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Syntactic Facilitation in Agrammatic Sentence Production

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Recently, proposals have been made to relate processing difficulties in aphasic language performance to limitations in resources for grammatical processing (Carpenter et al., 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 aphasia, 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. The main findings were that (a) Brocas show stronger syntactic priming effects than controls; (b) the effects are automatic rather than strategic; and (c) in conditions with priming, Brocas produce relatively complex sentences (e.g., passives). We discuss these results in relation to capacity theories.

A defining symptom of Broca's aphasia is a reduced complexity of syntactic structure (e.g., Caplan, 1987; Gleason et al., 1975; Goodglass et al., 1994; Menn & Obler, 1990). Menn and Obler (1990), in the concluding chapter of a large crosslinguistic study, state that ''syntax (in agrammatic sentence production) is simplified, both within and across clauses'' (p. 1370, material in parentheses ours). What can account for this syntactic simplification?

One notion that has figured prominently in recent discussion of difficulties in syntactic processing is that of ''computational resources'' or ''processing

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capacity'' both in the study of aphasic comprehension as an instance of a severe capacity reduction (Caplan et al., 1985; Caplan & Hildebrandt, 1988; Frazier & Friederici, 1991; Haarmann et al., 1997; Hagiwara, 1995; Hartsuiker, 1996; Kolk, 1995; Kolk & van Grunsven, 1985; Martin & Romani, 1994; Martin et al., 1994) and in the study of individual differences in capacity among the normal population (Just & Carpenter, 1992; Miyake et al., 1994, 1995).

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. First of all, there is considerable debate about the specificity of these resources: Are we dealing with separate resources for semantic, syntactic, and phonological processing (e.g., Caplan & Waters, 1995; Martin, 1995; Martin & Romani, 1994; Waters & Caplan, 1996) or with a general verbal working memory, involved in all of these components of the language processor (e.g., Just & Carpenter, 1992; Miyake et al., 1994, 1995)?

Second, it is unclear whether the same resources would be used both in production and in comprehension. It should be noted that there are observations suggesting that resources for producing and comprehending language are not the same, from dissociations between comprehension and production in aphasia (Kolk et al., 1985; Miceli et al., 1983) and from (modest) correlations between production span tasks and comprehension span tasks (Daneman & Green, 1986).

A third issue concerns the nature of these supposedly limited resources. According to Salthouse (1988), the notion of computational resources has centered around three metaphors: space, time, and energy. Although Salthouse addressed deterioration of cognitive processes in aging, the same kind of metaphors can be found in the literature on aphasic sentence comprehension. For instance, Caplan and Hildebrandt's (1988) workspace hypothesis is an instance of the space metaphor. The time metaphor plays a dominant role in the approach taken by Kolk and his colleagues (cf. Haarmann & Kolk, 1991a,b, 1992; Kolk, 1995). Kolk assumes that either by slow activation/computation or by too-fast decay during grammatical formulation, the required synchronicity/simultaneity of the various parts of the syntactic tree cannot always be reached and sentence processing is disrupted (see Haarmann & Kolk, 1991a, for a computer simulation of this hypothesis). Finally, the energy metaphor seems to be reflected in Miyakes et al.'s (1994) capacity theory of language comprehension disorders, in which it is assumed that aphasics suffer from a limitation in the total ''pool of activation'' that is available for language processing. Interestingly, the latter model also makes use of the time metaphor: if there is a shortage of activation, there is either a reduced ''efficiency'' (slowing down) of sentence processing or a reduced ''maintenance'' (fast decay) of processing results.

In the present study on agrammatic production, we will be neutral with

respect to the specificity issue, but we will assume that the capacity limitation is a temporal one. This limitation could be due to a restriction in the amount of capacity, as proposed by Miyake et al., or to a direct effect that brain damage has on activation and decay rate of linguistic processing (Kolk, 1995). Its effect would be that computational simultaneity between different parts of the syntactic tree cannot or only rarely be reached, in particular, if the constituent structure is a relatively complex one (passives, datives, sentences with embedded clauses, and the like). The main question we address in this study is the following. If agrammatic speakers suffer from a limitation of temporal resources, that is, if they generate grammatical information too slowly, or lose it too rapidly, it should be possible to counteract the results of this limitation by temporarily increasing the availability of the relevant syntactic structures. A structure that is already active above rest level will take less time to reach threshold. The result would be that there is less chance of premature decay of parts of the sentence representation.

