy

3 De tram/chauffeur snijdt de fietser/brommer
the streetcar/driver cuts the cyclist/moped

4 De loep/fotograaf vergroot de vlieg/het portret
the looking glass/ photographer enlarges the fly/the portrait

5 De dame/duisternis verbergt het juweel/de dief
the lady/darkness hides the juwel/the thief

6 Het schip/toerist laat de matroos/het blikje achter
the ship/tourist leaves the sailor/the can behind

7 De modder/boer bevuilt/vervuilt de wandelaar/sloot
the mud/farmer dirties/pollutes the walker/drain

8 De doelman/ketting houdt de bal/hond tegen
the goalkeeper/chain holds the ball/dog back

[a] Dutch sentence in active voice, followed by literal English translation.

9 De kok/zon verwarmt de soep/zwemmer
the cook/sun warms the soup/swimmer

10 De zeurpiet /verkeersboord stuurt de wijn/fietser terug
the bore/traffic sign sends the wine/bicyclist back

11 De directeur/het zwemvest redt het bedrijf/de drenkeling
the manager/the life jacket saves the company/the drowned

12 De verkeerstoren/verkeersleider roept de piloot/het vliegtuig op
the traffic tower/traffic leader calls the pilot/ the airplane up

13 De auto/agent rijdt de dief/auto klem
the car/police officer drives the thief/car stuck

agent inanimate/animate patient inanimate/animate.

1 De bromfiets/ambtenaar hindert de bus/boer
the moped/civil servant hinders the bus/farmer

2 De ton/spin vangt het water op/de mug
the barrel/spider catches the water up /the mosquito

3 Het lawaai/kind verstoort de rust/vogel
the noise/child disturbes the peace/bird

4 Het onweer/knecht stoort de TV/baas
the thunderstorm/assistant disturbes the TV/boss

5 De krant/vader brengt het bericht/kind
the paper/father brings the news/child

6 De bus/kat haalt de fiets/muis in
the bus/cat gets the bicycle/mouse in
('the bus/cat overtakes the bicycle/mouse')

7 De boot/pestkop duwt de bak/het kind
the boat/bully pushes the cargo boat/the child

8 De lak/leeuwin beschermt het hout/de welpen
the paint/lionesse protects the wood/the cubs

9 De steen/bokser treft de ruit/tegenstander
the stone/boxer hits the window/opponent

10 De auto/jager raakt het paaltje/de fazant
the car/hunter hits the pole(diminuative)/pheasant

11 De dam/agent houdt de zee/mensen tegen
the dam/police officer holds the sea/people back

12 De deur/moeder houdt de warmte/het meisje binnen
the door/mother holds the warmth/the girl inside

13 De bom/soldaat schakelt het kanon/de spion uit
the bomb/soldier switches the canon/the spy out
'The bomb/soldier eliminates the canon/the spy'

14 De bal/speler gooit de kegel/doelman omver
the ball/player throwes the pin/goalkeeper around
'The ball/player overthrowes the pin/goalkeeper'

Dative Prime sentences

1 De chef geeft een brief aan de boekhouder
the boss gives a letter to the accountant

2 De slager geeft een stuk worst aan het kind
the butcher gives a piece sausage to the child

3 Het meisje laat een sticker zien aan haar zus
the girl lets a sticker see to her sister

4 De vrouw laat een foto zien aan de bezoeker
the woman lets a picture see to the visitor

5. De journalist vraagt een reaktie aan de getuige
the journalist asks a comment to the witness

6 De toerist vraagt de weg aan de agent
the tourist asks the way to the police officer

7 De boer verkoopt een varken aan zijn buurman
the farmer sells a pig to his neighbor

8 De visser verhuurt een boot aan de man
the fisherman rents a boat to the man

9 De klant betaalt tien gulden aan de verkoper
the customer pays ten guilders to the salesman

10 De jongen geeft een armband aan zijn vriendin
the boy gives a bracelet to his girlfriend

11 De klant geeft een fooi aan de ober
the customer gives a tip to the waiter

12 De man laat zijn been zien aan de dokter
the man lets his leg see to the doctor

13 De soldaat laat het geweer zien aan de recruut
the soldier lets the rifle see to the recruit

14 De dame vraagt een wijntje aan de kelner
the lady asks a wine (diminuative) to the waiter

15 De makelaar verkoopt het pand aan de prins
the broker sells the building to the prince

16 De bakker verkoopt een brood aan de dame
the baker sells a bread to the lady

17 De zeeman schrijft een brief aan zijn vrouw
the sailor writes a letter to his wife

18 Opa vertelt een verhaal aan de jongen
Grandfather tells a story to the boy

19 De bejaarde geeft een gulden aan de bedelaar
the senior citizen gives a guilder to the beggar

20 De Sint geeft marsepein aan mijn broer
the saint (i.e. St. Nicholas) gives marchpane to my brother

21 De scholier laat het briefje zien aan zijn vriend
the student lets the note see to his friend

22 De baron liet een fortuin na aan zijn zoon
the baron let (past tense) a fortune after to his son
'the baron left a fortune to his son'

23 De zwerver vraagt een kwartje aan de voorbijganger
the tramp asks a quarter to the passerby

24 De kruidenier verkoopt een stuk kaas aan de toerist
the grocer sells a piece cheese to the tourist

25 De vrouw verhuurt een kamer aan de student
the lady lets a room to the student

26 De kapper vertelt een mop aan de klant
the hairdresser tells a joke to the customer

27 De zakenman betaalt veel geld aan de afperser
the businessman pays much money to the extorter

Part II

Subject-Verb Agreement

Chapter 4

One or more labels on the bottles? Notional concord in Dutch and French[1]

Abstract

Three experiments, the first two in Dutch and the other in French, in which subject-verb agreement errors were induced, are reported in the present chapter. We investigated the effects of the number of tokens in the conceptual representation of the to-be-uttered subject noun phrase (i.e., distributivity). Previous studies failed to show an effect of this variable in English (Bock & Miller, 1991; Vigliocco, Butterworth & Garrett, in press). However, Vigliocco Butterworth & Semenza (1995) and Vigliocco et al. (in press) found an effect of distributivity in Italian and Spanish. In an attempt to account for this difference across languages, three structural differences between English and Spanish/Italian have been considered: (1) Richness of verbal morphology; (2) possibility to have post-verbal subjects; (3) possibility to have null subjects. In the present paper we tested French and Dutch, which share some, but not all of these properties with Italian and Spanish. In both languages a distributivity effect was obtained; this result strongly supports an account in which neither null subjects nor post-verbal subjects are the main determinants, across languages, of the different sensitivity to conceptual factors.

Introduction

Most languages of the world require the verb to agree in number with the subject of the sentence. In the language production literature, it is assumed that agreement is computed at the stage of *grammatical encoding* (Levelt, 1989). During this stage lexical representations are retrieved, and the syntactic structure of the sentence is constructed, on the basis of the information specified in the discourse model (Bock & Levelt, 1994; Garrett, 1976). Getting subject-verb agreement right involves the speaker accessing a set of conceptual, syntactic and morphological information. Access itself is under the control of a number of processes: Selection of a discourse element as head of a noun phrase, access to the lexical representation of the noun, selection of the appropriate number and gender features for it, assignment of this noun to the subject function, selection of a

[1] Vigliocco, G., Hartsuiker, R.J., Jarema, G., & Kolk, H.H.J. (1996). *Language and Cognitive Processes.*, **11**, 407-442. Part of the data was also presented as Vigliocco, G. & Hartsuiker, R.J. (1995). Notional concord in French and Dutch, paper presented at the CUNY conference on sentence processing, Tucson, Arizona.

predicate, access to the corresponding lexical representation, selection of features such as tense and mood, and finally some processes that ensure the same person and number features on the subject and on the verb. Each step can in principle go wrong, but subject-verb agreement is usually constructed correctly and effortlessly in spontaneous speech. However, from time to time errors occur. In (1)-(3) below, examples of subject-verb agreement errors are presented (taken from a sample of written English, Strang, 1966, pp. 78-79).

(1) It is then this world of dreams created in the idle brain which take out the realm of reality into the sphere of self-deception.

(2) This country house group divert themselves in genteel ways, walking and talking, roaming the countryside and viewing the estate

(3) He therefore is presenting the Yashoos as a symbol of what 'man' considered 'en masse' are becoming.

Two major categories of errors have been discussed by descriptive grammarians (Quirk, Greenbaum, Leech & Svartvik, 1972): (i) *Proximity concord*, the verb agreeing with a noun that is closer to the verb than the subject noun, as in the example reported as (1), where the verb *take* agrees with the closer plural noun *dreams* instead of the singular subject *world* (ii) *Notional concord*, the verb agreeing with the 'notional number' (instead of the grammatical number) of the subject. In (2), the verb *divert* agrees with the plural meaning of the subject head noun *group*, instead of its grammatical singular number. A similar account can be given for the error reported in (3) where the conceptual reading of the subject noun *man* seems to be *all the men*.

These two forms of derailment have been studied in series of experiments designed to induce agreement errors (Bock & Cutting, 1992; Bock & Eberhard, 1993; Bock & Miller, 1991; Fayol, Largy, & Lemaire, 1994; Vigliocco, Butterworth, & Semenza, 1995; Vigliocco, Butterworth, & Garrett, in press). In most of these experimental investigations, subject-verb agreement errors were induced by presenting the participants with preambles consisting of a subject head noun and a local noun embedded in a phrase or clause that modified the subject noun phrase, as shown in (4)-(5). The participants' task was to provide a sentential completion for the preamble.

(4) The king of the colonies
(5) The king of the colony

All these studies reported a *proximity effect*:. The presence of a local noun, mismatching in number with the subject head noun, and in the immediate preverbal environment, as in (4) increased subject-verb agreement error rates in comparison to the number control condition, exemplified in (5), where the head and the local noun had the same number features (Bock & Cutting, 1992; Bock & Eberhard, 1993; Bock & Miller, 1991; Fayol et al., 1994; Vigliocco et al., 1995; Vigliocco et al., in press).

The question whether speakers produce verbs that agree with the conceptual number of the subject instead of its grammatical number - *notional concord* - has also been addressed in some studies (Bock, Cutting, & Eberhard, 1992; Bock & Eberhard, 1993; Bock & Miller, 1991; Vigliocco et al., 1995; Vigliocco et al., in press) but results differ across languages.

One of the conceptual variables that has received most attention in these studies is *distributivity*. We indicate with this label the number of 'tokens' a singular head noun can refer to. For example, in the discourse model of a preamble such as (6), there will be just one baby sitting on a number of blankets, as shown in Figure 1a. Preambles of this sort are called *single token preambles*. In (7), instead, there will be a label on each of several bottles, in order for the preamble to be in line with our world knowledge. This is depicted in Figure 1b. In fact, if we attempt to interpret the preamble in (7) as a single token preamble we would end up with the representation depicted in Figure 1c, which is possible to imagine, but incompatible with what we know about the relation between 'bottles' and 'labels'. These sentential preambles are called *multiple token preambles*. In these preambles, the subject NP refers to an entity distributed over multiple objects.

(6) The baby on the blankets

(7) The label on the bottles

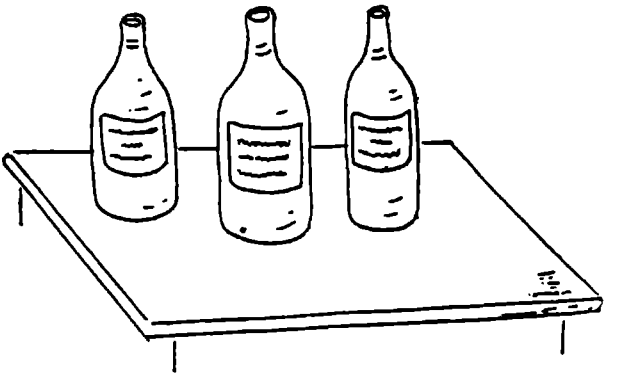
For single token preambles, the conceptual number is singular and congruent with the grammatical number of the head noun while for multiple token preambles the conceptual number is plural and conflictual with the singular grammatical number[2].

[2]Note, however, that this distinction only applies if a token interpretation is considered. If for multiple token items we consider a type interpretation, than the conceptual number of the head noun would be singular and congruent with its grammatical number.

a) The baby on the blankets

The label on the bottles

b)



c)

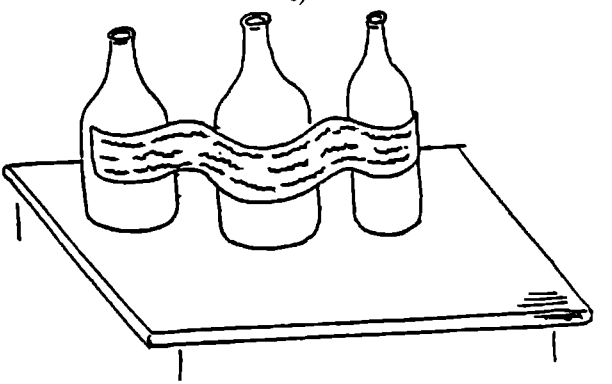


FIGURE 1. An hypothetical interpretation of the preambles 'The baby on the blankets' (1a) and 'The label on the bottles' (1b), (1c). For single token preambles such as (1a), an interpretation in which there is just one baby sitting on a number of blankets is in agreement with our world knowledge; while for multiple token preambles, such as (1b), only an interpretation in which there are many labels, one for each bottle is in agreement with our world knowledge. A single token interpretation of such a preamble would result in the bizarre scenario depicted in (1c).

Bock & Miller (1991) reported that this variable did not affect subject-verb agreement error rates for English speaking subjects: Errors in the agreement of number where equally common after a preamble such as (6) and (7). This result has also been replicated by Vigliocco et al. (in press) with slightly different materials and with a different population.

However, an effect of the conceptual number of the subject on the rates of subject-verb agreement errors has been reported by Vigliocco et al., (1995) and Vigliocco et al. (in press). They showed that speakers of Italian and Spanish were sensitive to distributivity: Subject-verb agreement errors were more frequent for multiple than for single token items.

This is not to say that English speakers are never sensitive to the conceptual number of the subject head noun. Bock and colleagues (Bock, Eberhard, & Cutting, 1992; Bock, 1995) reported some data showing semantic effects in English subject-pronoun agreement. Bock, Eberhard & Cutting (1992) presented complete sentences with single or multiple token complex subject NPs to speakers of English, who were requested to add a 'tag' question at the end, as is shown in example (8), with the correct completion in squared brackets.

(8) The bridge to the islands broke. [Didn't it?]

In that study, plural pronouns were produced more often after a multiple token than after a single token preamble. In another series of experiments, (reported in Bock, 1995; Eberhard, personal communication) they found that collective head nouns (such as *gang, committee*) induced a very high percentage of plural verbs (around 40%) as well as very high percentage of plural pronouns (around 50-60%). In those experiments, speakers of US English were given sentential preambles such as in (9a) or sentences such as in (9b) and their task was to provide a completion which contained the verb (for 9a) or which contained just the reflexive pronoun (for 9b).

(9) a. The gang with the dangerous rivals...
b. The gang with the dangerous rivals armed...

These results show conceptual control of subject-pronoun agreement but also of subject-verb agreement, a result apparently in contrast with the data on distributivity reported above. However, it can be argued that collective nouns represent a particular case in English, as demonstrated by the fact that in British English a plural verb in (9a) would be grammatical. Even in US English, while 'The leader with the dangerous rivals

ARE arming themselves' is a genuine error, the matter seems less clear for 'The gang with the dangerous rivals ARE arming themselves'.[3]

In this chapter we discuss three hypotheses put forward to account for the different sensitivity of English and Italian/Spanish to conceptual factors (Vigliocco et al., in press). In order to narrow down the number of hypotheses, we conducted a series of experiments in French and Dutch.

In most models of speech production, agreement is computed during *grammatical encoding* (Levelt, 1989; Bock & Levelt, 1994), and more specifically after grammatical functions have been assigned (Bock & Levelt, 1994) but prior to a stage in which words are placed in their linear order (Bock & Cutting, 1992; Vigliocco & Nicol, in prep.). Traditionally, in the linguistic literature, agreement has been described as a copying of features from the subject to the verb (see for example, Akmajian & Heny, 1975; Chomsky, 1981), and most psycholinguistic models (Bock & Miller, 1991; Garrett, 1984; Kempen & Hoenkamp, 1987; Levelt, 1989) assumed the same view. However, an alternative view has also been proposed: Unification or feature merging (Barlow, 1993; Kempen & Vosse, 1989; De Smedt, 1990). According to this second possibility the features for the subject and the features for the verb can be independently retrieved from the discourse model, then a checking procedure (unification) would ensure that the two elements are compatible. Agreement would therefore be computed as a merging of compatible features carried by the agreeing elements (in our case, the subject and the verb).

We argued that the finding of a distributivity effect implies that the number features for the two agreeing elements can be independently retrieved from the discourse model (Vigliocco et al., 1995; Vigliocco et al., in press). If the number feature was copied from the subject to the verb, then the conceptual number of the subject NP should be irrelevant (cf. Vigliocco et al., in press, for an extensive discussion of this issue).[4]

The problem to be solved is why, during the process that builds the syntactic representation of the sentence, the number can be retrieved for the verb phrase in Italian and Spanish whereas this does not seem to be the case in English. In an attempt to account for the different behavior of these languages, three cross-linguistic structural differences can be considered. These structural properties are:

(1) The possibility to drop the subject of the sentence versus having mandatory subjects. If a language allows subjectless sentences, then the number marking of the verb may be retrieved directly from the discourse model. The lack of an explicit agreement *controller*

[3]Notice also the different error rates induced by: (a) collective head nouns (around 40%); (b) control count nouns (around 18%).

[4]This seems to be the case especially for complex NPs, as were used in these experiments, where the conceptual plurality comes about only if the PP is taken into account.

(i.e., the subject pronoun) is to be considered normal for subject-verb agreement in Italian and Spanish (for Italian, Bates (1976) reported that the subject NP is omitted in up to 70% of declarative sentences). In English, verbs rarely lack an explicit controller for subject-verb agreement, but this is not true for subject-pronoun agreement, since in this case the referent can be just in the perceptual or discourse context. This hypothesis can account for the cross-linguistic difference in subject-verb agreement and it can also account for the different behavior in English of verbs and pronouns (cf. Bock, 1995). That is, in English (as in the other tested languages) the discourse model of the sentence influences agreement only when the grammatical controller is not overtly expressed. Of course, then we must assume that for these agreement relations, even when the controller is overtly expressed, the conceptual referent may be used to compute agreement.

(2) The possibility to have post-verbal as well as pre-verbal subjects versus a strict Subject-Verb-Object (SVO) word order.

In Italian and Spanish, the subject NP can appear in the string long after the verb as in the example (10) in Italian while English does not allow post-verbal subjects.

(10) E' andata dal dentista Daniela
Is gone to-the dentist Danielle
(Danielle went to the dentist)

If we assume that the grammatical encoding of a sentence proceeds in an incremental fashion (De Smedt, 1990; Garrett, 1976, 1990; Kempen & Huijbers, 1983; Kempen & Hoenkamp, 1987; Levelt, 1989; Levelt & Maassen, 1981; Schriefers, 1993), then the verb can start to be phonologically encoded before the encoding of the subject is completed. If that is the case, the number specification for the verb has to be retrieved first from the discourse model. Because in English declarative sentences the subject always precedes the verb, there is no need to retrieve the number specification for the verb from the discourse model first and the verb can receive its number specification from the subject without delay in the ongoing encoding. Again, we need an additional assumption: That even when the subject is pre-verbal, in Italian and Spanish, the verb can receive its number from the discourse model. This hypothesis can account for the cross-linguistic variability we found, however is not clear how it could explain the difference between verbs and pronouns in English.

(3) Rich verbal inflectional system versus poor verbal morphology.

In Italian and Spanish, person and number are always expressed by the verb inflectional morphology while this is not the case in English. Since in English in most cases there is no need to specify the number feature on the verb, it is conceivable that it is usually not retrieved from the discourse model. Furthermore, since number is always expressed on

pronouns in English, this hypothesis could explain the different sensitivity to conceptual factors of verbs and pronouns.

In the present experiments we use Dutch and French as the test languages since they share some properties with Italian, Spanish and English but not others so that we can manipulate, as much as nature allows us, one or two of the properties described above while keeping the others constant. In these experiments, we asked speakers of Dutch and French to complete single and multiple token preambles of the sort reported in (6) and (7) on page 5.

In the following section we mention the properties of Dutch and French which are relevant to our hypotheses.

Dutch (Geerts, Haeseryn, De Rooij, & Van den Toorn, 1984; Kooij, 1990) does not allow subjectless sentences and like in English a 'dummy' subject is used when necessary (e.g., *het regent* [it rains]). It allows post-verbal subjects as exemplified in (11).

(11) De bloemen op de tafel vindt Jan mooi
The flowers on the table finds John beautiful
(John finds the flowers on the table beautiful)

Finally, the verb forms are always marked for number, while the person distinction is present only in the present tense as a contrast between first person singular versus second and third person singular (see Table 1 for an example). An exception to this is the verb 'to be' where person is differentially marked for each singular form.

TABLE 1
Example of present tense conjugations for 'to walk' and for the 'to be' in Dutch

	lopen [to walk]	*zijn [to be]*
ik (I)	loop	ben
jij (you,S)	loopt	bent
hij/zij (he/she)	loopt	is
wij (we)	lopen	zijn
jullie (you, P)	lopen	zijn
zij (they)	lopen	zijn

Therefore, Dutch resembles English in that it does not allow null-subjects, but it also resembles Italian and Spanish in that the sentential subject can be post-verbal and the verb forms are univocally marked for number.

Dutch is an interesting language to study also because it allows us to test another difference across languages. Italian, Spanish and French are *Romance* languages while English and Dutch are *Germanic* languages Therefore, if we find a distributivity effect in Dutch, we can exclude the possibility that, for one reason or another, some characteristics of the Romance language family are responsible for conceptual influences on subject-verb agreement

In French, subjectless sentences are not allowed, and like Dutch and English, a 'dummy' subject is used when necessary French is regarded to be a canonical SVO language (Harris, 1990, p 235) and therefore postverbal subjects are not allowed [5] In French, verbs are always marked for person and number in the written format However, in spoken language the matter is more complex. Simplifying, in the present indicative there are six main conjugation types in French (Harris, 1990, pp. 224) For all of these conjugation types, the person distinction is absent in the singular forms In addition, for two of these conjugation types (e g , 'donner' and 'ouvrir') the third person plural is pronounced as the singular forms For irregular verbs, such as 'to be', both person and number distinction is maintained (see Table 2 for an example) [6]

TABLE 2

Example of present tense conjugations for irregular (to be and to do) and regular (to find) verbs

	être *[to be]*	*faire* *[to do/make]*	*trouver* *[to find]*
je (I)	suis	fais*	trouve*[a]
tu (you,S)	es	fais*	trouves*
il/elle (he/she)	est	fait*	trouve*
nous (we)	sommes	faisons	trouvons
vous (you,P)	êtes	faites	trouvez
ils/elles (they,M/F)	sont	font	trouvent*

a Forms within a column marked by '*' are pronounced identically

[5] According to some authors (Harris, 1990, Trévisse, 1986) the existence of two interrelated phenomena -- the presence of clitic pronouns and the possibility to dislocate NPs -- combine to give a relatively free word order For example

la table il la touche le garcon
the-F,S table-F,S he-M,S it F,S touches the-M,S boy-M,S

However in these constructions the subject pronoun is always preverbal

[6] In general, the more frequent a verb is in spoken language, the more likely it is to preserve the distinction between 3rd singular and 3rd plural form McDonald and Heilenman (1991) pointed out that of the 20 most frequent French verbs 65% retain this distinction, while of the 20 most infrequent verbs only 10% do

Although the number distinction on the verb, which is crucial for our argument, is not always expressed in spoken language, we would like to argue that number is represented as a syntactic feature during grammatical encoding also for regular verbs, since it is overtly expressed in the written format

Therefore, French resembles English in that the subject is always overtly expressed and always in preverbal position but it resembles Italian and Spanish in that its verbal morphology is richer than English

It is also important to note that French is a *Romance* language as Italian and Spanish In Table 3 we give a summary describing the relevant characteristics of the different languages

TABLE 3

Summary of the characteristics shown by the different languages.

	Null-Subjects	*Post-verbal Subjects*	*Rich Verbal Morphology*[a]
Italian	+	+	+
Spanish	+	+	+
Dutch	-	+	+
French	-	-	+
English	-	-	-

a Of course, richness of verbal morphology is a matter of degree, rather than an absolute characteristic However for the purposes of the present experiment, the distinction can be viewed as one between usually a marking of number (+) and usually no marking ( )

A word of caution is necessary here We acknowledge that properties such as allowing postverbal subjects and richness of verbal morphology are a matter of degree, rather than absolute Dutch allows postverbal subjects but this syntactic construction is not as common in this language as it is in Italian or Spanish Dutch and French verbal morphology is richer than English verbal morphology but at the same time is not as rich as it is in Italian or Spanish

The plan of the study

In this study we report a series of three experiments in which speakers of Dutch and French were requested to repeat and complete single token and multiple token preambles

From the discussion above, we can derive the following predictions First, in both Dutch and French the subject pronoun is mandatory, therefore they resemble English in this respect If the possibility to drop the subject is the only factor determining the

sensitivity of a language to conceptual number, then we should find the same result we obtained in English, that is no difference between single token and multiple token preambles. If we do find a difference, we must conclude that the lack of an explicit controller for the agreement relation is not a necessary condition for an independent retrieval of number features from the discourse model. Second, Dutch allows postverbal subjects, while French does not. If the possibility to have subjects after the verb is important for having conceptual number effects in a language, then Dutch should behave like Italian/Spanish, while French should behave like English. Third, the verbal morphology of Dutch and French is richer than English verbal morphology. If indeed the presence of an overt number marking on the verb is a relevant factor, then Dutch and French should behave as Italian and Spanish.

Finally, using Dutch as a test language allows us to test whether other differences between Italian/Spanish and English may have contributed to the results reported in the literature. If the sensitivity to conceptual number is a characteristic of Romance languages only, then Dutch should behave like English (while French should behave like Italian and Spanish). Furthermore, in English number in the experimental noun phrases is only marked on the noun, since the determiner 'the' does not carry number information, in Italian/Spanish number is redundantly specified on both the determiner and the noun (e.g., 'la macchina, le macchine', 'el coche, los coches' [the car/s]). Dutch allows to control for this variable. In Dutch number marking on the determiner depends on the gender of the noun. The definite determiner of neuter nouns is marked for number ('het' in singular, 'de' in plural), but the definite determiner preceding masculine/feminine nouns is not marked (always 'de'). By using preambles with masculine/feminine subject nouns in Dutch we create a situation similar to English: Only the subject noun is marked for number. If for whatever reason, the presence of more than one morphological number markers in the NP has an impact on the reported results, this may emerge in this study.

Experiment 1: Dutch

The first experiment tested whether speakers of Dutch are sensitive to the distributivity dimension. Single and multiple token items were visually presented to participants who were instructed to read them and to turn them into full sentences. Previous work (e.g. Bock & Miller, 1991; Vigliocco et al., 1995) showed that agreement error incidence, even in experiments specifically designed to induce this kind of error is very low (around 2-4%) and seems to be related (among other things) to speech rate (the instructions given to participants usually emphasized rapid speech). In an attempt to increase agreement error rates we introduced a new methodology in this experiment. Preambles were briefly presented on the computer screen and were followed by a deadline signal after a short interval. Participants were instructed to produce the full

sentence within this interval. For example, the participants saw: 'De datum op de munten' (The date on the coins), and they had to say something like 'De datum op de munten was oud' (The date on the coins was old) before the deadline signal. The main virtue of this methodology is that the rate of speech is kept as high as possible in a controlled fashion.

In order to ensure that possible differences between single and multiple token items can be reliably attributed to their different conceptual number (since the distributivity manipulation was necessarily confounded with items), the following controls have been considered. First, analysis was not restricted to agreement errors but also included other kinds of errors in reading and completing the preambles. Furthermore, plausibility ratings for items classified as single and multiple token have been collected for the same subjects, after they had finished the production experiment.

Method

Participants

Thirty-two undergraduate students of the University of Nijmegen participated in the present study. All were native speakers of Dutch. They received course credits or Dfl. 5 for their participation.

Materials

Experimental materials were sentential fragments consisting of subject Noun Phrases (NPs) followed by Prepositional Phrases (PPs). All experimental preambles had a singular head noun. The preferred semantic reading of the preambles (i.e. single or multiple token) was evaluated by 10 independent judges, all native speakers of Dutch. Only those items classified as single or multiple token by at least seven judges were included in the experiment. There were 24 experimental items: 12 were judged as single token, and 12 were judged as multiple token.

The number of the local noun was manipulated within items. Notice that distributivity applied only to singular head noun and plural local noun sentential preambles where it is possible to contrast a singular to a plural reading of the sentential subject (e.g. one single road to several islands, or a label for each of several bottles); for items with a singular head noun followed by a singular local noun, the preferred reading is congruent with the syntactic characteristics of the subject (e.g., 'one road to one island' or 'one label on one bottle'). Examples of items in the different experimental conditions are reported in Table 4.

TABLE 4

Examples of experimental sentence preambles in Experiment 1 (Dutch)

Experimental Condition	*Examples*
Single Token, number match (ST, control)	De aanslag op de minister (The strike on the minister)
	De diefstal van de diamant (The theft of the diamond)
Single Token, number mismatch (ST)	De aanslag op de ministers (The strike on the ministers)
	De diefstal van de diamanten (The theft of the diamonds)
Multiple Token, number match (MT, control)	De afbeelding op de mok (The picture on the mug)
	De bon in de folder (The coupon in the flyer)
Multiple token, number mismatch (MT)	De afbeelding op de mokken (The picture on the mugs)
	De bon in de folders (The coupon in the flyers)

Each preamble consisted of the same number of words (five). The number of syllables was on average higher in the single-token set than in the multiple-token set (7.6 vs. 7.0). This difference was not significant ($t(22)=1.47$; $p=.157$).

Experimental items all contained head and local nouns of the non-neuter gender (i.e. they all started with the same definite determiner: 'De') which is unmarked for number, and therefore can be considered as parallel to the English 'the'. All preambles are listed in Appendix A.

There were 36 filler items: 24 had the same syntactic structure as the experimental items, but with a plural head noun. Half of these had a singular local noun, the other half had a plural local noun. The remaining 12 fillers were simple NPs, consisting of a

determiner, one or more adjectives, and a noun. Simple NP-fillers were singular in six cases and plural in the remaining six cases. Filler items all had head nouns of the non-neuter gender.

Four 60-item lists were created. Each list consisted of 24 experimental items (six single token items, six single token control items, six multiple token items, and six multiple token control items) and 36 fillers. In each list the experimental and filler items were organized in a pseudo-random order, with the constraint that the list started with four fillers, and that no more than two experimental items followed each other. Across the four lists, each item occurred twice in the match condition and twice in the mismatch condition.

In the plausibility rating task the same lists were used as in the production experiment.

Procedure

Participants were tested in individual sessions, lasting about 10 minutes. They were instructed to read aloud and complete the preambles that were presented on the computer screen. No instructions were given about the form of the completion, other than that a complete sentence had to be produced before the deadline signal.

A trial was initiated by a button press. A fixation point appeared after 1 sec in the center of the screen. The preambles were presented visually at the center of the screen. Presentation of the preamble lasted 800 ms. A deadline window appeared, two cm. below the fixation point, 300 ms after the preamble disappeared from the screen. In this window, a bar was filled from left to right. When the bar was completely filled, a short tone announced the deadline was reached. Time from appearance of the deadline-window to the deadline signal was 1140 ms. The participants were instructed to press a button in order to move from one trial to another.

At the beginning of the experimental session a practice set of ten items of the filler type was presented to the participants to complete. The experimental session was recorded on audio tape.

Following the sentence completion task, subjects were given a sheet of paper on which the same preambles were listed. They were instructed to rate the plausibility of each item on a four-point rating scale (1 very plausible, 4 very implausible).

Scoring

The tape-recorded sessions were first transcribed and then assigned to one of the following scoring categories: Correct responses were scored when the participant said the preamble correctly and produced a correctly inflected verb form in the completion. Agreement errors were scored when the participant said the preamble correctly, but produced a wrongly inflected verb form. Number repetition errors were scored when the

participant incorrectly reported the number of the sentential subject, then produced a verb form inflected correctly with the produced number of the subject Repetition plus agreement errors were scored when the participant changed the number of the head noun but then the verb form mismatched in number with the produced subject Finally, utterances were scored as miscellaneous responses when the participant failed to report the preamble, omitted or substituted some words, said (part of) the preamble more than once, changed the number of the local noun, produced a sentence with a post-verbal subject, did not produce a complete sentence, or did not produce a verb form before the deadline signal If two different utterances were produced in succession, only the first was scored, including those cases in which an agreement error was produced and immediately corrected

Design and Data Analysis

The number of agreement errors and the number of miscellaneous responses constituted the dependent variables for the statistical tests Two analyses of variance, one with subjects (F1) and the other with items (F2) as the random factor were carried out for each dependent measure The experimental factors orthogonally combined were (1) Distributivity (single token vs. multiple token) and (2) Number match (match vs mismatch) between the head noun and the local noun The combination of these two factors yielded four conditions Every participant received six items in each condition

Difference in the plausibility between single and multiple token items was assessed using analyses of variance with the same experimental factors as the production experiment Furthermore, average plausibility ratings were treated as a covariate in an analysis of covariance which included the two main factors distributivity and number match

Results

Production experiment

Application of the scoring criteria yielded 492 (64 1%) correct responses, 58 (7 6%) agreement errors, and 3 (4%) repetition plus agreement errors There were 16 (2%) number repetition errors and 199 (25 9%) miscellaneous responses [7]

Table 5 shows the distribution of responses in the different scoring categories for the experimental conditions.

[7]It is worth noting that the large majority of miscellaneous responses included cases in which the speaker did not supply a verb before reaching of the deadline

TABLE 5

Distribution of responses by scoring category in Experiment 1 (Dutch)

Experimental condition[a]	*Correct* *(n)*	*Agreement Errors* *(n)*	*Repetition Errors* *(n)*	*Agreement/ Repetition Errors* *(n)*	*Miscellaneous Responses* *(n)*
ST, control	136	0	0	0	56
ST	114	6	10	0	62
MT, control	153	0	0	2	37
MT	89	52	6	1	44

a ST, control (Single Token, number match), ST (Single Token, number mismatch), MT, control (Multiple Token, number match), MT (Multiple Token, number mismatch)

As is clear from the table, agreement errors were most common (52) for multiple token preambles, while we found only six errors in the single token condition and no errors in the control (singular head noun, singular local noun) conditions [8] The distribution of responses was different for number repetition and miscellaneous responses Number repetition errors seem to be limited to the conditions with a mismatch between the numbers of subject and local noun Miscellaneous responses were more common for single token items than for multiple token items.

Since for agreement errors, there were no observations in the number match condition, the analysis of variance just contrasted single vs. multiple token conditions. This difference was significant both by subjects and by items ($F1(1,31)=39\ 52$, $p<.001$, $F2(1,22)=15.19$; $p< 001$).

The analysis of variance conducted on miscellaneous responses revealed a significant effect of Distributivity, but only in the test by subjects ($F1(1,31)=15\ 03$, $p< 001$, $F2(1,44)=2\ 604$, $p=.114$). There was no significant effect of Number match nor was the interaction between these variables significant.

Plausibility ratings

Data were gathered on only 30 of the 32 subjects, due to an omission of the experimenter. Mean plausibility (1 very plausible, 4 very implausible) was 1 5 in the single token, plural local noun condition, 2 0 in the multiple token, plural local noun condition, and 1 3 in both control conditions Preambles in the multiple token condition were rated as more implausible than in the other conditions The analysis of variance on the plausibility ratings yielded significant main effects of Distributivity ($F(1,44)=8\ 20$;

[8] A similar pattern of results emerges when assignment to scoring categories does not take the deadline into account

p<.01) and of Number match (F(1,44)=21.97, p<.001). The interaction was also significant (F(1,44 =8.20, p<.01).

In order to test the role of plausibility in the production experiment, we performed an analysis of covariance on agreement errors, with plausibility as the covariate. The results of this analysis showed that the effect of Distributivity cannot be attributed to a confound with Plausibility. With Plausibility as a covariate, the effect of distributivity remained [F(1,21)=7.75; p=.011].

Discussion

The main results of the present experiment can be summarized as follows. In the production experiment, agreement errors were reliably more common in the multiple token condition than in the single token condition. Miscellaneous responses were more frequent in the single token conditions, regardless of the number of the local noun. Repetition errors were more frequent in the number mismatch conditions, regardless of distributivity. The multiple token items also received a significantly lower plausibility rate, but the difference between single and multiple token items in the production experiment is significant even when their plausibility is taken into account.

The finding of a distributivity effect in Dutch can rule out the possibility that the cross-linguistic difference between English and Italian/Spanish is to be accounted for in terms of being a null subject language or not. In fact, Dutch (like English) does not allow null subject sentences.

However, the evidence of this first experiment is not conclusive since the items in the multiple token condition were also judged as less plausible than the items in the single token condition. In fact, although analysis of covariance showed that the distributivity effect was significant when plausibility was taken into account, it may be that multiple token items, being generally more implausible, induced an extremely high number of errors.

The second experiment, therefore, was carried out in order to see if we could replicate this result with a new set of materials judged equally plausible in both experimental conditions. The same variables were experimentally manipulated and the procedure was exactly the same.

Experiment 2: Dutch

Method

Participants

Forty undergraduate students of the University of Nijmegen participated in the present study. All were native speakers of Dutch. They received course credits for their participation.

Materials

A new set of items was constructed for this experiment. As in experiment 1, items were sentential fragments consisting of a singular subject NP followed by a PP. Sixteen independent judges, all native speakers of Dutch evaluated the preferred semantic reading of the preambles. The experimental items were classified as single or multiple token by at least 13 judges. There were 20 items: 10 were judged as single token, and 10 were judged as multiple token.

In addition, the items were subjected to a plausibility test for which four lists were constructed that included experimental items and filler items. Across the lists, each item occurred twice with a plural local noun and twice with a singular local noun. Forty subjects, none of which participated in the production experiment, rated the items' plausibility on a five-point rating scale, with a score of one being very plausible and five very implausible. Each item was judged by 20 subjects, and each subject received five items in each condition. Mean plausibility was 1.30 for single token items, 1.47 for single token control items, 1.29 for multiple token items, and 1.16 for multiple token control items. Although single token items were on average slightly more implausible, the effect of Distributivity failed to reach conventional levels of significance ($F(1,36)=3.577$, $p=.067$). There was no effect of Number Match ($F(1,36)<1$), and the interaction was not significant ($F(1,36)=3.14$, $p=.085$). In Table 6, some examples of the new items are reported.

Each preamble consisted of the same number of words (five). The number of syllables was on average greater in the multiple-token set than in the single-token set (8.0 vs. 7.7). This difference was not significant ($t(18)=.46$; $p=.65$).

Experimental items all contained head and local nouns of the non-neuter gender (i.e., they all started with the same definite determiner: 'De') which is unmarked for number, and therefore can be considered as parallel to the English 'the'. Local nouns either required the morpheme '-en' or '-s' to indicate plurality. This variable was balanced within the single and multiple token sets. All preambles are listed in Appendix B.

TABLE 6

Examples of sentence preambles used in Experiment 2 (Dutch)

Experimental Condition	*Examples*
Single Token, number match (ST, control)	De kerk bij de heuvel (The church near the hill)
	De kooi met de gorilla (The cage with the gorilla)
Single Token, number mismatch (ST)	De kerk bij de heuvels (The church near the hills)
	De kooi met de gorillas (The cage with the gorillas)
Multiple Token, number match (MT, control)	De puzzel in de krant (The puzzle in the newspaper)
	De handtekening op de cheque (The signature on the cheque)
Multiple token, number mismatch (MT)	De puzzel in de kranten (The puzzle in the newspapers)
	De handtekening op de cheques (The signature on the cheques)

There were 30 filler items: 20 had the same syntactic structure as the experimental items, but with a plural head noun. Half of these had a singular local noun, the other half had a plural local noun. The remaining 10 fillers were simple NPs, consisting of a determiner, one or more adjectives, and a noun. Simple NP-fillers were singular in five cases, and plural in the remaining five cases. Filler items all had head nouns of the non-neuter gender.

Four 50-item lists were created. Each list consisted of 20 experimental items (five single token items, five single token control items, five multiple token items, and five multiple token control items) and 30 fillers. Across the four lists each item contributed

twice to the number match condition and twice to the number mismatch condition. In each list the experimental and filler items were organized in a pseudo-random order, with the constraint that the list started with four fillers.

Procedure Same as Experiment 1.

Scoring Same as in the preceding experiment.

Design and Data Analysis

The number of agreement errors and the number of miscellaneous responses constituted the dependent variables for the statistical tests. Two analyses of variance, one with subjects (F1) and the other with items (F2) as the random factor were carried out for each dependent measure. The factors orthogonally combined were: (1) Distributivity (single token vs. multiple token) and (2) Number match (match vs. mismatch) between the head and the local noun. The combination of these two factors yielded four conditions. Every participant received five items in each condition.

Results

Application of the scoring criteria yielded 498 (62.3%) correct responses, 36 (4.5%) agreement errors, and 5 (.6%) repetition plus agreement errors. There were 3 (.4%) number repetition errors and 258 (32.3%) miscellaneous responses. In Table 7, the numbers of responses in the different scoring conditions are reported. As is clear from the table, agreement errors were most common (29) in the multiple token condition, whereas we observed only five errors in the single token condition, and one error in each of the control conditions.

TABLE 7

Distribution of responses by scoring category in Experiment 2 (Dutch)

Experimental condition[a]	*Correct (n)*	*Agreement Errors (n)*	*Repetition Errors (n)*	*Agreement/ Repetition Errors (n)*	*Miscellaneous Responses (n)*
ST, control	142	1	0	0	57
ST	131	5	1	0	63
MT, control	133	1	1	2	63
MT	92	29	1	3	75

a. ST, control (Single Token, number match); ST (Single Token, number mismatch); MT, control (Multiple Token, number match); MT (Multiple Token, number mismatch).

Since for agreement errors, there was only one observation in each of the number match conditions, the analysis of variance just contrasted single vs., multiple token conditions. The effect of distributivity was reliable both by subjects and by items ($F1(1,39)=11.80$; $p<.001$; $F2(1,18)=10.49$; $p<.005$).

The analysis of variance conducted on miscellaneous responses revealed no significant main effects or interactions.

Agreement error rates for this experiment were lower than for Experiment 1 (7.6% and 4.5% respectively), while miscellaneous responses were more common in the present experiment than in the previous one (32.2% and 25.9% respectively). It is important to note that items differed in the two experiments. In particular, items in the multiple token set differed in their plausibility (lower in Experiment 1 than in Experiment 2); and they differed in their length (on average, 7 syllables in Experiment 1 and 8 syllables in Experiment 2). In order to test for significant differences between the Experiments we conducted two analyses of covariance. In the first analysis, the dependent measure was the proportion of agreement errors for the different items (computed as the numbers of agreement errors in that condition over the total number of items presented in that condition). Experiment was treated as a between item factor, and the rated plausibility was entered as a covariate. This analysis failed to reveal a significant effect of Experiment ($F<1$) on agreement errors when the plausibility of the items was taken into account. In the second analysis, the dependent measure was the proportion of miscellaneous responses for the different items. Experiment was treated as a between item factor, and the length in syllables was entered as a covariate. This analysis failed to reveal a significant effect of Experiment ($F<1$) on miscellaneous responses when the length of the items was taken into account. It is important to mention here that the majority of responses scored as miscellaneous were in fact cases in which the participants did not produce a verb before the deadline signal. An increase in the length of the preamble to be repeated, therefore, can easily affect responses in this scoring category.

Discussion

In this second experiment we found a distributivity effect in Dutch. Items in the multiple token condition induced more agreement errors than items in the single token condition.

Given this result, we must conclude that being a null subject language is not a necessary condition for an independent retrieval of number features for the subject NP and for the verb.

It is important to note that the presence of a distributivity effect in Dutch also rules out the two additional hypotheses put forward in the Introduction. The cross-linguistic difference is not due to some features of *Romance* languages, since we found an effect of

distributivity in a *Germanic* language such as Dutch. Furthermore, this result rules out the possibility that the number of morphological markers of number in the head or local noun phrases has any impact. In fact, in the present experiment all the nouns used were introduced by the determiner 'de', that has the same morphological form for the singular and for the plural, parallel to 'the' in English.

Since Dutch shares with Italian and Spanish the other two discussed characteristics (i.e. post-verbal subjects and rich verbal morphology) we cannot decide between the two on the basis of these data alone. In the third and final experiment we tested French.

Experiment 3: French

In this experiment we tested whether speakers of French are sensitive to the conceptual number of the subject, in subject-verb agreement construction. As mentioned above, French shares with Italian/Spanish a rich verbal morphology while it shares with English the fact that the subject pronoun is mandatory and the fact that the subject pronoun always precedes the verb. From the previous experiments we know that being a null subject language is not a necessary condition. The results of the present experiment therefore can tell us something about the role of the other two differences. If we find a distributivity effect in French we must conclude that the possibility of having the subject after the verb is also not an important factor for retrieving information about the number of the subject from the conceptual representation when the verb phrase is computed.

In the experiment we report here we used visual presentation in order to provide the most clear number information to the speaker (since, as previously discussed, the singular and plural phonetic form of regular nouns is indistinguishable). The visual presentation also allowed us to use a technique to increase subject-verb agreement errors introduced by Vigliocco et al. (1995).[9] This technique takes advantage from the fact that in French (as in Italian and Spanish) predicates agree in number (and gender) with the sentential subject, as is shown in (12).

[9]For the clearest outline of our argument Experiment 3 is presented last, although it was performed prior to the other experiments. This explains the different methodology: In Dutch we could not use the procedure with the adjective, as adjectives are not marked for number in these constructions.

(12) a. Le vase sur les tables est vert
The-M,S vase-M,S on the-F,P tables-F,P is green-M,S

b. Les vases sur la table sont verts
The-M,P vases-M,P on the-F,S table-F,S are green-M,P

Notice that also for adjectives, the singular and plural forms are distinguishable only in the written format while, apart from a few exceptions, they are pronounced the same.

We visually presented the adjective (singular or plural) immediately followed by the sentential preamble. The participants' task was to turn the preamble into a full sentence using in their completions the adjective they saw before. For example, the participant saw 'vert' [green] and then 'Le vase sur les tables' (The vase on the tables) and his/her task was to say something like 'Le vase sur les tables est vert' (The vase on the tables is green). The adjective was congruent, in that it had the same number as the head noun (adjective singular, head noun singular) or incongruent, with a different number (adjective plural, head noun singular). The rationale underlying the use of this manipulation is that when the adjective was mismatching (i.e. plural) it should increase the likelihood of finding agreement errors, since when the preamble is presented, the participants have already read the adjective. The adjective congruent condition served as the control condition in order to ensure that the mere introduction of the adjective did not increase the error rates for unrelated reasons.

A further advantage of the use of this methodology is that participants were required to use the verb 'être' (to be) in their utterances. The conjugations of this verb are never ambiguous with respect to number (see Table 2).