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 et al., 1992; Branigan et al., 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.[1] 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 and Kolk (1995) tested the active/passive contrast in a number of 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 represen-

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

tation 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 and 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: Brocas 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 age-matched healthy subjects. In addition, the procedure followed by Saffran and Martin departed from that followed by Bock (1989), Bock and Loebell (1990), Bock et al. (1992), and Hartsuiker and Kolk (1995). These authors, in contrast to Saffran and 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, the subject's attention was diverted from the sentence production component of the task, in order to eliminate any strategies on the subjects side.

Because Saffran and Martin's task was not covered up, the possibility of strategic involvement cannot 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 and Martin's pilot study, by testing a relatively large group of Brocas, by testing a group of age-matched 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 Brocas susceptible to syntactic priming, and if so, are they susceptible to syntactic priming to the same extent as normal controls? A priming effect for Brocas, especially

for more complex sentence structures, would support the hypothesis that priming can overcome a resource limitation.

Second, is it true that Brocas show syntactic simplification 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 experimental task 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 and 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 and 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 male, 3 female) diagnosed as Brocas aphasic on the Dutch version of the Aachener Aphasie Test (AAT) and 12 healthy control participants (7 male, 5 female), who were matched in age and educational level with the group of aphasics. The mean age was 47 years for the Broca's aphasics and 53 years 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, and naming pictures with sentences. Table 2 shows that the group of Brocas 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	(Years since onset)	(Former) profession	Etiology
NU	65	m	12	Municipal worker	CVA
BO	38	f	2	Housewife	CVA
FR	28	m	5	Truck driver	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

TABLE 2
Scores on Subset of AAT Scales

	Spontaneous speech (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

Note. 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 function words and inflections were missing.

TABLE 3
Examples 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.
P1, congruent	De spreker wordt onderbroken door het lawaai. The speaker is interrupted by the noise.
AC, incongruent	De journalist onderbreekt het gesprek. The journalist interrupts the conversation.
P1, 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.

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 about equally often on the left side of the picture (48%) and 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.[2] 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).

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 (next two rows of Table 3). Each of the four sentences in a set was presented equally often. This ensured controlling

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

TABLE 4
Examples 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 10 guilders to the salesman.
DO	De klant betaalt de verkoper tien gulden. The customer pays the salesman 10 guilders.
INT	De vrouw rookt teveel. The woman smokes too much.

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).

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.

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, then 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 3 weeks.

Each interview, lasting about 10 min, was recorded on audio tape. Brocas were encouraged to tell as extensively as possible about their illness history, former occupation, family, and daily activities. Control subjects were asked to tell about their occupation, motivation to pursue that vocation, and, if there remained time, 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 instructed that he was taking 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, 10 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 now 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 classified as a canonical active (AC), an active with the word order object verb subject (OVS), a full passive with sentence-final by-phrase (PI), a full passive with a sentence-final passive participle (P2), or other (OT). Although verb-final passives (P2) and noncanonical 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, Brocas made many errors in selecting prepositions (as one patient, WI, put it ''voorzetsels vreselijk,'' ''prepositions terrible''). Therefore, in those cases where Brocas supplied a different preposition instead of ''aan,'' but where it was unambiguously clear that this was a paragrammatism with ''aan'' the correct target, we accepted the utterance as a prepositional dative.[3] For dative verbs containing an auxiliary and an infinitival complement (i.e., ''laten zien,'' ''to show,'' literally ''to let see''),

[3] Note that we did not allow for any 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'').

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.[4] In a double-object dative, there is no prepositional phrase, and the indirect object precedes the direct object.

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 which had 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

[4] 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 synonymous verb ''tonen'' (to show).

number of *narrative words* (Saffran et al., 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 1 of each session); nine prepositional datives and nine double-object datives preceding dative pictures; and nine actives and nine passives preceding transitive pictures (distributed across Block 2 and Block 3 of each session).

Separate ANOVAs 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 ANOVAs 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 ANOVAs, testing effects of variables such as position of agent on the picture and animacy.