It is important to note that there are few main differences between Experiments 1 and 2, and the present experiment. First, the methodology differed. Second, in the present experiment there were no control conditions with a number matching local noun. This difference is motivated in part by the results of a pilot experiment in French in which the subjects could freely complete the sentential preambles and in which the number control conditions were present. The pattern of results of that experiment was similar to that in Dutch (multiple token items eliciting more errors (9) than single token items (2), and fewer errors were found in the number control conditions). However, the overall error rate was surprisingly low (1.6 %). Finally, we did not use parallel versions of the materials in the different languages for the following main reasons: First, and most important, certain items univocally classified as single or multiple token in a language did not receive an univocal judgment in the other language and second, languages differ in the use of certain prepositions to represent a given relation.

Method

Participants

56 students of the University of Montreal ranging from 19-25 years old participated in the present experiment. They were native speakers of (Quebecian) French and they volunteered or received course credits for their participation. Ten additional subjects from the same pool evaluated the plausibility of the materials. Before starting the experiment, a questionnaire investigating the level of French proficiency was presented to the participants. As a general criterion, French had to be not only the first language they acquired but also they (a) had to have attended up to high school in a French school, and (b) they had to use French at least 90% of the time during everyday activities.

Materials

The basic materials for the present experiment consisted in sentential preambles composed by a subject NP followed by a PP. All the experimental items had a singular head noun and a plural local noun. Half of them were classified as single token, the other half as multiple token. The preferred semantic reading of the preambles was evaluated by sixteen independent judges, all native French speakers. Only those items unambiguously classified as single or multiple token by at least 12 judges were included in the experiment. In addition to the experimental items a set of filler items was also created. Each experimental and filler item was matched with a semantically plausible adjective.

Each preamble consisted of the same number of words (five). The number of syllables was not significantly different in the two sets of materials (single token = 6.38; multiple token = 6.13; $t(30) = .52$, $p = .61$). The gender of the head noun and of the local noun was balanced, therefore, there were four preambles in which both head noun and local noun were masculine; four preambles in which the head was masculine and the local noun was feminine; four in which both head noun and local noun were feminine; and four in which the head noun was feminine and the local noun was masculine. The gender of the filler items was also balanced. All the nouns used in the experiment were regular in that both the singular and plural form were always pronounced identically.

Two 64-item lists were created. Each list consisted of 32 experimental items (16 single token and 16 multiple token) and 32 filler items. Sixteen of the filler items were NP-PP preambles, with a plural head and a plural local noun, while the other 16 were simple NP preambles, eight being singular and the other eight being plural. The items were preceded by a singular adjective in one list and by a plural adjective in the other list. In Table 8 we report some examples of the experimental sentence preambles (all the experimental sentence preambles are reported in Appendix C).

TABLE 8

Examples of sentential preambles in the different experimental conditions in Experiment 3 (French) with adjectives are parentheses

Experimental Condition		*Examples*
Singular adjective, single token	(fatigué)	Le lecteur des romans
(SAdj., ST)	(tired)	The reader of the novels
	(arrivé)	Le témoin des avocats
	(arrived)	The witness of the lawyers
Plural adjective, single token	(fatigués)	Le lecteur des romans
(PAdj., ST)	(tired)	The reader of the novels
	(arrivés)	Le témoin des avocats
	(arrived)	The witness of the lawyers
Singular adjective, multiple token	(varié)	Le menu des restaurants
(SAdj., MT)	(varied)	The menu of the restaurants
	(dorée)	L'étiquette des bouteilles
	(golden)	The label on the bottles
Plural adjective, multiple token	(neufs)	L'uniforme des soldats
(PAdj., MT)	(new)	The uniform of the soldiers
	(spacieuxes)	Le bureau des gérants
	(large)	The office of the directors

Experimental and filler items were arranged in the lists in a pseudo-random order. Each list started with five fillers, the arrangement of the remaining experimental and filler items was randomized with the constraint that there were no more than three experimental items consequently.

The same experimental and filler items were presented to an additional group of 10 subjects requested to provide plausibility ratings on the materials. In this task, participants were required to use a 4 point scale (1 = very plausible; 4 = very implausible). Single token items received a mean plausibility score of 1.8, while multiple token items received a mean score of 1.9. The difference was not significant $t(30)=.71$; $p=.48$.

Procedure

Each participant was tested individually in sessions lasting about 10 minutes. After a warning signal that initiated the trial, the adjective was presented at the center of a computer screen for 600 ms, followed by an interval of 600 ms, and by the preamble that was presented for 900 ms. The exposure duration for the adjective and the preamble was chosen as the shortest duration for the subjects to correctly read the adjective and the preamble (Vigliocco et al., 1995). For example, they saw 'incompétents' (incompetent-M,P) and then 'Le méchanicien des voitures' (The mechanic of the cars) and they had to produce a sentence like 'Le méchanicien des voitures est incompétent' (The mechanic of the cars is incompetent), thus changing the number of the adjective in this case. The written instructions emphasized rapid speech and gave examples of possible sentences both with a congruent and an incongruent adjective. Subjects had, in fact, to be ready to find incongruence between the number of the head noun and the number of the adjective but no mention to grammatical number was made. Since we did not want participants to change the number of the head noun, instructions also emphasized that the preamble had to be always repeated as it was. Adjective-preamble pairs were presented one at the time. Subjects were instructed to press the space bar on the computer keyboard in order to move from one trial to the next.

If the participant failed to read or comprehend either the adjective or the preamble, the experimenter repeated it to him/her. At the beginning of the experimental session a practice set of eight NP-PP items (four with a congruent and four with an incongruent adjective) was presented to the participants to complete. The experimental sessions were tape-recorded with an analog recording system.

Scoring

The produced utterances were transcribed and then placed in one of the following scoring categories. Correct responses were scored when the participant said the preamble correctly and produced a correctly inflected verb form in the completion. Agreement errors were scored when the participant said the preamble correctly but produced a wrongly inflected verb form. Responses in this category were further divided into Errors in the agreement of number when the produced verb form mismatched in number with the sentential subject (i.e., when they produced plural verbs), and others when the predicate disagreed with the subject in gender or number. Repetition errors were scored when the participant incorrectly reported the number of the sentential subject, then produced a verb form inflected correctly with the produced number of the subject. Repetition plus agreement errors were scored when the participant changed the number of the head noun but then the verb form mismatched in number with the produced subject. Finally, utterances were scored as miscellaneous responses when the participant failed to report

the adjective, the preamble (or part of it), substituted some words or did not produce a verb form. If two different utterances were produced in succession, only the first was scored, including those cases in which an agreement error was produced and immediately corrected.

Design and Data Analysis

The number of agreement errors, the number of repetition responses and the number of miscellaneous responses constituted the dependent variables for the statistical tests. Two analyses of variance, one with subjects (F1) and the other with items (F2) as the random factor were carried out for each dependent measure. The factors orthogonally combined were (1) Distributivity (single token vs. multiple token); and (2) number of the adjective (congruent vs. incongruent). The combination of these two factors yielded four conditions. Every participant received eight items in each condition.

Results

Application of the scoring criteria yielded 1492 (83.33%) correct responses, 65 (3.63%) agreement errors, of which 63 were errors in the agreement of number and two were 'other' agreement errors, and 10 (0.55%) repetition plus agreement errors. There were 110 (6.14%) repetition errors and 115 (6.42%) miscellaneous responses.

Table 9 shows the distribution of responses in the different scoring categories for the experimental conditions.

TABLE 9

Distribution of responses by scoring category in Experiment 3 (French)

Experimental condition[a]	*Correct (n)*	*Agreement Errors (n)*	*Repetition Errors (n)*	*Agreement/ Repetition Errors (n)*	*Miscellaneous Responses (n)*
SAdj, ST	373	8	26	5	36
PAdj ST	364	13	40	4	27
SAdj, MT	395	10	17	0	26
PAdj, MT	360	34	27	1	26

a. SAdj., ST (Singular Adjective, Single Token); PAdj., ST (Plural Adjective, Single Token); SAdj., MT (Singular Adjective, Multiple Token); PAdj., MT (Plural Adjective, Multiple Token).

As can be seen from the table, agreement errors were more common for multiple token items than for single token items and also more common when the adjective was incongruent with the subject head noun.

The analyses of variance conducted on errors in the agreement of number showed a significant effect of distributivity (F1(1,55)=6.19; p=0.016; F2(1,30)=5.90; p= 0.021). Errors were more common for multiple than for single token preambles. The congruency between the number of the adjective and the number of the head noun was also significant (F1(1,55)=11.51; $p < 0.001$; F2(1,30)=11.31; p=0.002), as well as the interaction between the two factors (F1(1,55)=4.7; p=0.05; F2(1,30=5.35; p = 0.03).

It is worth noting that in the present experiment the adjective was at times a plausible modifier of the head noun only and at other times it was a plausible modifier of both the head and the local noun. It can be argued[10] that in this second case, plural verbs (scored as agreement errors) may reflect erroneous selection of the sentential subject. That is, the local plural noun is taken as the subject of the sentence and therefore a plural verb would be correct (since the local noun was always plural in this experiment). However, in order to obtain a difference in error frequencies between single and multiple token preambles due to this confound factor, items in which the adjective was a plausible modifier of the local noun should have been more common among the multiple token than in the single token preambles. This was not the case in our experiment: six out of sixteen items in the multiple token set and eight out of sixteen items in the single token set were of this kind. Furthermore, if we consider those cases in which the adjective plausibly modified only the head noun ('pure cases'), the error rates in the single token and in the multiple token conditions are closely matched with the overall rates in these two conditions. The error rate for single token 'pure cases' is .02; while for multiple token 'pure cases' is .054. The overall error rate for single token items is also .02; while it is .05 for multiple token items.

The analyses of variance carried out on number repetition errors showed a significant main effect of the congruency between the number of the adjective and of the head noun (F1(1,55)=11.37; p=0.001; F2(1,30)=6.32; p=0.018]. Repetition errors were also more common in the single token condition than in the multiple token condition, this effect, however, was significant by subjects [F1(1,55)=10.48, p=0.002] but not by items [F2(1,30)=2.51; p = 0.12).

Finally, miscellaneous responses were not influenced either by distributivity or congruency between the adjective and the subject head noun.

Discussion

The results of this final experiment can be summarized as follows. The distributivity of the subject head noun influenced the agreement error rates but not the

[10]We thank Dr. Fayol for directing our attention to this important point.

rates for repetition and miscellaneous responses. Only agreement errors were more common after multiple token than single token preambles. The procedure of presenting an incongruent adjective prior to the preamble was successful in eliciting a fair percentage of agreement errors (error rates went from 1.6% in our pilot study in which we used a free completion task to 3.6% in this study).

The number of repetition errors and repetition plus agreement errors is considerably larger in Experiment 3 than in the previous experiments. This can probably be best explained by the difference in methodology. In the present experiment, the subject was presented with a number marked adjective. It is conceivable that the presence of an additional number cue, conflicting half of the times with the head noun, leads to a greater probability of confusing the number of head and local noun.

The finding of a distributivity effect in French allows us to exclude both the possibility of dropping the subject pronoun and the possibility of having the subject after the verb as factors determining an independent retrieval of number features for the subject and for the verb.

General Discussion

This series of experiments extends previous investigations of conceptual agreement to Dutch and French. The conceptual variable we considered was distributivity. In previous studies (Bock & Miller, 1991; Vigliocco et al., 1995; Vigliocco et al, in press) it was shown that English did not show any effect of this variable, while Italian and Spanish did. The main purpose of the present study was to assess a number of psychologically plausible hypotheses which have been put forward to explain this cross-language difference. These hypotheses try to relate the different behavior of these languages to some structural properties of the studied languages. The present study of Dutch and French was therefore motivated by the fact that these two languages share some of these structural properties with either English or Italian (and Spanish). We found an effect of distributivity in both languages. In Figure 2, we report the proportions of agreement errors in the single and multiple token condition for the entire set of studied languages as a comparison.

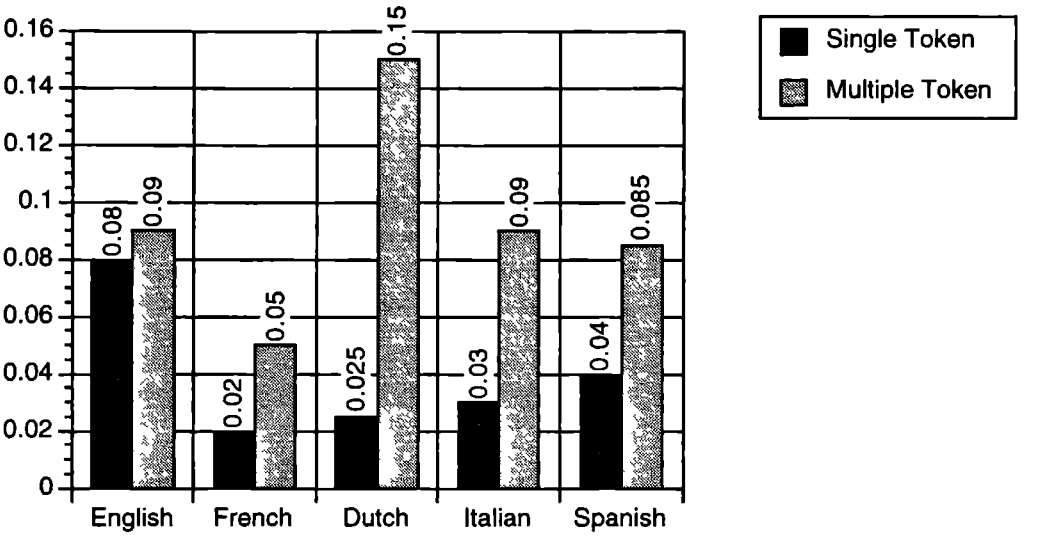


FIGURE 2. Proportions of agreement errors in the different tested languages (proportions are computed as the number of agreement errors over the total number of items in that condition). Data for English, Italian and Spanish are taken, with authors' permission, from Vigliocco et al., in press).

In the Introduction three main structural differences were proposed in order to account for the different results in Italian/Spanish and English: The possibility to drop the subject pronoun, the possibility to have postverbal subjects, and the richness of the verbal morphology. The experiments reported in this paper allow us to conclude that neither the possibility to drop the subject nor the possibility to have postverbal subjects can account for the different results obtained in English. Specifically, the finding of a distributivity effect in Dutch allows to exclude the first hypothesis and the finding of a distributivity effect in French allows to exclude both the first and the second hypothesis.

The present results also allow us to exclude that the cross-linguistic difference has to do with being a *Romance* vs. a *Germanic* language, since we found a distributivity effect in Dutch. Furthermore, the reported results rule out the possibility that the difference was related to the number of morphological markers for number in the experimental NP (i.e. number information is or is not redundantly present on the determiner and on the noun): We found a distributivity effect in Dutch, using preambles in which the determiner did not give any information about number (as was the case in the English materials).

It is worth mentioning again here that the same preambles which did not induce any difference in subject-verb agreement in English (Bock & Miller, 1991) did show an effect of distributivity when subject-pronoun agreement was considered (Bock, Eberhard,

& Cutting, 1992), as discussed on page 143, therefore the absence of an effect in English does not seem to be easily attributed to idiosyncrasies of the experimental materials

In the linguistic literature, the fact that different languages can be sensitive to conceptual number for different agreement relations has been observed and discussed Starting from the study of Slavic languages, Corbett (1978, 1983) postulated that the probability of conceptual agreement, rather than syntactic agreement, increases as the agreement target occupies a rightward position in the following series of syntactic positions· Attributive modifier, predicate, relative pronoun, personal (anaphoric) pronoun Different languages can occupy different positions in this hierarchy and, if a language allows conceptual agreement at a certain agreement position (e g , relative pronoun) in the hierarchy, it should allow conceptual agreement for all positions to the right (personal pronoun, in the example above) The sentence in (13) is a further example In Italian for nouns such as "Guardia" (guard), which are grammatically feminine but typically refer to men, gender agreement between subject and verb is with the grammatical gender, but gender agreement between subject and anaphoric pronoun is with natural (conceptual) gender.

(13) La guardia è arrivata tardi, (lui) è stato
The F,S guard-F,S is-3p,S arrived F,S late, (he) is 3pS been-M,S

a parlare con il direttore
to talk with the director

The finding of a distributivity effect for tag questions reported by Bock & colleagues (Bock, Eberhard, & Cutting, 1992, Bock 1995) is also particularly important since it shows that English speakers can be sensitive to the distributivity dimension but in a position further to the right in the hierarchy Additional data showing a conceptual influence on the relation between subject and anaphoric pronoun in English and Spanish comes from work by Gernsbacher and colleagues (Gernsbacher, 1991, Carreiras & Gernsbacher, 1992, Oakhill, Garnham, Gernsbacher & Cain, 1992) These authors reported a series of experiments exploring the comprehension of "conceptual anaphors", such as *"I think I'll order a frozen margarita. I just love THEM"* both in English and Spanish They found that conceptual anaphors are quickly read and easily understood in both languages

Extrapolating from this proposal, conceptual agreement could be found in English for targets in a position further to the right of the hierarchy than in all other tested languages The data regarding subject-pronoun agreement in English are compatible with this view Furthermore, a prediction that can be derived from this proposal is that Dutch, French, Italian and Spanish should allow conceptual agreement for subject-pronouns

relations (a more extensive discussion of this issue can be found in Vigliocco et al., in press).

In the framework of a processing model, the agreement hierarchy may represent the points, during the encoding of a sentence, at which features such as number are retrieved from the conceptual representation. Therefore, what are the properties of a language that determine its position on the agreement hierarchy?

The only structural difference we did not rule out in the present study is the richness of verbal morphology.

It is not immediately clear why this should be the case, that is, why an independent retrieval of number features for the subject and for the verb should be possible only if number is expressed in the verb phrase. However, one possible reason is that in English the verbal inflectional morphology is *meaningless* while it is *meaningful* in the other tested languages (i.e. in contrast to the other tested languages, English verb inflections do not carry information about how many participants are in the scenario described by the sentence).

According to this possibility, since the verbal morphology of English is limited to a distinction between a marked form (the third person singular) and all the other forms, in most cases, it does not carry any meaning of number. In the other tested languages, since the verb form carries information about the number, the verb form is meaningful with respect to number. Some evidence compatible with this idea comes from language acquisition studies. Berko (1958) and Keeney & Smith (1971) showed that noun number inflections are produced prior to verb number inflections by English children. Keeney & Wolfe (1972) reported that English speaking 3-4 year-olds were at chance level when required to choose between two pictures with one or two 'birds' if the verb form 'sing' or 'sings' was presented. In the same task, childrens' performance was better than chance if the whole sentence was presented. The cross-linguistic data reported by a number of researchers on sentence interpretation (Bates, McNew, MacWhinney, & Devescovi (1982); Kail, 1989; Kilborn & Cooreman, 1987; MacWhinney, Bates, & Kliegl, 1984; McDonald & Heilenman, 1991) are also compatible with this view. The authors used a sentence interpretation paradigm in which subjects were required to choose the subject/agent of a sentence with a structure like (14) (from MacWhinney et al., p. 139).

(14) a. Licks the cow the goat
b. Lecca la mucca la capra
c. Leckt die Kuh die Ziege

In these experiments, they manipulated and put in "competition" different *cues* (such as agreement, animacy, stress and word-order) to establish which cues would be most

relevant for speakers of different languages. MacWhinney et al., (1984) found that Italian speakers relied on agreement to make decisions about the subject/agent of the sentence while English speakers relied overwhelmingly on word order. Dutch, French and Spanish behave similar to Italian in that respect: Kilborn & Cooreman (1987) showed that speakers of Dutch rely more on agreement than on word order, and Kail (1989) and McDonald & Heilenman (1991) showed the same for French and Spanish. It is important to note that what the authors refer to with the label *agreement* is in fact the number marking on the verb. According to this view, number information would be retrieved from the discourse model only when the syntactic constituent has a *number meaning*, otherwise it would just be inherited from the agreement controller: In English subject-verb agreement the number feature on the verb would be inherited from the subject; in subject-pronoun agreement it would be taken from the discourse model, since the pronoun has a *number meaning*. Further research is necessary in order to see if English speakers do not attribute number meaning to the verb form while speakers of the other languages do.

Insofar we discussed the cross-linguistic difference we reported in terms of production mechanisms. However, further research is also necessary in order to test the role of the comprehension component of the task. In fact, our results do not rule out the possibility that the cross-language difference we found is related to different on-line interpretations of the preambles for speakers of different languages. Two unpublished studies seem to support this possibility. Eberhard (personal communication) found a significant effect of distributivity with a different set of materials and Vigliocco & Veres (in progress) found an effect of distributivity in English using modified versions of the preambles used by Vigliocco et al. (in press). Although at present it is difficult to explain such findings, if replicated these studies would show that indeed agreement in English and in the other languages is computed in the same way (i.e. through unification) and that the difference originally found between English and the other tested languages may be attributed to differences in the interpretation of the linguistic input.

Whatever turns out to be the final explanation, our experiments have clearly excluded two psycholinguistically well-founded hypotheses: (1) That retrieval from the conceptual representation of number information in subject-verb agreement depends on the possibility to omit subject pronouns, and (2) That it depends on the possibility to have post-verbal subjects.

The present experiments also stress once more the importance of cross-linguistic research of agreement phenomena. Given the assumption that the same general architecture underlies language production in different languages, nonetheless the system can be differentially 'tuned' to specific properties of a language. This seems to be the case in other domains of psycholinguistics such as speech segmentation (Cutler, Mehler, Norris, & Segui, 1986), where it has been shown that speakers of different languages

rely on different information in order to extract words from the speech stream (i.e., English speakers use stress location whereas French speakers use syllabification).

Appendix A
Experimental sentence preambles for Experiment 1.

Single Token
De aanslag op de minister/s
(The assault on the minister/s)
De arts van de zieke/n
(The doctor of the sick person/s)
De baby op de foto/'s
(The baby on the photo/s)
De beker voor de winnaar/s
(The cup for the winner/s)
De boodschap voor de reiziger/s
(The message for the traveller/s)
De diefstal van de diamant/en
(The theft of the diamond/s)
De discussie over de drug/s)
(The discussion about the drug/s)
De eigenaar van de koffer/s
(The owner of the suitcase/s)
De eis van de ontvoerder/s
(The demand of the kidnapper/s)
De klacht van de scholier/en
(The complaint of the student/s)
De monteur van de motorfiets/en
(The mechanic of the motorcycle/s)
De regisseur van de film
(The director of the movie/s)

Multiple Token
De afbeelding op de mok/ken
(The picture on the mug/s)
De bel op de fiets/en
(The bell on the bicycle/s)
De beschrijving in de gids/en
(The description in the guide/s)
De bon in de folder/s
(The coupon in the flyer/s)
De datum op de munt/en
(The date on the coin/s)
De ingang van de flat/s
(The entrance of the apartment/s)
De kraag van de jas/sen
(The collar of the coat/s)
De leuning van de stoel/en
(The back of the chair/s)
De paraaf op de declaratie/s
(The initials (singular) on the declaration/s)
De reclame op de bus/sen
(The advertisement on the bus/ses)
De sleutel van de kast/en
(The key of the cupboard/s)
De stop op de fles/sen
(The stopper on the bottle/s)

Appendix B.
Experimental sentence preambles for Experiment 2.
Single Token
De actie tegen de kerncentrale/s
(The protest against the nuclear plant/s)
De diefstal van de diamant/en
(The theft of the diamond/s)
De discussie over de startbaan
(The discussion about the runway/s)
De doos met de moorkop/pen
(The box with the moorkop/pen [Dutch pastry])
De intocht van de tank/s
(The entry of the tank/s)
De kerk bij de heuvel
(The church near the hill/s)
De kooi met de gorilla
(The cage with the gorilla/s)
De muur met de decoratie/s
(The wall with the decoration/s)
De vaas met de zonnebloem/en
(The vase with sunflower/s)
De weg naar de berg/en
(The road to the mountain/s)

Multiple Token
De afbeelding op de mok/ken
(The picture on the mug/s)
De chip in de computer/s
(The chip in the computer/s)
De handtekening op de cheque/s
(The signature on the cheque/s)
De inscriptie in de ring/en
(The inscription in the ring/s)
De kop op de gulden/s
(The head on the guilder/s)
De magneetstrip op de bankpas/sen
(The magnetic strip on the bankcard/s)

De medaille voor de Vierdaagselopers
(The medal for the Four-day-marches walker/s)
De plaatsnaam op de wegwijzer/s
(The city name on the roadsign/s)
De puzzel in de krant/en
(The puzzle in the newspaper/s)
De reclame op de bus/sen
(The advertisement on the bus/ses)

Appendix C.
Experimental materials (adjective-preamble pairs) for Experiment 3.