Syntactic Persistence

Transitives. Application of scoring criteria yielded 130 responses classified as active or passive (P1) for Brocas 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

TABLE 5
Response Frequencies for Transitives (Percentages in Parentheses)

	AC	P1	OT	Total
		Brocas, Session 1 (N = 12)		
AC	40 (37)	2 (2)	66 (61)	108
P1	37 (34)	13 (12)	58 (54)	108
B	37 (34)	1 (1)	70 (65)	108
		Brocas, Session 2 (N = 11)		
AC	39 (39)	5 (5)	56 (56)	100
P1	30 (31)	9 (9)	59 (60)	98
B	28 (28)	2 (2)	69 (70)	99
		Brocas, Session 3 (N = 11; some subjects not tested on all blocks)		
AC	25 (35)	6 (8)	41 (57)	72
P1	22 (31)	14 (19)	36 (50)	72
B	48 (48)	2 (2)	49 (50)	99
		Normal controls, Session 1 (N = 12)		
AC	37 (34)	21 (19)	50 (46)	108
P1	46 (43)	20 (19)	42 (39)	108
B	30 (28)	24 (22)	54 (50)	108
		Normal controls, Session 2 (N = 11)		
AC	22 (22)	29 (29)	49 (49)	100
P1	32 (33)	26 (27)	40 (41)	98
B	22 (22)	23 (23)	54 (55)	99
		Normal controls, Session 3 (N = 11)		
AC	68 (69)	11 (11)	20 (20)	99
P1	3 (3)	87 (88)	9 (9)	99
B	29 (29)	24 (24)	46 (46)	99

of responses classified as ''others.'' A substantial part of these responses consisted of passive sentences with a clause-final participle, the P2-passive (for Brocas 3% across sessions, for normal controls 12%), and of active sentences with the word order OVS (for Brocas 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, Brocas 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.

In Fig. 1, we depict the proportion of passives in each condition for Brocas. Visual inspection of Fig. 1 suggests a priming effect and no effects of Ses-

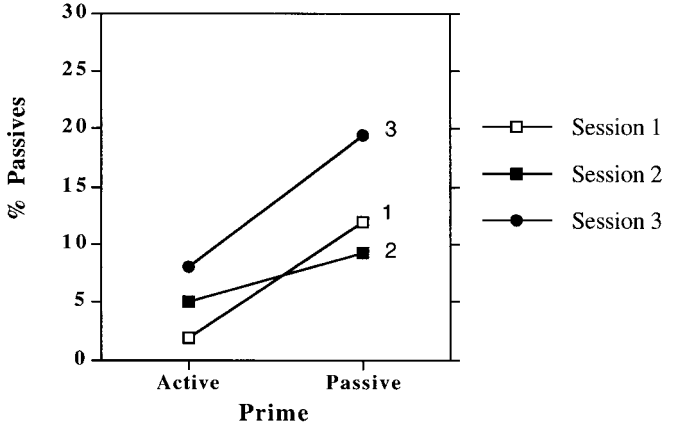

FIG. 1. Proportion of passives in each session for Brocas.

sion. Indeed, for Brocas, the ANOVAs 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. Also, the interaction between Prime type and Session did not reach significance.

The proportions of actives for normal controls in every session are depicted in Fig. 2. Figure 2 clearly shows negative priming effects in the first two sessions and a much stronger positive priming effect in the third session. ANOVAs 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, $F(1, 10) = 49.98$; $p < .001$].

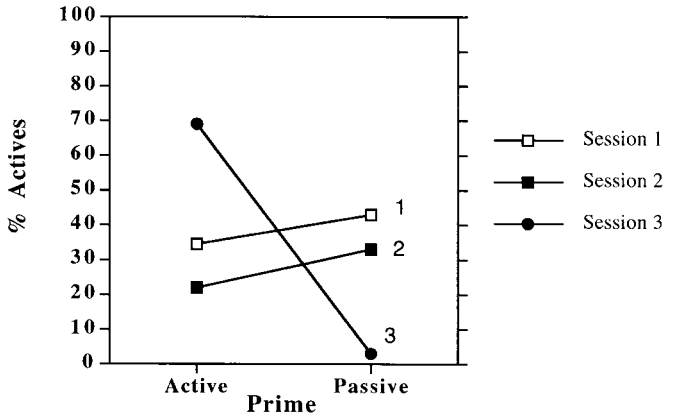

FIG. 2. Proportion of actives in each session for normal controls.

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, $F(2, 20) = 38.94$; $p < .001$].

Because inspection of Fig. 2 and Table 5 makes it obvious 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 [$F(1, 10) = 81.88$; $p < .001$].

Datives. For Brocas 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.