Single Token
fatigué, Le lecteur des romans
(tired, The reader of the novels)
mignon, Le cadeau des bébés
(small, The present for the babies)
célèbre Le réalisateur des films
(famous, The director of the movies)
arrivé, Le témoin des avocats
(arrived, The witness of the lawyers)
rouge, Le foulard aux roses
(red, The scarf with the roses)
réussi, Le portrait des lauréates
(good, The picture of the graduates)
long, Le chemin à travers les forêts
(long, The trail across the forests)
incompétent, Le mécanicien des voitures
(incompetent, The mechanic of the cars)
pittoresque, La ville près des collines
(pitoresque, The village near the hills)
généreuse, La marraine des filles
(generous, The God mother of the girls)
lavée, La casserole aux poignées
(washed, The pot with the handles)
chaleureuse, La lettre des tantes
(warm, The letter from the aunt)
triste, La chanson des compositeurs
(sad, The song by the composers)
spacieux, La maison des cousins
(large, The house of the cousins)
panoramique, La route vers les lacs
(scenic, The road to the lakes)
définitive, La réponse des experts
(final, The response by the experts)

Multiple Token
varié, Le menu des restaurants
(varied, The menu of the restaurants)
feutré, Le chapeau des hommes
(lining, The hat of the men)
étranger, Le prénom des enfants
(foreigner, The name of the babies)
spacieux, Le bureau des gérants
(large, The office of the directors)
illisible, Le numéro des plaques
(unreadable, The number on the car-plates)
souriant, L'agent aux intersections
(smiling, The cop at the intersections)
vert, Le vase sur les tables
(green, The vase on the tables)
honnête, Le maire des villes
(honest, The major of the villages)
dorée, L'étiquette des bouteilles
(golden, The label on the bottles)
chère, La radio sur les étagères
(expensive, The radio on the shelves)
effacée, L'étampe sur les enveloppes
(cancelled, The stamp on the envelopes)
brisée, La cloche des écoles
(broken, The bell of the schools)
belle, La reproduction des livres
(beautiful, The copy of the books)
neuf, L'uniforme des soldats
(new, The uniform of the soldiers)
blonde, L'héroïne des films
(blonde, The heroine of the movies)
noire, La tache sur les pantalons
(black, The stain on the pants)

Chapter 5

On the specificity of computational resources: Evidence for a semantico-syntactic resource limitation in agrammatic construction of subject-verb agreement[1]

Abstract

We provide evidence for the hypothesis that the deficit underlying agrammatic processing difficulties can be characterized as a limitation of computational resources, and that these resources are not restricted to syntactic processing only. This hypothesis was tested by eliciting subject-verb agreement errors in a sentence-fragment completion paradigm. Sentence fragments were complex noun phrases, containing a subject (head) noun and a modifying prepositional phrase, containing a 'local' noun. We varied the number of 'tokens' a singular head noun referred to. Therefore, in one condition, grammatical and conceptual number of the head noun mismatched, whereas these numbers were the same in another condition. We observed an effect of this variable (i.e. more errors when conceptual number was plural and grammatical number singular) in normal controls. Broca's aphasics, on the other hand, showed no effect. We argue that these results are incompatible with the notion of a limitation in resources specific for syntactic processing. Instead, we interpret this as the result of a trade-off: Broca's aphasics lack computational resources to take into account both grammatical and conceptual information in morphosyntactic processing. They rather rely on grammatical information only.

Introduction

In the last decade, an increasing number of researchers have proposed that agrammatics' difficulties in the comprehension and production of sentences can be characterized as the result of a limitation in computational resources (e.g. Caplan, Baker, & Dehaut, 1985; Caplan & Hildebrandt, 1988; Carpenter, Miyake, & Just, 1994; Frazier & Friederici, 1991; Hagiwara, 1995; Hartsuiker & Kolk, submitted; Kolk, 1995; Kolk & Van Grunsven, 1985; Linebarger, Schwartz, & Saffran, 1983; Martin & Romani, 1994; Miyaki, Carpenter, & Just, 1994, 1995). However, there is considerable

[1]Hartsuiker, R.J. & Kolk, H.H.J. (submitted). *Brain and Language.* Part of these data were presented earlier as Hartsuiker, R.J. & Kolk, H.H.J. (1995). Modularity results from Resource Limitation: Evidence from agrammatics' sentence production. Paper presented at the RUG-SAN-AVN conference on aphasiology, Groningen.

debate about the specificity of these resources. For instance, Just & Carpenter (1992) presented a theory of a general verbal working memory which is used for different levels of processing within sentence comprehension (however, they do suggest there is a separation between resources applying to production and comprehension). On the other hand, both Caplan and colleagues (Caplan & Waters, 1995; Waters & Caplan, in press) and Martin and colleagues (Martin, 1995; Martin & Romani, 1994; Martin, Shelton, & Yaffee, 1994) conceive resources as specific for each level of processing. For instance, Martin & Romani (1994) report upon one aphasic patient (A.B.) who shows decreased performance with memory load in a sentence anomaly judgment task, but not in grammaticality judgment task, and another aphasic patient (M.W.) who shows the reverse pattern of results.

In the present chapter we will focus on the question of how specific the resource limitation is in sentence production. We test Broca's aphasics with a constrained production task, which requires morphosyntactic processing: Constructing agreement between subject and verb. Getting agreement right is necessary in almost every sentence a speaker produces (in most of the world's languages). It is usually unproblematic, even in patients who produce many paragrammatisms in spontaneous speech (Butterworth, Panzeri, Semenza, & Ferreri, 1990). We present evidence for the claim that Broca's aphasics suffer from an impairment in verbal working memory resources, and that these limited resources are not specific to syntax. In fact, they are involved both in syntactic and semantic processes.

One of the earliest papers in which the notion of a resource limitation was proposed was a study by Linebarger et al. (1983). In this study, four agrammatic patients were required to judge syntactically anomalous sentences. All of these patients showed agrammatic comprehension in picture-pointing tests. Quite surprisingly, these patients were able to correctly judge grammaticality of a wide variety of constructions. This finding clearly disagrees with many theories of agrammatic comprehension which locate the agrammatic deficit in the parsing device itself (Berndt & Caramazza, 1980; Grodzynski, 1986). Linebarger et al. suggested two possible explanations of the discrepancy between grammaticality judgment and understanding. First of all, the deficit could reside in the mapping of syntactic representations on semantic objects such as thematic roles, rather than in parsing. Second, because of a lack of computational resources, there could be a trade-off between syntactic and semantic processing. A task requiring both syntactic and semantic analysis would overload the processing capacity, but a task requiring mainly syntactic analysis or mainly semantic analysis would not. These two hypotheses have received attention in a number of subsequent studies (Kolk & Weijts, 1996; Schwartz, Linebarger, Saffran, & Pate, 1987). Schwartz et al. rejected the trade-off hypothesis because they failed to find an effect of syntactic complexity ('padding' sentences) in a semantic anomaly judgment task. However, in line with the

mapping hypothesis, they did obtain effects of argument movement. They reasoned that argument movement leads to a more difficult mapping, and that if agrammatic comprehenders have problems in mapping syntactic structure to semantic roles, sentences with argument movement should indeed be more difficult. Recently, Kolk & Weijts (1996) presented evidence for the opposite view, namely that the trade-off hypothesis is in fact more plausible than the mapping hypothesis. They argued that Saffran et al.'s complexity manipulation (conjoining sentences) was insufficient. They replicated Saffran's experiment, but added a new condition: Center-embedded sentences. In the latter condition, they did obtain complexity effects, as predicted by the trade-off hypothesis. Furthermore, Kolk & Weijts proposed that the trade-off hypothesis may even be a better alternative than the mapping hypothesis, since the mapping hypothesis makes no predictions concerning phrase-structure complexity, whereas the trade-off hypothesis predicts effects of phrase-structure complexity as well as effects of movement. Indeed, a computational model of parsing, based on Just & Carpenter's (1992) theory of sentence comprehension, successfully simulates effects of phrase-structure complexity as well as effects of movement (Haarmann, Just, & Carpenter (in press).

Because the trade-off hypothesis thus seems a reasonable alternative to the mapping hypothesis as an account of agrammatic comprehension, we consider it an important question whether evidence for a similar kind of trade-off can be obtained in agrammatic sentence production. In order to test the trade-off hypothesis in production, we need to show that there are situations in which normal speakers simultaneously apply information from different components. Therefore, in the remainder of this section, we will first discuss some examples of production tasks in which speakers rely on syntactic as well as semantic information. Then we discuss an example from sentence comprehension in which a trade-off between syntactic and semantic processing occurs when resources can be assumed to be scarce. Finally, we will present our specific hypothesis and show how we tested it.

The first example of usage of multiple information components deals with computation of the correct form of a reflexive pronoun. Bock and colleagues (Bock, 1995; Bock, Eberhard, & Cutting, 1992) reported evidence for semantic control of constructing agreement between reflexive pronouns or the pronouns in tag questions with their antecedents in production. In their experiment, subjects had to repeat sentence fragments and complete them using reflexive pronouns or tag questions. Sentence fragments consisted of a complex Noun Phrase (NP) and a main verb not marked for number (1a-b). The critical manipulation was the conceptual number of the head noun. Sometimes the head noun was collective, i.e. conceptually plural (1a). Sometimes it was conceptually singular (1b). The dependent variable was the proportion of pronoun agreement errors. The results were clear-cut: Following a conceptually plural head

noun, participants were more likely to make errors in tag questions and reflexive pronouns, both within and across clauses.

(1a) The gang with the dangerous rivals armed...
(1b) The gangster with the dangerous rivals armed...

These results support the notion that the process of constructing pronoun agreement accesses the discourse model. However, it can not be the case that this process is entirely driven by semantics. Consider the following examples, taken from Pollard & Sag (1994).

(2a) The faculty is voting itself a raise
(2b) The faculty are voting themselves a raise
(2c) *The faculty are voting itself a raise
(2d) *The faculty is voting themselves a raise

In British English, a collective noun such as 'faculty' allows either a singular verb (2a) or a plural verb (2b). This does not mean that the number of the subject NP is unspecified, because once the speaker has dedicated himself to singularity or plurality, the inflection of the pronoun has to agree with that of the verb, hence the ungrammaticality of (2c-d). A purely semantic theory of pronoun agreement can not explain this pattern of results. (e.g. if one has a collective notion of 'the faculty voting', but a non-collective notion of 'the faculty receiving a raise', (2c) should be acceptable). Hence, we conclude that construction of pronoun agreement relies upon both semantic and syntactic information.

It is important to note here that agrammatic understanding of sentences with reflexive pronouns and tag questions has received scrutiny in Linebarger et al.'s (1983) study. The agrammatics, while generally being quite capable of performing grammaticality judgments, performed significantly worse on sentences containing tag questions and reflexive pronouns. According to Linebarger et al., this pattern of data can be expected if the trade-off hypothesis is the correct one. Problems with reflexives and tag question follow from the assumption that (lexical) semantic encoding is shallow in a task requiring syntactic analysis. The agrammatic participant lacks computational resources for both parsing the sentence and incorporating information on number and gender in a semantic representation. Therefore, information necessary to evaluate the acceptability of the tag question or reflexive pronoun is missing when such an element is subsequently encountered[2].

[2]Notice, however, that Schwartz et al. (1987) provided a different account of the deviating results with coindexed elements, in terms of a (revised) mapping hypothesis.

Additional evidence for a process that requires the speaker to access information at semantic as well as at syntactic levels of processing has been obtained with a slightly different task. Analogous to the subject-pronoun agreement experiments described above, semantic influences on the production of subject-verb agreement have been studied. Bock & Miller (1991) presented participants with sentence fragments, which had to be repeated and completed. Sentence fragments consisted of complex noun phrases (NP's) which contained a head (subject) noun, and a 'local noun', embedded within a modifier. For instance, a sentence fragment could be (3).

(3) The king of the colonies

The dependent variable was the proportion of subject-verb agreement errors in the various conditions of these experiments. One manipulation concerned the conceptual number of the head noun. This could be singular, as is its grammatical number, but it could also be plural, in items with a distributed, or 'Multiple token' reading. For instance, consider (4).

(4) The label on the bottles

In (4), the head noun 'label' has to refer to a multitude of labels (one on each bottle) in order to be in line with our knowledge of the world. If, during the process of subject-verb agreement construction, the speaker takes semantic factors such as the conceptual number of a head noun into account, more errors should be observed following a head noun with a distributed reading than following a conceptually singular head noun. Although such an effect was absent in Bock & Miller's (1991) study with English speaking subjects, Vigliocco and colleagues (Vigliocco, Butterworth, & Semenza, 1995; Vigliocco, Butterworth, & Garrett, in press; Vigliocco, Hartsuiker, Jarema, & Kolk, 1996) have consistently found conceptual effects in Italian, Spanish, Dutch, and French. Although it is at present unclear why effects for English with subject-verb agreement have not been firmly established, the evidence points, in any case, to a picture of the speaker taking both information from the discourse model, and grammatical information (number) into account when performing a morphosyntactic process such as construction of subject-verb agreement.

There are also examples from parsing, showing that the process of constituent structure generation takes into account syntactic as well as semantic information (Trueswell, Tanenhaus, & Garnsey, 1994). In these experiments, sentences that were locally ambiguous with respect to a main clause or reduced relative clause reading were presented in an eye-tracking paradigm. For instance, (5a-b) are locally ambiguous upon encountering the verb 'examined'.

(5a) The evidence examined by the lawyer...
(5b) The defendant examined by the lawyer...

These sentence fragments differ in an important aspect. The subject noun in (5a), 'evidence', is not a good agent of the verb 'to examine', because it is inanimate. On the other hand, the subject noun of (5b) can be the agent of 'to examine', for instance in (6).

(6) The defendant examined the courtroom.

Do comprehenders take this semantic information into account? If they do, fixation times on the part of the sentence in which the ambiguity is resolved (the by-phrase) should be shorter in those sentences in which semantic information constrains interpretation. Ferreira & Clifton (1986), who were the first to address this question, found no such effect: Fixation times on the by-phrases were equally long. However, this may have been due to a too-weak manipulation of the conceptual variable. Some verbs, similar to 'examine' may take an inanimate entity as an instrument, as in 'the car towed...', or may have an ergative reading, as in 'the thrash smelled...', (examples taken from Trueswell et al, p. 289). Indeed, Trueswell et al. did obtain longer reading times for the 'defendant'-sentences with different materials.

Just & Carpenter (1992) also found effects in this task. They too eliminated from the materials sentences such as 'the car towed...'. Moreover, they showed that the occurrence of an effect depended on the verbal working memory capacity of their subjects. They divided their subjects into group with low and high spans of verbal working memory, as determined with the reading span task (Daneman & Carpenter, 1980). The reading span task measures recall of sentence-final words in a paradigm that taxes both hypothesized components of verbal working memory: Storage and processing. It turned out that participants with high reading span scores would take into account semantic and syntactic information, but that participants with low spans do not[3]. Just & Carpenter concluded that verbal working memory can be conceived as a general pool of resources, used for syntactic as well as semantic processing. When there is enough capacity, one can use both types of information simultaneously. However,

[3]Notice that Waters & Caplan (in press) pointed out that when one compares the reduced relative clauses with the control condition, unreduced relative clauses, one can still maintain that both groups of participants were garden-pathed in both types of sentence Although this is certainly true, it is still the case that the two groups make differential use of the animacy cue high-span speakers use the animacy cue, but it is insufficient to completely avoid the garden path. Low-span speakers, on the other hand, do not use the animacy cue Such a notion of an animacy cue as a 'gentle force', influencing, but not fully determining, garden-pathing, seems compatible with modern constraint-satisfaction approaches (e g Trueswell, Tanenhaus, & Garnsey, 1994).

when there is not enough capacity, one will rely on only one source of information, the source of information most critical for the task at hand.

Given the assumptions that in principle speakers and comprehenders can take both syntactic and semantic information into account, that the degree to which they are able to do that depends on computational resources, and that Broca's aphasics have a severe limitation in the resources necessary to draw upon different information components, we predict that Broca's aphasics, as opposed to normals, should be unable to apply both semantic and syntactic cues in morphosyntactic processes of sentence production. In order to test this hypothesis, we presented a group of agrammatic speakers and a control group of healthy adults with sentence fragments similar to the ones used by Vigliocco, Hartsuiker, Jarema, & Kolk (1996)[4], that is complex NP's with either a distributed (multiple token) or a non-distributed (single token) reading. Experimental sentence fragments all had grammatically singular head nouns and grammatically plural local nouns. Note that the local noun needs to be plural in order to obtain a distributed reading. In addition, for each item there was a control sentence fragment which had a singular local noun.

From the hypothesis of an a-specific, semantico-syntactic resource limitation in Broca's aphasia, it follows that agrammatics are unable to rely on both cues. Instead, when constructing subject-verb agreement they will use the cue most relevant for the task at hand: The grammatical number of the subject. We therefore predict that Broca's aphasics, as opposed to normal controls, are not sensitive to a mismatching conceptual number. In other words, there should not be an increased number of errors in the one condition with a distributed reading, the multiple token condition. What would follow from an alternative hypothesis, the hypothesis that there is a limitation in resources specific for syntactic processing (cf. Caplan & Waters, 1995; Martin, 1995; Waters & Caplan, in press)? On the basis of such an hypothesis, two predictions can be made. One possibility is that the participant is unable to maintain the number of the subject noun long enough, and would only use the information that is available to him, the number of the local noun. That would result in an exaggerated 'attraction' effect, but no errors in the control conditions. Another possibility would be that the patient is unable to do the required syntactic processing and relies on semantic information only. That would result in an exaggerated distributivity effect.

A similar experiment with a single agrammatic patient and a conduction aphasic was reported in Vigliocco, Butterworth, Semenza, & Fossella (1994). For the agrammatic patient, they obtained an effect of distributivity: There were more errors in the multiple token condition than in the single token condition. Interestingly, the conduction aphasic showed no effect of distributivity. However, one can raise two

[4]In fact, with one exception, these were the same items used in their Experiment 1 on Dutch.

objections to this study. First, the result is limited to a single agrammatic patient, and according to the test results mentioned by the authors, a patient with a relatively mild impairment. It seems desirable to test a group of patients in order to examine whether any distributivity effect occurs consistently across individuals. Second, Vigliocco et al. did not include the control condition with singular local nouns. Inherently in these kinds of experiment, manipulation of conceptual number can not be done within-items. Therefore, single and multiple tokens items are bound to differ with respect to lexical content, and perhaps with respect to an abundance of other variables. Such idiosyncratic factors may be responsible for differential rates of randomly occurring errors (see Bock, 1995). In order to control for idiosyncratic factors of the different items, one needs to evaluate any differences between the multiple and single token items with respect to control items that have grammatically singular local nouns. Only if there remains a distributivity effect, when the error proportion in the control conditions is compared with the error proportion in the experimental conditions, one can safely conclude that conceptual number exerts an influence.

Method

Participants

Participants were eight aphasic patients, six males and two females, diagnosed as Broca's Aphasic on the Dutch version of the Aachener Aphasie Test (AAT) and 12 healthy control subjects, eight males and four females, matched in age and educational level to the group of Broca's aphasics. Mean age was 52, both for Broca's aphasics and for normal control subjects. Demographic information on the group of Broca's aphasics is supplied in Table 1. Furthermore, Table 2 lists some relevant AAT-scores. Table 2 shows that the group of Broca's aphasics had relatively spared comprehension and repetition skills. This is important, as the present task required them to (i) comprehend a complex NP (ii) repeat and complete the NP.

TABLE 1

Demographic information on the group of Broca's aphasics

Subject	*Age*	*Sex*	*Onset*[a]	*(former) profession*	*Etiology*
NU	65	m	12	Municipal Worker	CVA
FR	28	m	5	Truck Driver	CVA
HA	47	m	7	Bricklayer	TRAUMA
KL	64	f	>3	Hairdresser	CVA
LO	44	m	7	Accountant	CVA
TH	36	m	3	Mover	Meningitis
BE	70	f	0;10	Cashier	CVA
HO	61	m	1	Planner	CVA

a. Years since onset.

Table 2
Scores on subset of AAT scales

Subject	*Spont. Speech*[a] *(0-5)*	*Token Test (50-0)*	*Repetition (0-150)*	*Repetition sentences (0-30)*	*Auditory Comprehension (0-60)*
NU	1	5	?	?	48
FR	2	13	122	24	46
HA	2	24	115	21	40
KL	2	11	120	24	53
LO	2	33	112	17	50
TH	3	10	129	19	55
BE	2	14	138	23	49
HO	2	32	118	23	51

a. The score on Spontaneous (Spont.) Speech indicates, on a scale from 0 (very severe disturbance) to 5 (no or minimal disturbance) the syntactic structure of utterances. Scores of 1 and 2 indicate that no complex sentence structures were observed and that function words and inflections were missing.

Materials

Experimental materials were sentential fragments consisting of subject Noun Phrases (NP's) followed by Prepositional Phrases (PP's). All experimental preambles had a singular head noun. The preferred semantic reading of the preambles (i.e. single or multiple token) was evaluated by 10 independent judges, all native speakers of Dutch. Only those items classified as single or multiple token by at least seven judges were included in the experiment. There were 24 experimental items: 12 were judged as single token, and 12 were judged as multiple token.

The number of the local noun was manipulated within items. Notice that distributivity applied only to singular head noun and plural local noun sentential preambles where it is possible to contrast a singular to a plural reading of the sentential subject (e.g. one single road to several islands, or a label for each of several bottles); for items with a singular head noun followed by a singular local noun the preferred reading is congruent with the syntactic characteristics of the subject (e.g. 'one road to the island' or 'one label on the bottle'). Examples of items in the different experimental conditions are reported in Table 3. A complete listing of materials is provided in the Appendix.

Each preamble consisted of the same number of words (five). The number of syllables was on average higher in the single-token set than in the multiple-token set (7.6 vs. 7.0). This difference was not significant ($t(22)=1.47$; $p=.157$). Experimental items all contained head nouns and local nouns of the non-neuter gender (i.e., they all started with the same definite determiner: 'De') which is unmarked for number, and therefore can be considered as parallel to the English 'the'.

Table 3
Examples of experimental sentence preambles

Experimental Condition	*Examples*
Single Token, number match (ST, control)	De eigenaar van de koffer (The owner of the suitcase)
	De discussie over de wet (The discussion about the law)
Single Token, number mismatch (ST)	De eigenaar van de koffers (The owner of the suitcases)
	De discussie over de wetten (The discussion about the laws)
Multiple Token, number match (MT, control)	De reclame op de bus (The advertisement on the bus)
	De bon in de folder (The coupon in the flyer)
Multiple token, number mismatch (MT)	De reclame op de bussen (The advertisement on the busses)
	De bon in de folders (The coupon in the flyers)

There were 36 filler items: 24 had the same syntactic structure as the experimental items, but had a plural head noun. Half of these had a singular local noun, the other half with a plural local noun. The remaining 12 fillers were simple NPs, consisting of a determiner, one or more adjectives, and a noun. Simple NP-fillers were singular in six cases, and plural in the remaining six cases. In this way, the set of items a participant received (experimental items and filler items) was completely balanced for number of head noun and local noun. Filler items all had head nouns of the non-neuter gender.

Furthermore, we coupled an adjective to each experimental and filler item. In the sentence types presented here, Dutch adjectives are not marked for number. Adjectives were selected by presenting preambles to eight normal subjects (mainly graduate students from Nijmegen University) and requiring them to complete them with an adjective. The most frequently supplied adjective was selected. If there were any ties, we choose the adjective we preferred. Adjectives in the multiple and single token conditions did not differ with respect to number of syllables, number of characters, imagebility, frequency, and age of acquisition (norms for the latter three variables were taken from Van Loon-Vervoorn, 1985).

Four 60-item lists were created. Each list consisted of 24 experimental items (six single token items, six single token control items, six multiple token items, and six multiple token control items) and 36 fillers. In each list the experimental and filler items were organized in a pseudo-random order, with the constraint that the list started with four fillers, and that no more than two experimental items followed each other. Across the four lists, each item occurred twice in the match condition and twice in the mismatch condition.

Procedure

The experimenter read each item aloud. First, he read the adjective and then he read the sentence fragment. The subject was required to repeat the sentence fragment and complete it to a full sentence using a form of 'to be' and the adjective. The main reason for presenting adjectives was to facilitate ease of sentence completion.[5] In those cases where the subject failed to repeat the sentence fragment correctly or when the subject explicitly asked for a repetition, the experimenter read the item again (including the adjective). A second repetition was only supplied on specific request of the participant. If the participant repeated the preamble correctly, supplied a verb, but had difficulties in recalling the adjective, the experimenter sometimes supplied the adjective.

Before the experiment started, at least three example items were presented. If the participant did not understand the task, more examples were provided until he did. If the participant was unable to repeat and complete five example items or more, the experiment was terminated.[6]

[5] In the first patient tested, NU, no adjectives were presented. Because he showed considerable difficulty in rapidly coming up with a plausible continuation of the sentence fragments, we decided to present adjectives to the remaining participants

[6] This happened with four patients which were therefore excluded from further participation.

Scoring

The tape-recorded sessions were first transcribed and responses were assigned to one of the following scoring categories. Correct responses were scored when the participant said the preamble correctly and produced a correctly inflected verb form in the completion. We allowed for correct sentence completions containing a different adjective, or a correct sentence completion with a verb other than 'be'. We also allowed for repetitions of part of the preamble. Agreement errors were scored when the utterance adhered to all criteria for a correct response, with one exception: The verb form was wrongly inflected for number. Number repetition errors were scored when the participant incorrectly reported the number of the sentential subject, then producing a verb form inflected correctly with the produced number of the subject. Repetition plus agreement errors were scored when the participant changed the number of the head noun but then the verb form mismatched in number with the produced subject. Finally, utterances were scored as miscellaneous responses when even after two or more presentations of the preamble the participant failed to report the preamble, omitted the subject noun or local noun, changed the preposition, changed the number of the local noun, produced a sentence with a post-verbal subject, or produced an incomplete sentence. If two different utterances were produced in succession, only the first was scored, including those cases in which an agreement error was produced and immediately corrected.

Design

For each group (Broca's aphasics and Controls), separate analyses were carried out. The number of agreement errors and the number of miscellaneous responses constituted the dependent variables for the statistical tests. Two analyses of variance, one with subjects (F1) and the other with items (F2) as the random factor were carried out for each dependent measure. The experimental factors orthogonally combined were (1) Sentence type (single token vs. multiple token) and (2) Number of local noun (singular vs. plural). The combination of these two factors yielded four conditions. Every participant received six items in each condition.

Results

For the group of normal controls (N=12), application of our scoring criteria yielded 230 (79.9%) correct responses, 50 agreement errors (17.4%), seven miscellaneous responses[7] (2.4%), and one number repetition error (0.3%).

[7]Notice that there are far less miscellaneous responses and repetition errors here than in Vigliocco, Hartsuiker, Jarema, & Kolk (in press), where the same materials were presented to college students.

For the group of Broca's aphasics (N=8), there were 83 correct responses (43.2%), 57 agreement errors (29.7%), 49 miscellaneous responses (25.5%), two number repetition errors (1.0%), and 1 (0.5%) repetition/agreement error.

Consider first the pattern of results found with normal controls. The distribution of responses in the different scoring categories for the experimental conditions is listed in Table 4. In addition, the proportion of agreement errors, with the control conditions subtracted from the experimental conditions, is listed in Figure 1.

Table 4

Distribution of the responses by scoring category: Normal Controls

Experimental condition[a]	*Correct (n)*	*Agreement Errors (n)*	*Repetition Errors (n)*	*Agreement/ Repetition Errors (n)*	*Miscellaneous Responses (n)*
ST, control	71	0	0	0	1
ST	51	16	1	0	4
MT, control	70	1	0	0	1
MT	38	33	0	0	1

a. ST, control (Single Token, number match); ST (Single Token, number mismatch); MT, control (Multiple Token, number match); MT (Multiple Token, number mismatch). Total number is 72 for each condition.

As is clear from the table, agreement errors were most common (33) for multiple token preambles, while we found only 16 errors in the single token condition, and respectively one error and no error at all in the control conditions. This pattern of results is similar to the data Vigliocco, Hartsuiker, Jarema, & Kolk (1996) obtained with the same items, when testing student subjects (multiple token 52, single token 6, both control conditions 0). Because there were no observations in the single token control condition and only one observation in the multiple token control condition, the analysis of variance on the number of errors simply contrasted single vs. multiple token conditions. This difference was significant ($F1(1,11)=2.67$, $MSe=12.04$, $p<.01$; $F2(1,22)= 6.17$, $MSe=12.04$, $p=.021$).

Now consider the distribution of responses in the different experimental condition for Broca's aphasics, listed in Table 5.

There are two reasons for this difference: first, in order to elicit more errors, they presented their subjects with a deadline. Many of their miscellaneous responses were cases in which the speaker failed to produce a verb before the deadline. Second, in the current experiment a wrongly repeated preamble was presented another time by the experimenter.

Table 5

Distribution of the responses in the scoring categories: Broca's Aphasics

Experimental condition[a]	*Correct (n)*	*Agreement Errors (n)*	*Repetition Errors (n)*	*Agreement/ Repetition Errors (n)*	*Miscellaneous Responses (n)*
ST, control	27	3	0	0	18
ST	18	17	1	1	11
MT, control	26	13	0	0	9
MT	12	24	1	0	11

a. ST, control (Single Token, number match); ST (Single Token, number mismatch); MT, control (Multiple Token, number match); MT (Multiple Token, number mismatch). Total number is 48 for each condition.

The table shows that for Broca's aphasics too, errors were more frequent in the multiple token condition (24) than in the single token condition (17). However, a difference of similar magnitude exists between the two control conditions: Errors were more frequent in the multiple token control condition (13) than in the single token control condition (3).

The analysis of variance conducted on the number of errors showed a significant effect of sentence type ($F1(1,7)=14.99$, $MSe=9.03$, $p<.01$; $F2(1,44)=6.609$, $MSe=6.02$, $p=014$): The multiple token and its control condition elicited more errors than the single token and single token control conditions. The effect of local noun number was also significant ($F1(1,7)=14.07$, $MSe=19.53$, $p<.01$; $F2(1,44)=14.293$, $MSe=13.021$, $p<.001$): There were fewer errors in the control conditions than in the experimental conditions. The interaction, however, was far from significant ($F1<1$; $p=.584$; $F2<1$; $p=.652$).

In addition, we conducted separate analyses comparing the number of errors for multiple token and single token items in each number match condition. In the condition with plural local nouns, there was no effect of item type ($F1(1,7)=3.33$; $MSe=3.06$; $p=.111$; $F2(1,22)=1.52$, $MSe=2.042$, $p=.226$). In the condition with singular local nouns however, the effect was highly significant ($F1(1,7)=11.67$; $MSe=6.25$, $p=.011$; $F2(1,22)=8.209$, $MSe=4.17$, $p<.01$).

The analysis of variance conducted on miscellaneous responses revealed a marginally significant effect of Sentence type but only in the test by subjects ($F1(1,7)= 5.50$, $MSe=2.53$, $p=.051$; $F2(1,44)=2.116$, $MSe=1.688$, $p=.153$). There was no effect of local noun number nor was the interaction between these variables significant.

In sum, normal controls show an effect of distributivity, but Broca's aphasics do not. To further illustrate this point, we show error rate (the number of errors, as a percentage of total number of correct and agreement error responses) in Figure 1.

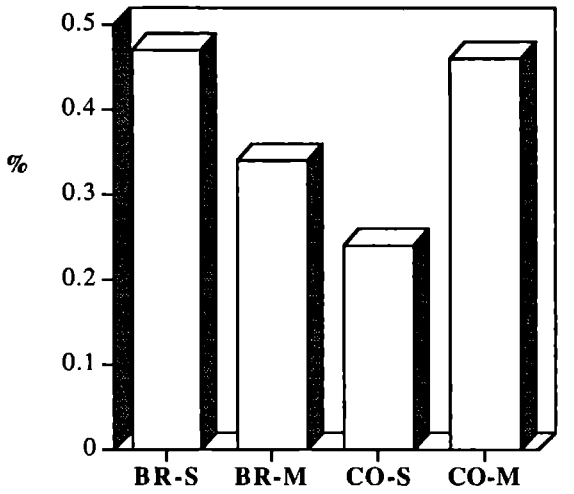


FIGURE 1. Difference scores in error percentages (experimental condition minus control condition). Bar labels are: BR-S (Broca's aphasics, single token), BR-M (Broca's aphasics, multiple token), CO-S (Controls, single token), and CO-M (Controls, multiple token). Error percentage is defined as number of agreement errors, divided by the sum of correct responses and agreement errors.

On the vertical axis of Figure 1 difference scores are plotted: The error rate in each experimental condition minus the error rate in the corresponding control condition. As is clear from the figure, we observe no effect of distributivity at all in Broca's aphasics: The difference error rate in the single token condition is even higher than in the multiple token condition. There is, however, a clear effect for normal controls.

In Figure 2, we plot the effect of distributivity per individual. 'Effect' refers here to the difference in error frequency between the multiple and single token conditions, with errors frequencies in the relevant control condition subtracted from each experimental condition. A positive effect thus indicates that items with a distributed reading elicited more errors than non-distributed items, when idiosyncratic effects of item type are controlled for. As is clear from the figure, nine out of 12 normal controls show a positive effect and three normal controls show an effect of zero. The data are quite different for the Broca's aphasics: Three show a positive effect, three show a

negative effect, and two show no effect at all. In other words, there is a consistent positive effect with normal controls, but the effect for Broca's aphasics varies around zero.

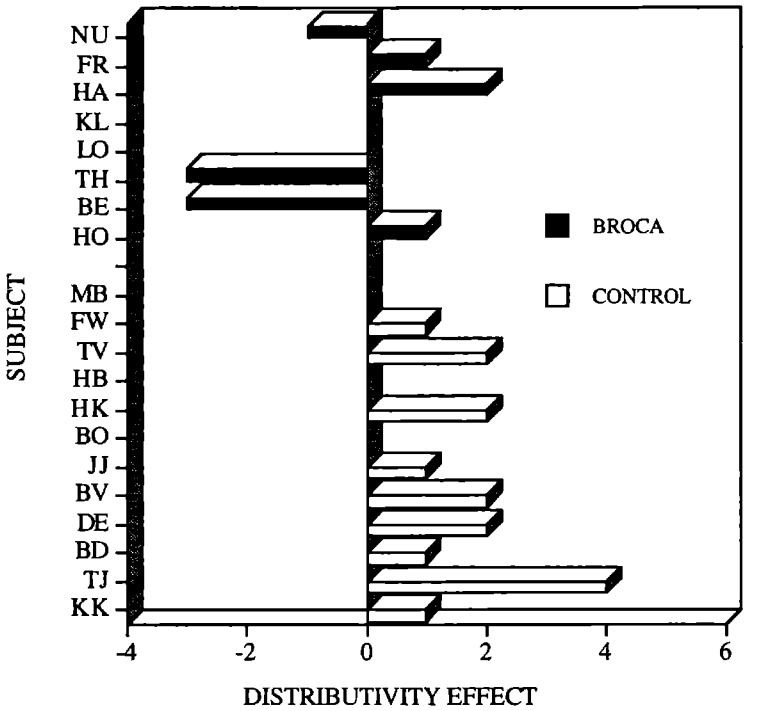


FIGURE 2. Individual scores of distributivity effect, in absolute numbers of errors: Multiple token effect (multiple token condition minus multiple token control condition) minus Single token effect (single token condition minus single token control condition). Effect is zero where no bar is plotted.

Furthermore, in Figure 3 we plot the effect of number mismatch (the 'attraction effect') for each individual. Effect refers here to the total number of errors in the number mismatch conditions (single token and multiple token conditions) minus the total number of errors in the number match conditions (the control conditions). As is clear from the figure, Broca's aphasics and normals have very similar number attraction effects. For all subjects, there were more errors in the number mismatch conditions, except for one Broca's aphasic and two normals which had effects of zero. Furthermore, the size of the effect for Broca's aphasics lies completely in the range of the normals. It is certainly not the case that Broca's aphasics have an exaggerated attraction effect.

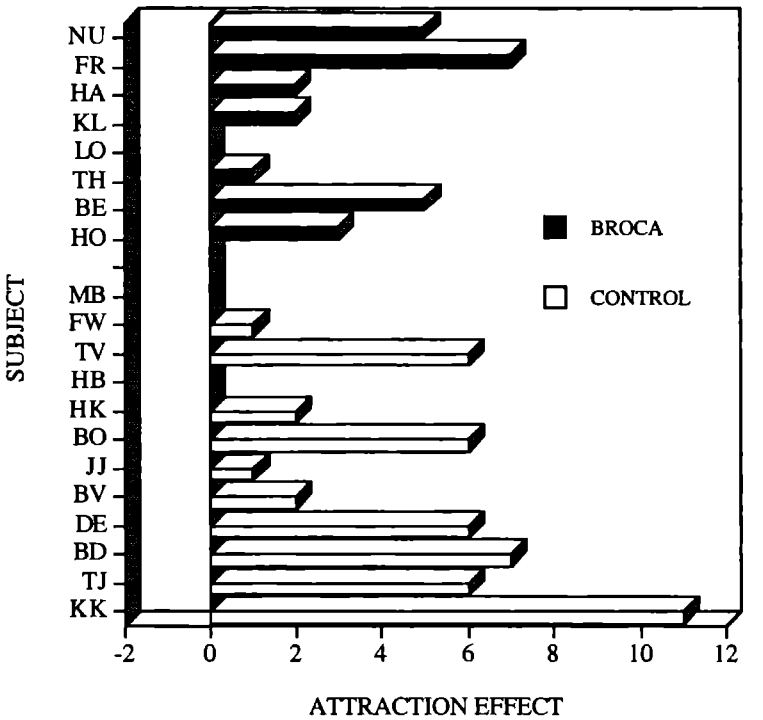


FIGURE 3. Individual scores of attraction effect, in absolute numbers of errors: Number mismatch conditions (multiple token condition plus single token condition) minus number match condition (multiple token control condition plus single token control condition). Effect is zero where no bar is plotted.

For completeness' sake, we also report individual error scores and total numbers of analyzable responses (errors and corrects) in Table 6. As is clear from the table, there is quite a lot of variation in the number of errors per individual, especially in the number mismatch conditions. In addition, for Broca's aphasics there is some variation in the total number of analyzable responses (errors plus corrects). However, the general pattern of findings occurs quite consistently, as is also clear from Figure 2 and Figure 3: Normals have effects of number match and of distributivity, Broca's aphasics have effects of number match, but not of distributivity.

Table 6

Individual error scores for each condition[a]

(total of error and correct follows slash)

Subject	*ST, control*	*ST*	*MT, control*	*MT*
Broca's aphasics				
NU	0/5	3/6	1/6	3/4
FR	0/5	3/4	1/5	5/6
HA	0/2	0/4	1/4	3/5
KL	2/3	3/5	4/6	5/5
LO	0/6	0/3	0/5	0/4
TH	0/4	2/3	2/4	1/2
BE	1/5	5/5	4/6	5/6
HO	0/0	1/5	0/3	2/4
Controls				
MB	0/6	0/6	0/6	0/6
FW	0/6	0/6	0/6	1/6
TV	0/6	2/6	0/6	4/6
HB	0/6	0/6	0/6	0/6
HK	0/6	0/6	0/6	2/6
BO	0/5	3/6	0/6	3/6
JJ	0/6	0/6	0/6	1/6
BV	0/6	0/6	0/6	2/6
DE	0/6	2/4	0/5	4/5
BD	0/6	3/6	0/6	4/6
TJ	0/6	1/4	1/6	6/6
KK	0/6	5/5	0/6	6/6

a. Experimental conditions are: ST, control (Single Token, number match); ST (Single Token, number mismatch), MT, control (Multiple Token, number match); MT (Multiple Token, number mismatch).

In the experimental conditions, Broca's aphasics made subject-verb agreement errors on about 40% of all trials (ranging from 35% in the single token control condition to 50% in the multiple token condition). Are they simply guessing? For comparison, we list the number of agreement errors made on filler trials in Table 7. The table shows good performance on items with plural head nouns. Interestingly, if this type of item incorporates a singular local noun, no effect of attraction is obtained. This finding, however, stands in good agreement with results obtained inter alia by Bock & Miller (1991) and Bock & Cutting (1992) who found no attraction effect for items with plural head nouns.

Table 7

Numbers of errors made on different types of filler items[a]: Broca's aphasics

Experimental condition[a]	*Correct (n)*	*Agreement Errors (n)*	*Repetition Errors (n)*	*Agreement/ Repetition Errors (n)*	*Miscellaneous Responses (n)*
S	33	6	0	1	8
P	34	3	1	1	9
PS	63	7	2	1	21
PP	64	7	0	5	22

a Filler types are: S (simple NP, singular), P (simple NP, plural), PS (Complex NP, Plural head noun, Singular local noun), PP (Complex NP, Plural head noun, Plural local noun). Due to a mistake, in one list a PP filler was substituted for a PS filler. Total number is 48 for the S and P conditions, 94 for PS, and 98 for PP

Discussion

The present results can be summarized as follows. Both Broca's aphasics and normal controls are sensitive to the number marking of head noun and local noun in complex noun phrases. Both show an attraction effect with singular head nouns, that is, more errors when the local noun is plural, than when it is singular. Both groups also show an effect of preamble type, that is, more errors with multiple token and multiple token control items than with single token and single token control items. However, there is a crucial difference: Normal controls show a strong interaction between the factors, such that most errors occur in the multiple token condition, the only condition in which conceptual number is plural, but grammatical number is singular. They take both syntactic and semantic information into account when constructing subject-verb agreement. Broca's aphasics, on the other hand, have additive effects of both factors and not a trace of an interaction. In other words, Broca's aphasics are not sensitive to a mismatch between conceptual and grammatical number. They do not take semantic information into account when constructing subject-verb agreement. This confirms our prediction derived from the theory that Broca's aphasics suffer from a pathological reduced capacity of resources which are applied both for syntactic and semantic processing.

In the remainder of this section we will deal with alternative interpretations of our findings and argue that the interpretation outlined above should be preferred. Following that, we will discus the implications of our findings for theory of sentence production and of agrammatism. First, our interpretation differs from that of Vigliocco et al. (1994) who reported a distributivity effect for a single agrammatic patient (PF). Are our

findings different from theirs? If we only compare the error proportion in the multiple and single token conditions, results are similar, although the difference was larger in their study (PF made 13 errors in the multiple token condition and three in the single token condition). However, PF was not tested with the control conditions. The present study shows the importance of supplying control conditions: Different error rates between multiple and single token conditions may have been induced by differences between the items that have nothing to do with conceptual number. Until an interaction between sentence type and local noun number has been shown with a group of Italian agrammatics, we maintain that agrammatics are not sensitive to conceptual number.

A possible objection one could raise against the present interpretation is that there is no real effect of conceptual number for normal controls: The results would have to be ascribed to a floor effect. This objection would entail that due to some idiosyncrasies of the items, multiple token and multiple token control items elicit more errors than single token and single token control items. Because normal controls simply make fewer errors and because the control conditions are very easy, there is no difference between the multiple token control condition and the single token control condition for normal controls. Because normal controls do make errors in the conditions with mismatching local nouns, an interaction between number match and item type is obtained. Broca's aphasics, being more error prone than normal controls, make errors in the control conditions as well as in the experimental conditions, thus showing additive effects of number match and item type.

Although this reasoning may seem intuitively plausible, it is hard to reconcile with the data obtained in the present experiment and with existing literature. First it should be noted that normal controls in the present experiment made quite a lot of errors (overall error rate 17.4%, Broca's aphasics 29.7%). Given such a high overall incidence of errors in normal controls, would one not expect at least some errors in the multiple token control condition if the type of item presented there is so error prone? Furthermore, it is worth noting that for Broca's aphasics, there was no significant difference between the multiple token and single token conditions when the local noun was plural (while such a difference did exist in the control conditions). If the pattern of results is to be attributed to a floor effect, one still has to explain why an idiosyncratic variable has a significant impact on the number of errors in the number mismatch condition for normals but not for Broca's aphasics, and a significant impact on the number of errors in the number match condition for Broca's aphasics but not for normal controls.

Furthermore, consider Experiment 1 in Vigliocco, Hartsuiker, Jarema, & Kolk (1996). As mentioned earlier, they found no errors in their control conditions, six errors in the single-token condition, and 52 errors in the multiple-token condition. If this would have to be explained as an artifact of material construction too, one needs to

assume that whatever idiosyncratic variable is responsible for the difference, the single and multiple token sets need to differ enormously on that variable (or that a slight difference in that hypothetical variable should have an enormous effect).This state of affairs seems unlikely, especially because in the present experiment there was no significant effect with Broca's aphasics in the number mismatch condition.

In addition, Vigliocco, Hartsuiker, Jarema, & Kolk (1996) found the same pattern of results with a different set of items (their Experiment 2). It seems very unlikely that this new item set would contain exactly the same idiosyncrasies responsible for the effect in Experiment 1. We therefore reject the floor effect explanation.

However, we still need to explain the fact that the multiple token and multiple token control conditions elicit more errors than the single token condition and its corresponding control condition in Broca's aphasics. What variable could be responsible for this difference? We balanced our items with respect to variables such as length, syntactic structure, and gender of nouns. However, there are two variables on which items in the different conditions may differ: Plausibility and imageability. We will discuss these in turn.

It is conceivable that the items in the multiple token conditions are, on average, more implausible than the items in the other conditions. Vigliocco et al. (1996) have gathered plausibility ratings for all experimental items in their Experiment 1 (the same items are used here). They concluded that indeed, items in the multiple token condition where more implausible than the other items (Multiple token: 2.0, Single token: 1.5 on a scale from 1 to 5). However, this did not apply to items in the control condition (Multiple token 1.3, Single token 1.3). Further, it is important to note here that Vigliocco et al. factored out the effect of plausibility in an Analysis of Covariance, and still obtained a distributivity effect. Plausibility, therefore, does not seem to be the important variable.