The proportion of prepositional datives in the three sessions for Brocas are depicted in Fig. 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. ANOVAs on prepositional dative responses and double-object responses of Brocas, 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 corre-

TABLE 6
Response Frequencies for Datives (Percentages in Parentheses)

	PP	DO	OT	Total
		Brocas, 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
		Brocas, 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
		Brocas, Session 3 (N = 11; some subjects not tested on all blocks)		
PP	40 (55)	11 (15)	22 (30)	73
DO	25 (35)	16 (23)	30 (42)	71
B	32 (32)	28 (28)	39 (39)	99
		Normal controls, 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
		Normal controls, 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
		Normal controls, 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

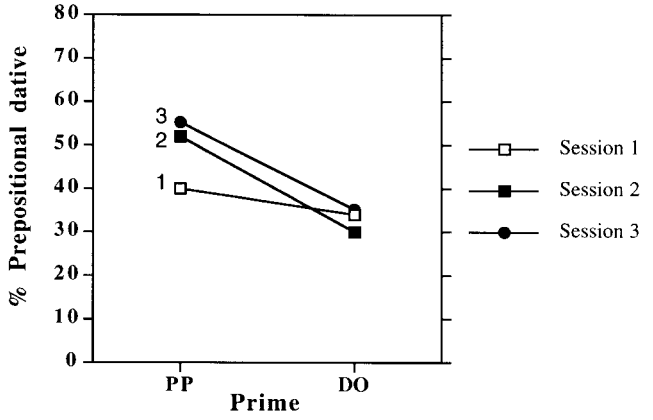

FIG. 3. Proportion of prepositional datives in each session for Brocas.

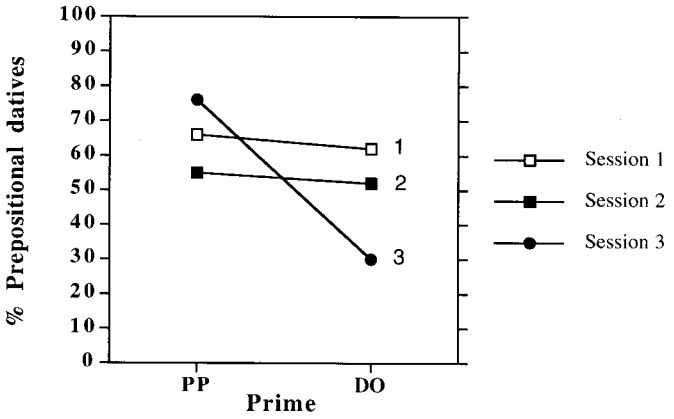

FIG. 4. Proportion of prepositional datives in each session for normal controls.

sponded to a very strong extent with prime type in Session 3. We depict the proportion of prepositional datives for normal controls in Fig. 4. As the number of ''other'' responses was roughly equal in each condition, the proportion of double-object datives follows a complementary distribution.

ANOVAs 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 Fig. 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 ANOVAs 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 of four tested structures for Brocas. 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 Brocas, 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 scored in the normal range, and at least one normal control scored 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 numbers 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 Brocas 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; Brocas, Median = 239). In order to compensate for that difference, we randomly[5] 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 Brocas. Nevertheless, even with such a procedure, we observed passives in 8 of 11 normal controls subjects (average 1.1, range 0–3).

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 Brocas and Controls. In the baselines of Sessions 1, 2, and 3, respectively, 10/12, 10/11, and 10/11 Brocas produced prepositional datives, and 9/12, 9/11, and 9/11 Brocas produced double-object datives. Across sessions, 12/12 Brocas 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.

Table 8 shows, as is particularly clear from the baseline of Session 1, that passives are almost never produced in unprimed conditions, but occur more

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

TABLE 7
Incidence of Passives in Spontaneous Speech

Subject	Number of passives	Number of narrative words
	Brocas	
NU	2	190
BO	0	188
FR	0	302
GE	0	484
HA	0	271
LA	0	338
KL	0	172
LO	0	166
WI	0	206
TH	0	899
PE	0	108
HO	0	371
		Mean = 308 Median = 239

Subject	Number of passives (Total)	Number of passives (random sample of 239 words)	Number of narrative words
	Normal controls		
JJ	4	1	1111
HB	9	1	1028
MB	0	0	697
BVD	5	3	920
THJ	1	0	772
OO	1	1	496
HK	4	1	894
WO	Not available	Not available	Not available
TV	3	3	391
KK	5	1	991
BS	2	0	907
DE	4	1	619
	Mean = 3.5	Mean = 1.1	Mean = 802 Median = 894

often in those blocks in which passive primes were presented. Across experimental sessions, 10/12 Brocas were observed to produce full passives.