Could it be the case that items differed with respect to imageability? In discussing the cross-linguistic difference (no effect of distributivity in English, as opposed to Italian, Spanish, French, and Dutch) Vigliocco et al. mention that there may be differences in on-line interpretation of the items. An important determinant of on-line interpretation may be how well one can imagine the situation the fragment refers to. In order to test this, the items of Experiment 1 (Vigliocco et al.) were subjected to an imagebility rating test. We tested 24 subjects, none of which had participated in any of the Dutch subject-verb agreement experiments. Instructions for the imagebility test were similar to the instructions Van Loon-Vervoorn (1985) used in a study on the imagebility of words. Unfortunately, only data in the conditions with plural local nouns are available. It turned out that multiple token items were on average more imageable than single token items (3.6 vs. 3.0, significant at p=.037, two-tailed). Assuming that imageability of the sentence fragments is highly correlated with word-imageability of

the head nouns and the local nouns, it is conceivable that a similar difference exists between the two control conditions. It may therefore be possible that the effect of item type is related to a difference in imageability. However it is not clear at all in what way imageability could influence error proportion. In sum, although we reject the floor effect explanation, we have to admit that the difference between multiple and single token conditions in Broca's aphasics needs an explanation. At present, the best candidate for such an explanation seems to be related to imageability.

Another objection one could raise is that in the present experiment, Broca's aphasics often did not use number information (grammatical or conceptual) but rather supplied infinitives. Indeed, in Dutch the third person, plural, present tense verb cannot be distinguished from the infinitive. That would explain the low error rate in the filler items with plural head nouns, and the high error rate in most of the experimental conditions. However, it would not explain the low error rate in the single token control condition. In addition, there is another reason that makes this an implausible suggestion: In constructions with the infinitive form, one tends to put the verb clause-finally. Kolk & Heeschen (1992) showed that agrammatics place almost all non-finite verbs clause-finally, and almost no finite verb clause-finally. Therefore, (7) is a plausible agrammatic utterance.

(7) De man boos zijn.
The man angry be.

If Broca's aphasics were really using infinitive forms, they would have tended to reverse the order of adjective and verb. In fact, this never happened.

Could it be that Broca's aphasics do not take into account conceptual number because they have comprehension difficulties? In other words, do they get multiple token interpretations for single token items, or rather single token representations for multiple token items? To our knowledge, agrammatic's comprehension of complex NP's such as used in the present study has never been the topic of systematic investigation. However, Kolk & Friederici (1985) tested comprehension of sentences containing prepositional phrases, such as (8a-b).

(8a) De pop is op het bed
The doll is on the bed

(8b) Op het bed is de pop
On the bed is the doll

Inspection of Kolk & Friederici's data (their Table V, p. 55) reveals that in the conditions with nonreversible sentences such as (8a-b), very few errors were made by Dutch speaking Broca's aphasics, regardless of whether word order was canonical (8a) or not (8b). Because most of our experimental items are similar to the sentences in their nonreversible condition (e.g. the corresponding preamble in our experiment would by (8c)) we expect no comprehension difficulties with these items.

(8c) De pop op het bed
The doll on the bed

However, Kolk & Friederici (1985) only tested sentences with singular subject and prepositional object nouns. Is it the case that Broca's aphasics do not understand the meaning of number inflections? That cannot be so. First of all, Haarmann & Kolk (1994) showed in an on-line word monitoring task, that agrammatics are sensitive to violations of subject-verb agreement. If they encountered a subject-verb agreement violation, and the next word was the target for which they had to monitor, their reaction times were delayed. Second, Nicol, Jakubowicz, & Goldblum (1994) investigated the sensitivity of non-fluent aphasics to number marking in sentence-picture matching, comparing an English-speaking and a francophone group. In the condition most relevant for our present purposes, in which sensitivity to number marking of head nouns was tested, English-speaking aphasics made correct responses on 85% of the trials, and French-speaking aphasics on 95% of the trials.

Furthermore, we submitted one patient, HO, to a noun phrase-picture matching test especially devised to measure sensitivity to grammatical number.[8] In this comprehension test, items had the same syntactic structure as the experimental items in the present experiment. As Table 2 shows, HO is one of the two patients performing worst on the Token test. His score on auditory comprehension ranked about average in the present group of patients. He can therefore be expected to exhibit comprehension difficulties. However, his comprehension of complex noun phrases with mismatching head and local nouns was at ceiling (1/16 errors with PP-modifiers, 0/16 errors with relative clause modifiers).

We conclude that our interpretation of the results is valid: Verb forms supplied were really finite verbs and not infinitives. The pattern of results does not seem to be caused by a floor effect and the difference between the single and multiple token conditions can not be ascribed to comprehension difficulties.

What are the implications of the present findings? To begin with, the findings have implications for theories of sentence production: We presented evidence against a

[8]This test was devised and kindly made available to us by Gabriella Vigliocco.

strictly modular view (e.g. Levelt, 1989).[9] Such a view implies informational encapsulation (Fodor, 1983), that is, the output of one module is the input for the next one, but the internal operation of a given module cannot be influenced by another. In the present study, we show that the mechanism of subject-verb agreement construction, a task of the grammatical encoder, can be influenced by information at the conceptual level. Note that it is unlikely that the referential number of the subject is part of the input representation for the grammatical encoder, as that would result in many plural subject nouns in the multiple token condition in the present experiment. Such number repetition errors were very infrequent.

We further show that not all groups of participants are equally sensitive to conceptual number: In Broca's aphasics, construction of subject-verb agreement was syntactically encapsulated. These results support Just & Carpenter's (1992) claim that syntactic encapsulation is not hard-wired into the processing system but the consequence of a capacity limitation: The more resources one has available, the more likely one is to take into account information from different modules. It deserves mentioning that we do not argue against the distinction between different levels of processing. Our results are entirely consistent with the view that different levels of linguistic information are represented and processed separately. However, we do argue with the view that processing within one level is entirely 'blind' to processing within another level. This point of view is in agreement with models of phonological encoding such as the one advocated by Dell (1986).

Our findings also have repercussions for the debate on the specificity of computational resources. Our data are compatible with the notion of more general verbal working memory resources (cf. Just & Carpenter, 1992; Miyake, Carpenter, & Just, 1994; 1995), used at least for semantic and for syntactic processing. As mentioned before, the theory of a specific impairment of syntactic resources (Caplan & Waters, 1995; Waters & Caplan, in press) would make radically different predictions in the current experiment. A severe shortage of syntactic resources would either lead to forgetting subject noun number and hence an exaggerated attraction effect or an inability to syntactically construct subject-verb agreement and hence an overreliance on semantic information. That would lead to an extremely strong effect of distributivity. Neither of these patterns of results were obtained (see Figures 2 and 3). Instead, as the theory of an impairment in a-specific, semantico-syntactic resources predicted, we found an attraction effect within the normal range, errors in the control conditions, and no distributivity effect for Broca's aphasics, but a clear distributivity effect for normal controls.

[9] Although it can be argued that Levelt's (1989) theory is not strictly modular either, as he has to allow a recurrent connection between the phonological encoding module and the grammatical encoding module (p. 9).

Appendix

(experimental items and , in capitals, adjectives to be used in the completion)

Single Token

BRUTAAL	De aanslag op de minister/s
(BOLD	The assault on the minister/s)
KNAP	De arts van de zieke/n
(CLEVER	The doctor of the sick person/s)
LIEF	De baby op de foto/'s
(CUTE	The baby on the photo/s)
GROOT	De beker voor de winnaar/s
(LARGE	The cup for the winner/s)
KORT	De boodschap voor de reiziger/s
(SHORT	The message for the travelers/s)
SUCCESVOL	De diefstal van de diamant/en
(SUCCESSFUL	The theft of the diamond/s)
SAAI	De discussie over de wet/ten)
(BORING	The discussion about the law/s)
SPOORLOOS	De eigenaar van de koffer/s
(GONE	The owner of the suitcase/s)
ONREDELIJK	De eis van de ontvoerder/s
(UNREASONABLE	The demand of the kidnapper/s)
TERECHT	De klacht van de scholier/en
(VALID	The complaint of the student/s)
HANDIG	De monteur van de motorfiets/en
(HANDY	The mechanic of the motorcycle/s)
BEKEND	De regisseur van de film/s
(WELL-KNOWN	The director of the movie/s)

Multiple Token

MOOI	De afbeelding op de mok/ken
(PRETTY	The picture on the mug/s)
LUID	De bel op de fiets/en
(LOUD	The bell on the bicycle/s)
ONDUIDELIJK	De beschrijving in de gids/en
(UNCLEAR	The description in the guide/s)
ONGELDIG	De bon in de folder/s
(INVALID	The coupon in the flyer/s)
ONLEESBAAR	De datum op de munt/en
(ILLEGIBLE	The date on the coin/s)
SMAL	De ingang van de flat/s
(NARROW	The entrance of the apartment/s)
VUIL	De kraag van de jas/sen
(DIRTY	The collar of the coat/s)
GAMMEL	De leuning van de stoel/en
(UNSOUND	The back of the chair/s)
VALS	De paraaf op de declaratie/s
(FAKED	The initials (*singular*) on the declaration/s)
OPVALLEND	De reclame op de bus/sen
(STRIKING	The advertisement on the bus/ses)
KLEIN	De sleutel van de kast/en
(SMALL	The key of the cupboard/s)
GROEN	De stop op de fles/sen
(GREEN	The stopper on the bottle/s)

General discussion

The results, reported in the various chapters of this dissertation, seem to sketch a consistent picture: we tested the theory that the underlying deficit involved in Broca's aphasia can be characterized as a pathological limitation of computational resources, and that these resources are non-specific, i.e. they are involved in semantic as well as syntactic processing. From that theory we made two predictions. First, it ought to be possible to elicit relatively complex sentence types from Broca's aphasics when the relevant mental representations are 'primed'. Second, on a task where normal speakers show simultaneous use of syntactic and semantic cues, Broca's aphasics should be unable to do so. Necessary corollaries for testing these hypotheses were that (i) it is indeed possible to facilitate the production of syntactic structures by priming (ii) there do indeed exist tasks in sentence production in which normal speakers simultaneously rely on syntactic as well as semantic information. In Chapters 1, 2 and 4 we provided evidence that support these corollaries. In Chapter 3 we provided evidence that supports the first hypothesis, and in Chapter 5 we provided evidence in support of the second hypothesis.

Unfortunately, a number of issues remain unresolved. In this General Discussion I will attempt to address the most important of these issues, often comparing theoretical proposals and empirical facts from different chapters. This section is divided into three parts.

First, I will focus on Part I of the dissertation. I will address the matter of what the results reported in Chapters 2 and 3 implicate for the 'Competition explanation' suggested in Chapter 1. I will argue that modifications to this hypothesis are required in light of the new data. I will then discuss the matter of reduced proportions of target responses in the baseline conditions, and propose an experimental approach for testing the two accounts we proposed for that phenomenon. Finally, I will summarize the stages and processes involved in our sentence production task.

In the second subsection, I will focus on Part II of the dissertation. I will briefly consider some open questions about the process of subject-verb agreement construction. To be more specific, what accounts for the fact that English, as opposed to the four other languages that have been tested by now, fails to show a distributivity effect? In addition I will briefly address the question whether the finding of a distributivity effect can be reconciled with an informationally encapsulated sentence production system. Finally, I will argue that in the presence of a resource limitation, grammatical number of the subject is indeed the sole determinant of the verb inflection.

In the third subsection, the status of the 'resource theory' will be considered. In particular, I will discuss some data that seem to go against the notion of 'mental energy'

playing a role in grammatical encoding. I will suggest that these data do not refute the claims made in this dissertation. Following that, I will explicitly address the question whether the results reported here could be explained by alternative approaches and conclude that they cannot. I will end by making specific predictions about agrammatic *comprehension.*

Syntactic priming and models of grammatical encoding

Let us begin by briefly summarizing the data and accounts offered to explain them: I reported evidence for dative sentences being sensitive to priming in normal speakers of Dutch, even an infrequent variant such as the medial dative. However, in none of four experiments reported in Chapter 1 did I obtain evidence for transitive priming (that is, for actives as well as passives being sensitive to priming). I managed to exclude a number of explanations for this null-effect. Further, I tentatively rejected the explanation that the null-effect comes about because there are pragmatic differences between actives and passives to a stronger extent than between dative alternatives, as pragmatics would probably have limited effects in experiments such as ours. Instead, I speculated that a persistence effect comes about as the result of a competition between alternative structures and that a prerequisite for such a competition is that the alternatives have equivalent baseline frequencies or, put into the activation metaphor, have equivalent resting activation levels. In that case, priming disturbs a delicate balance, leading to one structure getting an advantage over another one. However, in contrast to this hypothesis, I obtained an effect of the medial dative, which has a very low baseline frequency in comparison to the prepositional or double-object dative. I suggested that the Competition Hypothesis could be maintained, if it were to be assumed that two types of priming co-occur: One of them is priming of a sentence frame specified for constituency but not for word order. The medial dative and the prepositional dative would share this frame and this frame would compete with the one of the double-object dative. Furthermore, there would be priming of linearization, and priming that process would not require equivalent baseline activations.

However, it appears as if the competition explanation runs into trouble when we compare the results of Chapter 1 with transitives with the results obtained in Chapter 3. In contrast to the Competition Hypothesis, I observed that normals had equivalent baselines for actives and passives in that experiment, yet showed no priming effect (perhaps even a negative priming effect for actives). To make things worse, Broca's aphasics, having an extreme preference for the active in the baselines, *did* show syntactic priming of passives. It seems that a modification of the original Competition Hypothesis is in order. Below I present such a modification.

When a target picture has to be described, the grammatical encoder has the possibility to encode the message with a variety of grammatical structures. Assume that there is a resting activation level associated with each grammatical structure. As a result of priming, the activation level of one of the structures is increased. Assume further that the different grammatical structures involve in a competition, and that final activation states depend upon the amount of inhibition structures receive from other structures as well as upon their initial activations. It then seems conceivable that in order for a priming effect to occur, the two target structures put to test need to be in a *direct* competition with each other. That entails that both of them must be able to strongly inhibit all alternative structures. If there are many alternative structures and one of the target structures has a relatively low activation level, the advantage given to it by priming will disappear, as a result of combined inhibition from all the alternative structures. Direct competition, and hence priming effects, would occur in these two situations:

(1) If both target structures are equally strong, and much stronger than the alternatives.

(2) If one of the target structures is much weaker, but there are few or no alternatives.

Can this modified version of the Competition Hypothesis account for the results? It appears as if it can. An example of (1) would be the dative variants for normal speakers reported in Chapter 1. Double-object and Prepositional datives had equivalent baseline frequencies and there was no alternative response occurring with similar frequency. An example of (2) would be the transitives with Broca's aphasics reported in Chapter 3. Although it is true that the passive had an extremely low baseline frequency, there may have been fewer competing alternatives, due to the reduced variety of grammatical form. Notice that this was one of the accounts provided in Chapter 3 for the 'hyperpriming' with Broca's aphasics in that study. A further example of (2) would be the word order priming, reported in Chapter 2. Although we localized the priming effect in that experiment at the level of constituent *linearization*, one would still expect priming to come about as a result of competitive dynamics, and hence dependence on resting activation levels. We obtained priming with two alternatives that differed strongly in baseline frequency. However, because there are few word order variants of a given hierarchy of constituents (in fact, only two in our experiment) there were no competing alternatives.

What still needs to be explained is the finding of no transitive priming for normal controls in Chapter 3. Because passives and actives had similar baseline frequencies, the situation ought to be similar to (1), and hence priming should have been obtained.

However, it should be noted that normal controls in Chapter 3 did not show an effect for dative sentences either, in contrast to the robust finding of dative priming in the four experiments reported in Chapter 1. In our discussion in Chapter 3, we suggest 'that it seems plausible that an effect would have been obtained if we had tested a larger group of subjects'. Indeed, the number of observations in each cell were quite low in the Experiment in Chapter 3, certainly compared to the experiments in Chapter 1. Therefore, there remains a possibility that when a larger group of normal controls had been tested, a transitive effect would also have surfaced[1].

Clearly, it is hard to predict beforehand whether the pattern of priming we obtained indeed emerges from the competitive dynamics of an implemented activation model. At first glance, an additional assumption would have to be that response selection takes place before the system has settled in a state of equilibrium, since these models show 'winner-takes-all' behavior, with activation of non-selected nodes decreasing to resting level. Such an assumption can be justified, however, by the temporal constraints under which sentence formulation takes place. Notice that Dell (1986) makes the same assumption and varies the moment of selection in order to simulate effects of speaking rate.

Another issue that deserves attention is the consistent finding of more target utterances in the experimental conditions than in the baseline condition. We offered two explanations for this finding. The first explanation is that 'Long Term Priming' (LTP) leads to a gradual increase of the availability of both target structures during the course of the experiment. As a result, the probability of obtaining one of them increases on a particular trial, even if that picture is preceded by the other one. Baseline trials were always the first trials of the experimental session. Therefore they were not influenced by LTP. An alternative explanation is that structure priming, in addition to facilitating a certain sentence structure, also facilitates a representation the two target alternatives have in common, e.g. a representation of 'transitive verb'. I explicitly referred to Pollard & Sag (1994) for a linguistic description that indeed postulates representations of that kind. If the account of priming a common 'transitive' or 'dative' representation turns out to be correct, the question arises at which level of processing the effect takes place. Notice that in Chapter 2 I postulated that the communality of different syntactic structures describing the same event lies at the conceptual level. On the other hand, Pollard & Sag (1994) describe the active/passive communality in syntactic terms, as a permutation of subcategorization lists.[2] That leaves open three possibilities as to where

[1]Notice that there are three possibilities for the elevated baseline for passives in Experiment 3: these controls subjects were older than the university students, they had lower educations, and the task was slightly different: pictures contained labels. Given Weiner & Labov's (1983) observations that demographic variables had little or no impact on the frequency of passives, we assume that it is the labeling of picture elements that is the explanation.

[2]However, it is unclear whether Pollard & Sag's theory of passivization holds for Dutch, as this language allows intransitive passives (Cornelis, personal communication).

priming a common representation would occur: (1) at the message level (2) at the functional level (3) at both of these levels. Therefore I suggest that further research into this matter should try to disentangle these matters, beginning with the question whether the decreased incidence of target utterances should really be ascribed to 'priming a common representation'. The most straightforward approach would be to have baseline trials at the end of the session (Baseline 2) as well as at the beginning of the session (Baseline 1). If the effect is solely due to LTP, there should be more target structures in Baseline 2 than in Baseline 1.[3] If there is just priming of a common representation, no difference between these two baselines is expected.

We now turn to a question addressed in the introduction of Chapter 2: What is the psychological reality of constituent structure? We argued at length that priming only occurs when a certain representation is the object of 'gentle forces', not when it is predetermined by higher levels of processing. We then observed that the functional level representation is overspecified with respect to constituent structure, whereas the message level representation is underspecified. We concluded that priming effects for transitives and datives should be located during functional level processing, not during constituent assembly.

Does this mean we can do away with constituent structure assembly altogether, and postulate that a functional representation is direct input to linearization? I do not think so. The functional representation may be overspecified with respect to constituent structure, but that does not mean constituent structure is not 'spelled out'. I merely contend that this spelling out is a 'brute force' process, with a fixed outcome, similar in that respect to the spelling out of phonemes from a word form representation.

It is also important to note that I provided evidence for effects of conceptual accessibility: perceptual variables such as L/R location of different elements on the picture, and semantic variables such as animacy determine syntactic structure. The clearest evidence for L/R-effects was reported in Chapter 2, with FL-sentences. These effects, however, are 'gentle forces': they do not completely specify the output, just bias it in one direction or another. Furthermore, effects of this kind are completely in agreement with results from the literature (e.g. Flores d'Arcais, 1975; Harris, 1978; MacDonald, Bock, & Kelly, 1992). I propose that there are two loci for these effects: functional integration and constituent linearization. During functional integration, a highly accessible element may be assigned a prominent syntactic function. During linearization, a highly accessible element may be placed in a position at the beginning of the sentence.

In sum, these considerations lead us to propose the following account of the events in our primed sentence production task. First, a prime sentence is produced,

[3] I thank Casper Westenberg for pointing this out.

which leads to an increased availability of the relevant syntactic representations. The prime sentence's functional level representation, in particular argument structure of verbs and other grammatical categories, and its word order are made more available. Second, a picture is presented. Following visual and conceptual processing, lemma's, appropriately expressing conceptual content, and especially argument structures of lemma's engage in a competition. This process is a complex interaction of gentle forces. First, conceptually more accessible lemma's have a temporal advantage over other lemma's. Second, lemma's with primed argument structures have an activation advantage over other lemma's. Eventual selection of lemma's and assignment of grammatical functions to them comes about through competitive dynamics. An advantage given to a lemma with a low resting activation level can quickly be nullified by mutual inhibition of competing lemma's. Third, eventual function assignment is so overspecified that it predetermines hierarchical relations between constituents. Spell-out of hierarchical constituent structure is a 'brute-force' process: manipulations such as priming do not influence it. Fourth, constituent structure needs to be linearized: this, again, proceeds as the interplay of gentle forces. Constituents with a temporal advantage show a bias to appear at the beginning of the linear sequence. So do constituents with a grammatical function that is high on the hierarchy of such functions. In addition, priming effects bias this process.

With respect to the priming effects in Broca's aphasia, the implication is that agrammatic difficulties in generation of syntax also lie at the level of functional integration: This process, requiring complex competitive dynamics, might well be the most 'resource consuming' process. Interestingly, this conclusion is somewhat analogous to Hagoort's (1990) conclusion with respect to agrammatic understanding. According to him, the process of lexical access (automatic spreading of activation in a lexico-semantic network) is unimpaired. Difficulties arise at the more resource-consuming process of lexical integration (i.e. relating incoming words to previously processed material).

Subject-verb agreement

I now turn to some issues left unaddressed in Part II of this dissertation, in which the process of subject-verb agreement was studied.

One of the issues that awaits further explanation is the lack of a distributivity effect in English. It seems as if the only structural difference left to test is richness of verbal morphology. An alternative explanation may be that the difference results from a difference in *interpretation* of the preambles. As mentioned in Chapter 4, Vigliocco has unpublished data, suggesting that an effect of distributivity indeed occurs in English

when the interpretation of the preambles is more constrained, by adding adjectives to the subject NP. These data suggest that speakers of English often get 'multiple token' interpretations with 'single token' preambles. If that turns out to be true, than the question arises why this difference in interpretation occurs. Further research should address this and related questions.

In any case, the results of the distributivity experiments reported in Chapters 4 and 5 argue against a strictly modular view of producing agreement such as Bock & Miller (1991) proposed. If only number of subject is determined by conceptual information, and if verb inflection results from copying this feature through the syntactic tree, no effects of distributivity should have been found. The finding of such an effect in four languages, Dutch and French (this dissertation, Chapter 4), Italian (Vigliocco et al., 1995), and Spanish (Vigliocco et al., in press) argues against that proposal.

It should be noted that the results cannot be explained by a misselection of grammatical number, because number repetition errors, in which the number of the head noun changes, were very infrequent indeed. How exactly do these conceptual influences come about then? The theory Vigliocco et al. (in press) offer, briefly mentioned in Chapter 4, is that the number feature of the subject and of the verb are retrieved independently from the conceptual representation. Similar to De Smedt (1990), Vigliocco et al. propose that constituent structure results from a process of unification, that is, independent syntactic subtrees are merged into a larger tree, iff the syntactic features associated with the subtrees are mutually compatible (that is, the intersection of both sets of feature values for each feature is not empty). They extend this with the assumption that unification does not necessary fail in case of incompatibilities of the 'number feature', but can lead to one value overriding another one. In that case errors may occur. One argument in favor of this theory is that it seems likely that retrieval of tense, which is marked in the VP but not in other constituents, is indeed independently retrieved from the conceptual representation to determine the inflection of the verb.

However, this account runs into problems if we consider examples like (3).

(3) *The faculty are voting itself a raise

This example shows that once a commitment to number of the verb has been made, number of a pronoun is fixed. That 'horizontal constraint' is problematic for the notion that number of subject, of verb and of pronouns is retrieved independently. Why would these different retrieval processes not come up with different numbers?

I will now outline an alternative proposal, that can account for horizontal constraints as well as for effects of conceptual number. The reasoning, in brief, proceeds as follows. First of all it should be assumed that the conceptual representation

for multiple token items contains a plural specification of number. A further assumption is that the head noun lemma contains two features: one determining the noun inflection, and one determining agreement. Finally, the conceptual information that there are many tokens may sometimes override the agreement feature.

To begin with, it seems likely that number for a multiple token item is specified plural. Let us consider the way the message representation might look like:

(4)	[label	Known(Label)	Cardinality(Label)=many
	bottle	Known(Bottle)	Cardinality(Bottle)=many
	For each $Bottle_i$:	$ON[Label_i, Bottle_i]$	

If the cardinality of label were singular, and not plural such as in (4), the absurd interpretation depicted in Figure 1b in Chapter 4 would result. The message representation is input to the level of functional integration and the assumption is that this process 'knows' that a representation like this can be encoded as a singular subject noun phrase with a plural PP modifying the subject.

How would functional integration 'know' how to encode a message such as (4)? It seems likely that this kind of information is contained in the relevant lemma's. Let us consider an easier case, the lemma for a collective noun such as 'faculty'. The syntactic information incorporated in the lemma may look like (5).

(5) [Faculty-lemma

Syntactic Category:	Noun
Gender	
....	
If (cardinality=one)	Ninfl=singular, Agreement=singular
If (cardinality=many)	Ninfl=plural, Agreement=plural
If (members=many)	Ninfl=singular, Agreement=plural]

This representation contains *two* number features: Ninfl (noun inflection) and Agreement. This distinction allows for the use of 'faculty' as a collective noun. If a statement is made about one faculty, as a whole, the noun is inflected singularly (faculty) and verbs and pronouns agree with the singular feature. If a statement is made about many faculties, the noun will be plural and any dependent elements will be also inflected for plurality. However, when 'faculty'refers to its many individual members, the noun inflection will still be singular, but the agreement feature is plural. Thus, dependent verbs and pronouns will all be inflected for plurality. The assumption of a separate agreement feature accounts for the horizontal constraint. In addition, from this

assumption it follows that construction of agreement is inherently a grammatical process: it is under the control of a feature specified in the subject noun lemma.

A similar situation could apply to the construction of subject-verb agreement with multiple token items. That situation is slightly more complicated, because the 'distributed' interpretation follows from the plural modifying PP, that is, from the interaction of several lemma's. However, assume that a message such as (4) is encoded with a subject NP such as 'the label on the bottles' and with a singular agreement feature. Where do errors come from then? The answer must be from the message: because that message also specifies that there are many tokens of 'label', the agreement feature may be accidentally set to plural, instead of singular.

At this point, an important issue needs to addressed: In Chapter 5, as mentioned in the previous paragraph, I predicted that in the face of a resource limitation, grammatical rather than conceptual number would determine the verb inflection. But why? Could it not be the case that conceptual number would be the determinant? Or that representations for conceptual and for grammatical number would be equally degraded? The proposal I outlined above is certainly in concordance with the notion of grammatical control. In my proposal, the element controlling agreement would be the 'agreement'-feature specified in the head noun lemma. Conceptual influences may determine the number of that feature but cannot directly determine inflection of dependent elements. With respect to the finding of no distributivity effect in Broca's aphasics, the additional assumption would be that it is computationally expensive to have multiple influences from the message level, one specifying noun inflection number, one (sometimes incorrectly) specifying the agreement feature. It may be computationally 'cheaper', for instance, for the number for the agreement feature to be 'inherited' from the head noun inflection feature.

Clearly, the last word about conceptual influences on the construction of subject-verb agreement has not yet been said. However, the advantage of the proposal outlined above is that it can account for a number of phenomena: in addition to an account of distributivity effects, it explains how collective nouns in the singular can agree with plural verbs and how the 'horizontal constraint' that the number of the pronoun needs to be the same as that of the verb comes about. Furthermore, it can account for the phenomenon of 'reference transfer'. Consider the rather famous example (6), taken from Pollard & Sag (1994):

(6) The ham sandwich at table six is getting restless (said by one waitress to another)

The referent of the subject NP is not a ham sandwich, but rather a customer who ordered one. In cases like that, agreement is often guided by the referent, not by properties of the subject NP itself. Consider (7), also taken from Pollard & Sag:

(7) The hash browns at table nine is / *are getting angry.

Such examples can be easily accounted for, if it is assumed that there is an agreement feature which usually matches with the number feature of the head noun but can be different in exceptional cases such as (7).

Working memory and grammatical encoding: Some hesitations

We now turn to the status of resource theory with respect to grammatical encoding. We will begin by citing some counterevidence, observed in experiments with normal speakers. Both sources of counterevidence come from studies with the 'Speaking Span Test' (Daneman & Green, 1986). This test was designed to tax both hypothesized components of verbal working memory for language production: Storage of intermediate products and fueling processes with these representations. Participants taking this test view a number of word series on a computer screen. Words are presented one at a time and each word appears for 1 second only. Following presentation of a word series, a cue is given to the participant and she has to construct a single, grammatically correct sentence, for each word, and the order of sentences needs to be the same as the order of the words. There are five sets of word series, each containing five series. The length of each series in a set is fixed and there are sets containing series of length two, three, four, five, or six words. Speaking span is defined as the maximum series length at which the participant succeeds with at least three out of five series. Two series out of five is rewarded with half a point. Daneman & Green (1986) have shown that speaking span as measured with this test correlates with, for instance, verbal fluency.

Now let us turn to objections to the notion of verbal working memory playing a role in the speaking tasks I have presented to normal and aphasic participants. First of all, Bock & Cutting (1992) have presented the speaking span test along with the subject-verb agreement experiments. If constructing subject-verb agreement consumes computational resources, and if the amount of resources can be validly and reliably measured with the speaking span test, one would expect a correlation between span and error rate. However, they consistently observed the absence of a significant correlation between number of subject-verb agreement errors and speaking span. Number of repetition errors, on the other hand, did correlate, weakly but reliably, with speaking span.

In some of the experiments reported in this dissertation, a Dutch version of the speaking span test (Sleiderink, 1996) was presented to participants. In fact, the participants taking part in Experiment 4, reported in Chapter 1, and the participants taking part in the experiment reported in Chapter 2, were all tested with the speaking span procedure. Huiskamp (1996) computed a measure of priming effect for each individual participant in these experiments and correlated that with speaking span. None of these correlations reached significance (for details, see Huiskamp, 1996).

If subject-verb agreement construction is resource consuming, would one not expect a negative correlation between number of errors and speaking span? If syntactic persistence increases in the face of resource limitations, wouldn't one expect a negative correlation between priming effect and speaking span? There are a number of arguments against those expectations. To begin with, the speaking span test may not be a valid and reliable indicator of computational resources for sentence production. It should be noted that Waters & Caplan (1996) have argued extensively against the reliability and validity of the, somewhat analogous, reading span task (Daneman & Carpenter, 1980). In addition, it should be noted that the Dutch version of the speaking span has never been validated or tested for reliability. However, the finding of a null-effect, no correlation between speaking span and performance on a sentence production task has been reported (Sleiderink, 1996).

In addition, further arguments can be made against the contention that the results reported in Bock & Cutting (1992) and in Huiskamp (1996) are incompatible with the resource theory. For one thing, the hypothesis that there is a continuum of capacity, with subject populations varying on it, with High Span speakers on one end, followed by Low Span speakers, followed by Broca's aphasics, does not indicate how large the difference between High- and Low span speakers on the one hand, and Low span speakers and Broca's aphasics on the other hand is. It could be the case that an extreme limitation of resources, as is hypothesized with respect to Broca's aphasics, has consequences for the production tasks studied here, but that a slight limitation, as may be the case with Low span speakers, has no consequences at all.

I now turn to the question of where we stand with respect to the resource theory of agrammatic deficits. Objections that have often been raised are that the notion of resources is vacuous. For instance, Navon (1984) argued that tests that are usually interpreted as showing resources are involved in a particular task, can easily be interpreted without reference to the concept of resources. Salthouse (1988) also mentioned that 'it is sometimes suggested that the usage of these terms (i.e. processing resources and intelligence as *g*) is merely self-reinforcing rather than based on rigorous empirical investigation' (p. 252).

Given the conceptual flexibility of a notion such as 'computational resources', one should ask to what extent the results can be reconciled with alternative types of theories.

Let us therefore consider to what extent our results can be explained by alternative conceptions. I will begin with the data on syntactic priming and then address the data on subject-verb agreement.

First, our priming data argue against a loss-hypothesis, to the extent that a loss-hypothesis assumes deletion of knowledge on how to produce a passive. I showed how proportion of passive responses is variable, and susceptible to priming. Second, can the theory that Broca's aphasics utilize inappropriate strategies account for the present results? That does not seem to be the case. If reduced variety of syntactic structure solely results from inappropriate strategies, we would not expect to see passives in any experimental condition in Sessions 1 and 2. In addition, if the passive priming effect is due to a task-specific strategy, we would expect a much stronger 'priming' effect in Session 3. Third, can the theory of a reduced efficiency or a reduction in a specific capacity (cf. Martin, 1995; Martin & Romani, 1994) account for the results? It appears that it can indeed: If the grammatical encoder is less efficient for speakers with Broca's aphasia (or cast in my theory, if the process of functional integration is less efficient) it is conceivable that priming leads to a temporary increase in its efficiency. The study in Part I of this dissertation does not seem to allow the rejection of an efficiency-type account.

What about the studies on subject-verb agreement? To begin with, our results clearly argue against any loss-hypothesis that assumes verbal inflections are deleted. I showed that the ability to construct agreement is spared, although the error rate was high. It should be noted however that error rate for filler items with plural head nouns was quite low. I argued that this could not be ascribed to a tendency to use the infinitive. Can the results be explained by usage of inappropriate strategies? Clearly not; it is important to note that Broca's aphasics showed the same effect of attraction (mismatching local noun number) as normals. In addition, they did not rely on a strategy of 'semantic agreement', thus showing an exaggerated distributivity effect. It is interesting to note though that I tested one patient, not reported upon in Chapter 5, who used an odd 'strategy': he used the singular form in each and every preamble, thus having an error rate of 0% for the experimental items, and 100% for the filler items (this cannot be ascribed to loss of plural morphology, as he produced correctly inflected plural verbs in spontaneous speech). However, this was only one case: the eight cases reported in Chapter 5, did use plural as well as singular verbs, and no other patient was excluded from participation because of odd strategies.

How does the processing efficiency explanation fare with respect to the results with the subject-verb agreement experiment? Not good. It seems that such an explanation makes the same kind of predictions as the theory of a limitation of resources for a specific component does. If the syntactic component is slow, the number of the subject head noun would not 'reach' the verb in time: that would lead to

increased attraction from local noun number. If the syntactic component would fail completely, the semantic component may take over and fill in the missing number on the verb. That would lead to increased effects of distributivity. Neither of these patterns of data were observed. Hence, the conclusion seems justified that an explanation in terms of efficiency of the syntactic component should be rejected.

What remains is an explanation in terms of a limitation in computational resources that subserves syntactic as well as semantic processing.

Epilogue

Before concluding this dissertation, there is a final point I would like to make: The question of a parallel between comprehension and production. As often noted before, the agrammatic deficit in sentence production is paralleled by one in comprehension, although two famous case studies showing the existence of dissociations are often cited (Kolk, Van Grunsven, & Keyser, 1985; Miceli, Mazzuchi, Menn, & Goodglass, 1983). It is interesting to observe that a dissociation between computational resources for comprehension and production has also been proposed (Daneman & Green, 1986; Just & Carpenter, 1992). Given the fact that speaking span and reading span tests do correlate, although far from perfect, it is conceivable that resources for sentence production and sentence comprehension overlap only to some degree, and that a rare lesion can specifically impair one of these resource pools.

From that we can make two predictions: (1) cases must exist with agrammatic comprehension but not with agrammatic production (2) by temporarily increasing availability of sentence structure, Broca's aphasics suffering from agrammatic understanding, should be able to understand relatively complex sentence types. To begin with the first prediction, such cases have indeed been reported (e.g. Caplan & Hildebrandt, 1988). Agrammatic understanding is not restricted to patients with agrammatic production.

The second prediction is that 'syntactic priming' in sentence comprehension may lead to better comprehension performance for agrammatics. It should at this point be noted that students of parsing have indeed proposed the possibility that the parser can be 'tuned' by previous exposure (Mitchell, Cuetos, Corley, & Brysbaert, 1995). Exposure to certain syntactic structures, for instance one solution to a syntactically ambiguous sentence, would lead to an increased preference for the same solution with a similar kind of sentence.

In addition, empirical evidence for syntactic priming, from comprehension-to-comprehension was cited in Branigan, Pickering, Liversedge, Stewart, & Urbach (1995).

A recommendation for future research would thus be to firmly establish the existence of such priming effects in comprehension with normal speakers. If such effects can indeed be established, it seems worthwhile to test the comprehension equivalent of the hypothesis investigated in this dissertation: as a result of priming, performing a process such as syntactic tree formation requires less resources. Therefore, it should be possible to improve agrammatic *comprehension* performance with an appropriate priming task.

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Summary

There are two important aspects to cognitive processes such as those involved in speaking. First, there is the question what kind of architecture should be assumed. What stages of processing are there and in what way do these stages operate? What is the input representation of each stage and what output does each stage deliver? Can the stages be considered as modular or are there continuous interactions? The second aspect concerns the computational resources which are required for processing. 'Computational resources' should be viewed as a necessary commodity to fuel cognitive processes. The more processing is required and the more intermediate results need to be maintained, the more resource demanding a cognitive process is. In what way do stages use these resources? How specific are resources for a certain stage? What are the consequences for processing when resources are limited?

This dissertation deals with stages and resources in *sentence production*. When we talk about sentence production we refer to one component of speaking, the transformation of a 'message representation' into a hierarchical structure containing the constituents and words that make up the sentence. The goals we pursue are twofold. On the one hand we try to further specify the architecture of sentence production. On the other hand, we attempt to deepen our understanding of the role of computational resources in speaking. In particular, we test a theory of the impairment in *Broca's aphasia*, a language disturbance which results from brain damage. Broca's aphasics have severe trouble with speaking and the theory we put to the test ascribes these troubles to a pathological limitation of computational resources. Our results thus bear on the stages of processing in sentence production and on the nature of the resources involved.

We report a total of ten experiments. Some of these experiments test hypotheses about undisturbed sentence production, with students of the University of Nijmegen as the participants. Other experiments explicitly test hypotheses about the nature of the impairment in Broca's aphasia. The participants in those studies are a group of Broca's aphasics and a group of 'elderly controls' that are matched with respect to age and educational level to the aphasics.

Our starting points are theories of sentence production such as outlined in Levelt (1989) and Bock & Levelt (1994). In particular, we deal with theories that distinguish separate stages of processing, where each stage is viewed as module. Furthermore, these theories assume incremental processing and ascribe an important role to lexical information in the construction of sentence structure. Bock and Levelt divide sentence production into a stage of *functional processing*, in which lexical items are retrieved and in which major syntactic functions are assigned, and a stage of *positional*

processing. In that latter stage, syntactic structure is created. Important questions addressed in this thesis concern the way syntactic structures are generated; we focus in particular on the way a choice is made between alternative syntactic structures that can express (approximately) the same content. Another question we address is the degree in which different stages are 'informationally encapsulated'. That is, are production mechanisms in the stage of grammatical encoding, such as the mechanism responsible for the creation of subject-verb agreement, sensitive to variables in a different stage, that of 'conceptualizing'?

With respect to Broca's aphasia, our starting point is the adaptation theory of Kolk and colleagues. Important in that theory are the assumptions that (1) the language impairment can be characterized as a disruption of processing, not as a loss of knowledge, (2) the symptoms observed in actual speech are a function of an underlying impairment *and* the way the patient adapts to this impairment, (3) it is the stage of grammatical encoding that is impaired, (4) Broca's aphasics have a common underlying impairment, even though there is much variability in the severity.

In the present dissertation we provide evidence for a theory about the underlying impairment in Broca's aphasia. That theory attributes the impairment to a limitation of computational resources which are required for sentence production. If the amount of computational resources is pathologically limited, we expect more resource consuming processes, such as the construction of a complex sentence, to be impaired, whereas a simple sentence can be produced without a problem. Indeed, one of the defining symptoms of Broca's aphasia is a reduced variety of syntactic form: The syntactic repertoire is usually limited to a few, simple structures. The theory further assumes that the resource limitation is not restricted to computational resources for syntactic processing. Instead, we assume a single pool of resources that fuel all component stages of speaking. Note however that the impact of a resource limitation would be greatest for syntactic processing, as that would be the most resource demanding process.

This theory allows us to come up with two broad predictions. First, we predict that Broca's aphasics are able to produce sentences of relatively high complexity when the sentence structures are temporarily made more available (i.e. producing them requires less resources than normally). Second, we predict that Broca's aphasics, as opposed to normal controls, are unable to simultaneously use semantic and syntactic information: Taking into account these different kinds of information would be resource-requiring and Broca's aphasics lack these resources.

This dissertation consists of two parts, corresponding to the two predictions mentioned above. In Part I, the phenomenon of *persistent syntax* is investigated. It was noticed several years ago (e.g. Kempen, 1977) that speakers, when facing a conceptually repetitive situation, are repetitive in the kind of syntactic structures that

they use to describe the situation. However, it was unclear to what stage of processing in the sentence production system this phenomenon should be ascribed until Bock and colleagues (e.g. 1990) managed to exclude explanations that attributed this phenomenon to persistence of thematic roles, lexical content, or sentence prosody. What appeared to be the only explanation for this persistence was that it were the syntactic structures of the sentences that could be primed; due to priming one would have a tendency to reuse that structure. The task employed by Bock and colleagues was a combined sentence repetition/picture description task which had been disguised as a memory task. Critical trials consisted of a prime sentence participants had to repeat and a target picture they had to describe with a single sentence. In order to appropriately describe target pictures, a sentence could be used having the same syntactic structure as the prime sentence, or a syntactic alternative. For instance, a scene depicting a man being hit by the lightning could be described with a transitive active sentence or with a passive. It turned out that syntax is indeed persistent: The response frequency of a given syntactic structure was highest when the prime sentence has that same structure. Part I of this dissertation, consisting of chapters 1, 2 and 3, reports a series of studies in Dutch with this paradigm.

Chapter 1 reports an attempt of replication, in Dutch, of Bock's experiments in English. The series of four experiments show that there appear to be limits to the generality of the phenomenon: Whereas we obtain consistent evidence for syntactic persistence with dative alternatives such as 'the man gives a parcel to the girl' / 'the man gives the girl a parcel', no evidence is obtained for such effects with active and passive transitive sentences. An important new condition we add is a baseline-condition in which target pictures are preceded by syntactically unrelated sentences. It is observed that for most target structures, but especially for passives, the frequency is lowest in the baseline condition (i.e. in that condition are much more responses of a different type than any of the target structures). Because the baseline trials always are the first trials of the experiment, this suggests that the likelihood of producing a primed sentence increases in the course of the experiment. We consider this a 'long-term priming effect'. We conclude Chapter 1 with a tentative explanation for the lack of transitive priming: An explanation that attributes the effect of priming to competition between structures.

Chapter 2 reports an experiment with different kinds of structures: locatives (e.g. 'a ball is on the table' / 'on the table is a ball'). These alternatives can be viewed as two different word orders of the same syntactic structure. We obtain a priming effect with these kinds of sentences and argue that this effect should be attributed to a linearization process (see De Smedt, 1990) that is operative during grammatical encoding.

In the experiments reported in Chapter 3, we apply the syntactic priming task to Broca's aphasics' sentence production. As mentioned before, we predict that due to a temporarily increased availability of complex sentence types such as passives, these sentence types can be elicited. However, an important consideration is that the actual

speech produced by Broca's aphasics is a function of (i) an underlying impairment in formulation (ii) adaptation to that impairment. This makes it conceivable that a study of Broca's aphasics syntactic repertoire underestimates their abilities: They may strategically avoid those constructions that require great effort. Furthermore, it makes it conceivable that any effects of syntactic persistence should be ascribed to strategy, as opposed to an automatic facilitatory priming effect. In order to deal with these considerations, we study the incidence of target sentence structures in spontaneous speech, in picture description without a prime sentence (the baseline condition), and in picture description with a prime sentence. In addition, we vary task requirement. In one session we disguise the task as a recognition task, thus directing away attention from the sentence production part. In another session, we remove recognition instructions but do not mention the purpose of the experiment. In a final session, we explicitly instruct participants to reuse the previous sentence form. If it is possible to do so on our request, it is possible to apply such a task strategy. Conclusions from this experiment are clear. First, we obtain priming effects with the group of Broca's aphasics, both for passives and for datives. Second, these effects are stronger in the group of Broca's aphasics than in the group of normal controls. Third, the incidence of passives is extremely low in spontaneous speech and in the baseline condition for Broca's aphasics but increases substantially in the experimental conditions. Fourth, for Broca's aphasics there is no effect at all of task instructions, thus we can exclude the possibility of strategic involvement. In general, these results are conform to our prediction. However, the finding that Broca's aphasics are more sensitive to priming than normal controls, is unexpected. We offer a number of possible explanations for this difference. We further suggest that these findings constrain any model of agrammatic sentence production that assumes a resource deficit.

Part II of this dissertation deals with another phenomenon in sentence production: Derailments of a grammatical rule, the rule of subject-verb agreement. In most languages of the world, the number of the finite verb is required to agree with that of the subject. Thus we say *the boy walks*, but *the boys walk*. Although this process is usually error-free in normal speakers, sometimes derailments occur. Bock and colleagues (e.g. Bock & Miller, 1991) were the first to demonstrate that these kinds of errors can be elicited experimentally in a task in which participants have to repeat sentence fragments such as 'the king of the colonies' and complete them to full sentences. In the studies we report in Chapters 4 and 5, we examine the influence of 'conceptual number' on the incidence of agreement errors. In particular, we presented sentence fragments which may or may not have a so-called distributed reading. In a sentence fragment such as 'the label on the bottles', we have to assume that, even though 'label' is grammatically singular, there are many labels, one (distributed) on each of the bottles. There is thus a

conflict: Although the grammatical number is singular, the 'conceptual' number of 'label' can be said to be plural. If this variable exerts an influence, one expects the verb to agree in number with the conceptual rather than with the grammatical number of the subject, and therefore many errors in the condition with distributed readings (the so-called 'single token condition').

In Chapter 4, we show that speakers of Dutch and French are sensitive to this manipulation, as has previously been observed with speakers of Italian and Spanish, but not with speakers of English. This allows us to exclude a number of structural explanations for this crosslinguistic difference: The explanation that conceptual information controls grammatical agreement in languages which can omit subject pronouns, and the explanation that conceptual control of agreement depends on freedom of word order. Most important, this experiment clearly shows that speakers, when executing a morphosyntactic process such as getting agreement between subject and verb right, take into account both syntactic and semantic information.

In Chapter 5, we conduct the same experiment with a number of Broca's aphasics and age matched control subjects. We predict that Broca's aphasics, as opposed to normal controls, are insensitive to conceptual number because they lack the necessary resources to simultaneously use both conceptual and grammatical number. The results confirm this prediction: We observe that both Broca's aphasics and normal controls make substantial numbers of errors and that both groups show an effect of 'attraction' (more errors when the verb is preceded by a noun with number different from the subject noun). However, normal controls show a significant effect of distributivity whereas there is no such effect for Broca's aphasics.

Finally, in the General Discussion, we conclude that our results seem to sketch a consistent picture: We show that it is possible (within certain limits) to prime syntactic structure and that, as a result of syntactic priming, relatively complex sentences can be elicited from Broca's aphasics. This, we argue, supports the theory of a 'resource limitation'. Further, we have evidence that normal speakers can simultaneously rely on semantic as well as syntactic information but that Broca's aphasics cannot. We conclude the dissertation by addressing some unresolved issues. First, we attribute the lack of priming for transitives in normals, observed in Chapter 1, to baseline differences between the active and passive sentences. However, this explanation seems unable to account for the entire pattern of data, obtained in Chapters 1 through 3. We therefore offer a slightly modified competition explanation to account for the results. Second, we argue that an adequate account of the process of subject-verb agreement construction is still lacking. All existing theories seem to run into trouble. We offer an alternative theory, which has the potential to remove some of these objections. In the final paragraphs of the General discussion, we evaluate the implications of the present research for *parsing* and for Broca's aphasia. We tentatively suggest that, with an

appropriate experimental sentence priming paradigm, it ought to be possible to improve Broca's aphasic's comprehension performance on complex sentences.

Samenvatting

Er zijn twee belangrijke aspecten te onderscheiden aan cognitieve processen, zoals de processen die betrokken zijn bij het spreken. Ten eerste kan men zich afvragen welke architectuur verondersteld moet worden. Welke verwerkingsstadia zijn er en hoe verloopt verwerking gedurende elk stadium? Wat is de invoer voor elk stadium en welke uitvoer genereert het? Moet men deze stadia als modulair zien of zijn er voortdurend interacties? De tweede vraag die men kan stellen betreft 'computationele hulpmiddelen'. Bij het begrip 'hulpmiddelen' ofwel 'resources' moet worden gedacht aan een brandstof die nodig is voor het verloop van cognitieve processen. Hoe meer verwerking nodig is en hoe meer tussentijdse resultaten vastgehouden moeten worden, hoe meer resources een proces vergt. Op welke manier gebruiken de verwerkingsstadia resources? Hoe specifiek zijn resources voor een bepaald stadium? Wat gebeurt er met de verwerking wanneer de hoeveelheid resources beperkt is?

Dit proefschrift gaat over de stadia en resources bij *zinsproduktie*. Met dat begrip bedoelen we een onderdeel van het spreken, namelijk het omzetten van een zogenaamde boodschap in een hierarchische structuur. Deze structuur bestaat uit de zinsconstituenten en de woorden. De doelen die wij nastreven zijn tweeledig. Enerzijds willen we de architectuur van zinsproduktie verder specificeren. Anderzijds proberen we tot een beter begrip te komen van de computationele resources die nodig zijn voor het spreken. In het bijzonder testen we een theorie over de stoornis bij de *afasie van Broca*, een taalstoornis die het gevolg is van een hersenbeschadiging. Patiënten met de afasie van Broca hebben grote moeite met het spreken en de theorie die wij testen schrijft deze problemen toe aan een pathologisch tekort aan computationele resources. Onze resultaten hebben dus relevantie voor de verwerkingsstadia bij zinsproduktie en voor de aard van de daarbij toegepaste resources.

We rapporteren tien experimenten. In een deel van deze experimenten toetsen we hypothesen over ongestoorde zinsproduktie, met studenten van de KU Nijmegen als proefpersonen. In andere experimenten testen we hypothesen over de aard van de stoornis bij de afasie van Broca. De proefpersonen in die studies waren een groep Broca's afatici en een groep oudere controleproefpersonen, die met de afasiepatiënten gematchd waren op de variabelen leeftijd en opleidingsniveau.

Onze uitgangspunten zijn theorieën van zinsproduktie zoals die door Levelt (1989) en Bock & Levelt (1994) zijn voorgesteld. Dit zijn theorieën die verschillende verwerkingsstadia onderscheiden en ieder stadium beschouwen als een module. Verder veronderstellen die theorieën incrementele verwerking en kennen ze een belangrijke rol toe aan lexicale informatie waar het het bouwen van zinsstructuur betreft. Volgens Bock & Levelt kan zinsproduktie onderverdeeld worden in functionele verwerking (het

vinden van woorden en het toekennen van grammaticale functies) en positionele verwerking (het creëren van een hierarchische structuur en het plaatsen van woorden in die structuur). Belangrijke vragen die in dit proefschrift aan de orde komen, betreffen de manier waarop syntactische structuren gegenereerd worden. In het bijzonder besteden we aandacht aan de vraag hoe een keuze gemaakt wordt tussen syntactische alternatieven die ongeveer hetzelfde uitdrukken. Een andere vraag is in hoeverre diverse stadia 'ingekapseld' zijn met betrekking tot informatie uit andere stadia. Zijn productiemechanismen in het stadium van grammaticale codering, zoals het mechanisme dat congruentie tussen onderwerp en persoonsvorm tot stand brengt, gevoelig voor variabelen in een ander stadium, dat van conceptualizeren?

Wat de afasie van Broca betreft is de adaptatietheorie van Kolk en collega's ons uitgangspunt. Belangrijk in die theorie zijn de assumpties (1) dat de taalstoornis beschouwd wordt als een verstoring van verwerking en niet een verlies van kennis (2) dat de symptomen in de spraak van Broca's afatici een functie zijn van de aanpassing van de patiënt aan de stoornis en van de stoornis zelf (3) dat het stadium van grammaticale codering verstoord is (4) dat Broca's afatici een gemeenschappelijke stoornis hebben, hoewel de ernst van de stoornis sterk varieert.

In dit proefschrift presenteren we evidentie voor een theorie over de onderliggende stoornis bij de afasie van Broca. Deze theorie schrijft de stoornis toe aan een tekort aan 'computational resources'. Als hieraan een pathologisch tekort is, verwachten we dat processen die veel resources vergen, zoals de constructie van een complexe zin, gehinderd worden. Het construeren van een eenvoudige zin zou echter nog wel gaan. Inderdaad is een van de symptomen waardoor de afasie van Broca gedefinieerd wordt, een gereduceerde verscheidenheid van syntactische vorm. Het syntactische repertoire is meestal beperkt tot enkele eenvoudige zinsstructuren. Verder neemt de theorie aan dat het niet alleen resources voor syntactische verwerking zijn die beperkt zijn. Er zou een meer algemene capaciteit zijn, waar alle deelprocessen van het spreken gebruik van maken. Echter, een tekort aan resources zou vooral ernstige consequenties hebben voor syntactische verwerking.

Uit deze theorie volgen twee voorspellingen. Ten eerste voorspellen we dat Broca's afatici in staat zijn om relatief complexe zinnen te produceren wanneer de zinsstructuur tijdelijk extra beschikbaar wordt gemaakt. Ten tweede voorspellen we dat Broca's afatici, in tegenstelling tot normale controleproefpersonen, niet in staat zijn om tegelijk semantische en syntactische informatie te gebruiken: Met meerdere typen informatie rekening houden kost namelijk veel resources en Broca's afatici hebben een tekort in dit opzicht.

Dit proefschrift bestaat uit twee delen die overeenkomen met bovengenoemde voorspellingen. In Deel I onderzoeken we het fenomeen van 'inerte syntax'. Bijna

twintig jaar geleden (Kempen, 1977) werd gemeld dat sprekers, wanneer ze steeds soortgelijke situaties moeten beschrijven, soortgelijke syntactische structuren gebruiken. Het was echter onduidelijk waaraan dat herhaaldelijk gebruik van een syntactische structuur lag totdat Bock en collega's (bijv. 1990) verklaringen uitsloten die het fenomeen toeschrijven aan herhaalde thematische rollen, lexicale inhoud of prosodische factoren. Het enige wat over leek te blijven was een herhaling van de syntactische structuur.

De door Bock en collega's gebruikte taak is een gecombineerde zinsherhaal / plaatjesbeschrijvingstaak, waarbij de proefpersoon in de waan wordt gebracht dat het om een geheugenexperiment gaat. Kritische trials bestaan uit een primezin, die de proefpersonen moeten herhalen, en een targetplaatje dat met een zin beschreven moet worden. Een adequate beschrijving van de targetplaatjes vereist een zin die dezelfde syntactische structuur heeft als de primezin, of een syntactisch alternatief. Bijvoorbeeld, een afbeelding van een man die door de bliksem getroffen wordt, kan of met een actief transitieve zin beschreven worden ('de bliksem treft de man') ofwel met de passieve pendant ('de man wordt getroffen door de bliksem'). Het bleek dat syntax inderdaad persistent is: De frequentie van een bepaalde syntactische structuur was het hoogst in de conditie waar de primezin dezelfde structuur had. Deel I, bestaande uit de hoofdstukken 1, 2, en 3 bevat een serie studies in het Nederlands met dit paradigma.

In Hoofdstuk 1 rapporteren we een poging om Bock et al.'s Engelstalige experimenten in het Nederlands te repliceren. De serie van vier experimenten laat zien dat de algemeenheid van het fenomeen beperkt is. We vinden namelijk consistente evidentie voor syntactische inertie met datieve alternatieven als 'de man geeft een pakje aan het meisje' / 'de man geeft het meisje een pakje', maar we vinden dit effect niet voor actieve en passieve transitieve zinnen. Verder voegen wij een belangrijke nieuwe conditie toe, een baseline conditie waarin targetplaatjes voorafgegaan worden door syntactisch ongelateerde zinnen. We vinden dat voor de meeste targetstructuren, in het bijzonder voor passieven, de frequentie het laagst is in de baseline conditie (in die conditie zijn er dus meer responsen van een ander type dan van een van de targetstructuren). Aangezien de baseline trials altijd de eerste trials van het experiment zijn, suggereert dit dat gedurende een experimentele sessie de waarschijnlijkheid dat een gegeven targetstructuur geproduceerd wordt, toeneemt. We beschouwen dit als een effect van priming op lange termijn. We besluiten het hoofdstuk met een voorlopige verklaring voor het gebrek aan transitieve priming: Een verklaring die primingeffecten toeschrijft aan een *competitie* tussen syntactische alternatieven.

In Hoofdstuk 2 doen we verslag van een experiment met andere structuren, namelijk locatieven (bijv. 'de bal is op de tafel' / 'op de tafel is de bal'). Deze alternatieven kunnen gezien worden als twee woordvolgordes die afgeleid zijn van eenzelfde syntactische structuur. We verkrijgen een primingeffect met deze zinnen en

beargumenteren dat dit effect toegeschreven moet worden aan een zgn. 'linearizeringsproces' dat optreedt bij grammaticale codering (zie ook De Smedt, 1990).

In Hoofdstuk 3 wordt de zinsprimingtaak toegepast bij patiënten met de afasie van Broca. Zoals eerder vermeld voorspellen we dat de tijdelijk verhoogde beschikbaarheid van complexere zinstypen, zoals passieven, als een gevolg van priming, leidt tot het uitlokken van deze zinnen bij Broca-patiënten. Een belangrijke overweging is echter dat de zinstypen die door afasiepatiënten geproduceerd worden, ook afhangen van aanpassing aan de stoornis. Dat maakt het denkbaar dat bij een onderzoek van het syntactische repertoire van Broca-patiënten hun vaardigheid onderschat wordt: Zij zouden die constructies die veel moeite kosten, kunnen vermijden. Verder is het denkbaar dat eventuele effecten in een zinsprimingtaak toegeschreven moeten worden aan taakstrategieën in plaats van aan een automatisch, facilitoir primingeffect. Om rekening te houden met deze overwegingen onderzoeken we de incidentie van targetstructuren in spontane spraak, in plaatjesbeschrijving zonder priming (de baseline conditie) en in geprimede plaatjesbeschrijving. Bovendien variëren we taakvereisten. In de eerste sessie verhullen we de taak als een geheugentaak, waardoor we de aandacht hopen af te leiden van zinsproduktie. In de tweede sessie verwijderen we de herkenningsinstructie, maar wordt de ware aard van het experiment niet onthuld. In de laatste sessie geven wij de deelnemers expliciete instructies om de syntactische vorm van de primezin opnieuw te gebruiken. Indien men in staat is dit op ons verzoek te doen, is het mogelijk dat men dit in eerdere sessies als strategie deed. De conclusies van het experiment zijn duidelijk. Ten eerste vinden we primingeffecten bij de Broca's afatici, zowel met passieve als met datieve zinnen. Ten tweede zijn deze effecten sterker bij de Broca's afatici dan bij de controleproefpersonen. Ten derde is de incidentie van passieven buitengewoon laag in spontane spraak en in de baseline conditie voor de Broca's afatici, maar deze incidentie neemt belangrijk toe in de experimentele condities. Ten vierde vertonen Broca's afatici geen effect van taakinstructie, zodat we de mogelijkheid van een taakstrategie, zoals eerder geschetst, kunnen uitsluiten. Deze resultaten zijn, in hun algemeenheid, in overeenstemming met onze voorspellingen. Echter, de vondst dat Broca's afatici meer dan normale controleproefpersonen gevoelig zijn voor priming, is onverwacht. We vermelden een aantal verklaringen voor deze onverwachte vondst. Verder suggereren we dat onze bevindingen beperkingen opleggen aan mogelijke modellen van agrammatische zinsproduktie.

Deel II van dit proefschrift gaat over een ander fenomeen bij zinsproduktie: Het ontsporen van een grammaticale regel, namelijk de regel van onderwerp-persoonsvorm congruentie. In de meeste talen hoort het getal van het onderwerp overeen te stemmen met dat van de persoonsvorm. We zeggen *de jongen loopt* maar *de jongens lopen.* Hoewel dit proces meestal foutloos verloopt bij normale sprekers, treden er soms fouten

op. Bock en collega's (bijv. Bock & Miller, 1991) waren de eersten die demonstreerden dat congruentiefouten experimenteel uitgelokt kunnen worden, in een taak waarbij de proefpersonen zinsfragmenten moeten herhalen en afmaken. Een voorbeeld van zo'n zinsfragment is 'De koning van de eilanden'. In de studies die in Hoofdstukken 4 en 5 worden gerapporteerd gaan we de invloed na van 'conceptueel' getal op het voorkomen van congruentiefouten. We bieden proefpersonen zinsfragmenten aan, die al of niet een 'gedistribueerde' lezing kennen. Neem een fragment als 'het etiket op de flessen'. We moeten aannemen dat het hier gaat om een aantal etiketten, ook al is het woord 'etiket' enkelvoudig. Op elke fles zit een exemplaar van het etiket, dus er zijn meerdere exemplaren. Er is dus een conflict: Het grammaticale getal van 'etiket' is enkelvoudig, maar het conceptuele getal kan als meervoudig beschouwd worden. Als die variabele invloed heeft op de constructie van onderwerp-persoonsvorm congruentie, verwachten we dat het werkwoord soms in getal overeenstemt met het conceptuele getal van het onderwerp. Daarom verwachten we meer fouten bij zinnen met een gedistribueerde lezing (de zgn. 'multiple token' conditie) dan bij zinnen zonder zo'n lezing.

In Hoofdstuk 4 laten we zien dat sprekers van het Nederlands en het Frans gevoelig zijn voor deze manipulatie, zoals eerder al was aangetoond bij sprekers van het Italiaans en Spaans, maar niet kon worden aangetoond bij sprekers van het Engels. Onze bevinding maakt het mogelijk een aantal structurele verklaringen voor dat crosslinguïstisch verschil uit te sluiten: Ten eerste de verklaring dat conceptuele informatie grammaticale congruentie reguleert in talen die persoonlijke voornaamwoorden als onderwerp kunnen weglaten (de zgn. 'pro-drop' talen), en ten tweede de verklaring dat er een invloed is van conceptueel getal in talen met een relatief vrije woordvolgorde. Belangrijk voor onze doelen is dat dit experiment duidelijk aantoont dat sprekers, wanneer zij een morfosyntactisch proces uitvoeren zoals de constructie van onderwerp-persoonsvorm congruentie, gebruik maken van semantische zowel als syntactische informatie.

In Hoofstuk 5 rapporteren we een studie waarin dezelfde proef afgenomen wordt bij Broca's afatici en bij oudere controleproefpersonen. We voorspellen dat de afasiepatiënten (in tegenstelling tot de controleproefpersonen) niet gevoelig zijn voor conceptueel getal, omdat zij niet beschikken over de computationele resources om tegelijkertijd gebruik te maken van beide informatiebronnen. De resultaten bevestigen deze voorspelling: Beide groepen proefpersonen maken aanzienlijke hoeveelheden congruentiefouten en beide groepen vertonen een 'aantrekkingseffect' (meer fouten wanneer de persoonsvorm voorafgegaan wordt door een zelfstandig naamwoord met een ander getal dan het onderwerp). Echter, normale controleproefpersonen vertonen een significant distributiviteitseffect, terwijl Broca's afatici dat niet doen.

Tenslotte concluderen we in de Algemene Discussie dat de resultaten een consistent patroon laten zien. We hebben laten zien dat het (binnen bepaalde grenzen)

mogelijk is om de syntactische structuur te primen, en dat, als een gevolg van syntactische priming, relatief complexe zinnen aan Broca's afatici ontlokt kunnen worden. Dit ondersteunt de theorie van een tekort aan resources. Verder hebben we evidentie gevonden waaruit blijkt dat normale sprekers in staat zijn tegelijk semantische en syntactische informatie te gebruiken, maar Broca's afatici niet. Dit ondersteunt de theorie dat resources aspecifiek zijn, dat wil zeggen, gebruikt worden voor meer dan alleen syntactische verwerking.

Het proefschrift eindigt met enige onopgeloste kwesties. Ten eerste schrijven we het gebrek aan priming bij transitieve zinnen in de groep normale sprekers (Hoofdstuk 1) toe aan verschillen in baseline tussen actieve en passieve zinnen. Dit kan echter niet het hele patroon van resultaten verklaren dat we in Hoofdstukken 1 tot en met 3 hebben gevonden. Daarom stellen wij een enigszins gewijzigde Competitie verklaring voor. Ten tweede merken we op dat een adequate verklaring voor het genereren van onderwerp-persoonsvorm congruentie nog ontbreekt. Alle bestaande theorieën schijnen tekort te schieten. We stellen een alternatief voor, dat de mogelijkheid bezit bezwaren tegen de huidige theorieën weg te nemen. Tenslotte gaan we in de laatste alinea's na wat de implicaties zijn van het huidige onderzoek voor grammaticale *decodering* (parsing). We suggereren dat het, met een geschikt zinspriming paradigma, mogelijk moet zijn om het begrip van complexe zinnen bij Broca's afatici (tijdelijk) te verbeteren.

Curriculum vitae

Na in 1986 geslaagd te zijn voor het VWO-eindexamen aan het Rijnlands Lyceum te Wassenaar toog Robert Jan Hartsuiker naar Delft om zich te wijden aan de studie van Scheikundige Technologie. Het duurde minder dan een half jaar voor hij besefte dat hij minder belangstelling had voor de moleculaire structuur van paradimethylamino-benzaldehyd of pentachloormethylmethoxybroombutanol dan voor de vraag hoe de mens functies als waarnemen, onthouden, denken, redeneren, beslissen, luisteren en spreken uitvoert. Hij ging daarom psychologie in Leiden studeren met als specialisatie psychologische functieleer. Het toendertijd in Leiden ontbrekend studiedeel 'computationele psycholinguistiek', dat sterk zijn belangstelling had, volgde hij aan de KU Nijmegen (zelfs voor hij de beschikking kreeg over een OV-studentenkaart)

Al spoedig werd zijn interesse voor experimenteel onderzoek gewekt Twee van de onderzoeksprojecten waaraan hij deelnam mondden uit in een publicatie een ging over lexicale toegang[1], een ander over auditieve perceptie van tijd[2]. In 1991 vertrok hij voor een half jaar naar de University of Maryland in College Park (Verenigde Staten). Onder leiding van Professor Jim Reggia hield hij zich bezig met het ontwikkelen van (connectionistische) methoden voor het segmenteren van Engelse woorden in zogenaamde 'grafemen', groepen van letters die overeenstemmen met precies een spraakklank.

Hij studeerde in 1992 cum laude af Hij had toen al het aanbod van Herman Kolk geaccepteerd om aan het NICI, te Nijmegen, zijn onderzoeksterrein te verleggen naar afasie en taalproduktie. Dit proefschrift is het resultaat van de in dat project geleverde inspanningen.

Sinds 1 oktober 1996 is Rob Hartsuiker bij het NICI aangesteld als postdoc-medewerker, ten behoeve van een door NWO gefinancierd project getiteld 'computationele modellen van fonologische codering en monitoring'.

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[1] La Heij, W , de Bruyn, E , Elens, E , Hartsuiker, R , Helaha, D , & van Schelven, L (1990) Orthographic Facilitation and Categorical Interference in a Word-Translation Variant of the Stroop Task *Canadian Journal of Psychology*, **44**(1), 76-83

[2] Ten Hoopen, G , Hartsuiker, R , Sasaki, T , Nakajima, Y , Tanaka, M , & Tsumura, T (1995) Auditory isochrony time shrinking and temporal patterns *Perception*, **24**, 577-593

Stellingen behorende bij het proefschrift "Sentence Production in Normals and Broca's Aphasics: Stages and Resources". R.J. Hartsuiker. Nijmegen, 1996.

1. Syntactische priming is alleen mogelijk indien de formulator een keuze heeft tussen syntactische alternatieven. (dit proefschrift)

2. Constructie van onderwerp-persoonsvorm congruentie is gevoelig voor het conceptueel getal van het grammaticaal onderwerp. (dit proefschrift)

3. Bij locatieve zinnen hangt de plaatsing van de voorzetselfrase onder andere af van de bepaaldheid van de naamwoorden die de thematische rollen van 'theme' en 'location' vervullen. (dit proefschrift).

4 Een theorie die de taalverwerkingsproblemen bij afatici toeschrijft aan een beperking van "computationele resources", dient aangevuld te worden met een theorie over hoe diverse cognitieve processen gebruik maken van deze resources.

5. Indien de soms geopperde hypothese dat neurologische uitvalsverschijnselen niet zozeer samenhangen met de locatie van de laesie, maar met premorbide aanwezige 'zwakke plekken'in het cognitief systeem correct is, maakt de auteur van dit proefschrift na eventueel hersenletsel grote kans op het verwerven van prosopagnosia.

6. Aangezien de nieuwe eisen voor een individueel postdocproject bij NWO o.a. inhouden dat de aanvrager tenminste drie eerste-auteur publicaties heeft in goede internationale vaktijdschriften, en aangezien het soms jaren kan duren voor een artikel geaccepteerd wordt, verdient het voor een jonge promovendus met postdoctorale ambities aanbeveling om na het afronden van zijn 4-jarige AIO of OIO-contract nog 1 à 2 jaar op wachtgeld door te gaan, totdat er genoeg artikelen geaccepteerd zijn.

7. Het verdient aanbeveling om naast glasbakken vuilnisbakken te plaatsen, waarin men de met drank besmeurde plastic zak kan deponeren.

8. De verspreking 'in de trap vallen', waar de spreker 'in de val trappen' bedoelde, kan als een verwisseling van de woorden 'val' en 'trap' opgevat worden, maar evenzeer als een Anglicisme.

9. Als gevolg van de oriëntatie op de Engelse taal die de meeste promovendi noodgedwongen hebben, zijn zij beter in staat een artikel in goed Engels te schrijven dan in goed Nederlands.

10. De richtlijn met betrekking tot de promotie aan de KU Nijmegen waarin gesteld wordt dat het College van Decanen het ongepast vindt om in het voorbericht van het proefschrift bijzondere woorden van dank aan promotor en/of copromotor te richten brengt de promovendus in een lastig parket; de rest van de wereld vindt het namelijk ongepast indien dergelijke woorden van dank ontbreken (*Richtlijnen met betrekking tot de promotie aan de KU Nijmegen, II.4, p.23*).

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