Interestingly, for Brocas, 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 5 in the locative baseline condition (when P2-passives are included, these

TABLE 8
Conditions in Which Brocas Produced One or More Passives: Spontaneous Speech (SPON) and Baseline and Priming Blocks of the Three Sessions

		Session					
		1		2		3	
Subject	Spontaneous speech	Baseline	Priming	Baseline	Priming	Baseline	Priming
NU	(+)		+	(+)			+
BO			+	nt	nt	nt	nt
FR				+			+
GE			+	+	+	+	+
HA			+				+
LA							
KL		(+)	+	+	+	+	+
LO		+	+	+	+	(+)	+
WI		(+)					+
TH							
PE		(+)	+	(+)	+		+
HO			+		+		

Note. 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 (+). Subject BO was not tested (nt) in Sessions 2 and 3.

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, and the interaction was not significant either. 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 and Kolk (1995), who obtained evidence for a relatively long-lasting influence of a prime (long-term Priming). This refers to an increased accessibility of a primed structure, even after a number of other sentences have been produced since that structure was produced. Thus, a prime on trial n can influence the outcome on trial $n + 1$, even if these trials are separated by a number of fillers. The primed structure would remain more accessible for some time. Thus, a passive prime on a previous trial may reduce the effect of an active prime on a subsequent trial (see also Bock & Kroch, 1989; Bock & Loebell, 1990).

TABLE 9
Proportion of Different Transitive Responses for Different Animacy and Position Conditions

		Position					
		L			R		
		Resp			Resp		
Group	Animacy	ac	p	ot	ac	p	ot
Brocas	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

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 et al. (1980) that Brocas 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, Brocas make use of certain strategies to a stronger extent than normals, for example, 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 shows that both Brocas and normal controls show additive effects of the variables animacy and position. Brocas 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, Brocas 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 [$F(1, 10) = 2.03$; $p = .185$]. 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, 8 in pictures with animate patients, and the remaining 5 in the condition with inanimate patients.

To summarize, both Brocas 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, Brocas often resorted into producing noncanonical 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: Brocas 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 Brocas.

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 Brocas, 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 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 Brocas. 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 Brocas, means were in the predicted direction for all structures in both of these sessions. For normal controls, we saw a 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 and 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 Brocas 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 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 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, given the fact that their performance was far from perfect ($<$70% correct in some conditions). 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 Brocas, 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. These results indicate (i) 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; (ii) that 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 controls do 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; (iii) that Broca's aphasics either avoid producing passives or are not able to produce them; whereas normal controls regularly produce passives, both in spontaneous speech and in baseline conditions, Brocas 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 Brocas 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. Notice that the results argue in favor of the time metaphor or the energy metaphor of computational resources we mentioned in the Introduction. The results, however, argue against the space metaphor: It is unlikely that a process such as priming could alter the number of available slots in a workspace.

Before turning to the important issue of having obtained stronger priming effects in Brocas, we will address the issue of semantic and perceptual cues in picture description. Both Brocas 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[6] in agrammatic sentence production that could account for the results of Saffran et al. (1980) with respect to word ordering in noun-verb-noun sequences:

(1) Produce sentences in the active voice.
(2) Put the agent left of the verb.
(3) Put the animate entity left of the verb.[7]

[6] 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 production.

[7] 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 et al. (1996).

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 et al., 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 Brocas rely to a stronger extent on these strategies.

Interestingly, for Brocas, 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 OVS sentences should be really interpreted as such or whether these utterances should be considered 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 both with 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.

Enhanced Priming Effects in Broca's

The present experiment yielded another unexpected result. The remarkable fact is that Brocas show syntactic priming, whereas normal controls fail to do so. We should repeat here that Hartsuiker and 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. Notice that Bock and colleagues usually tested very large groups of participants (e.g., Bock & Loebell, 1990, tested 96 participants in each experiment). 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) as, obviously, el-

derly controls resembled the group of Brocas much more in those respects (see Method). A further issue is whether Brocas have a *larger* priming effect or a more *reliable* priming effect. In the case of passives there is clearly a larger effect, as 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 Brocas 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 Brocas. We tentatively conclude that Brocas are more susceptible to priming than normal controls. Why is this the case?

We had no initial hypotheses about a difference between Brocas and controls concerning the magnitude of priming effects. In previous studies examining other forms of priming in aphasia (i.e., lexical priming), it has been found that effects which were present in normals, were weaker or absent in aphasics. For instance, Haarmann and Kolk (1991b), 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. Friederici and Kilborn (1989) found the reverse: Priming effects at the shortest SOA but not at the longest SOA for the Broca's aphasics, but priming at all SOA's for controls. Finally, Blumstein et al. (1991) observed syntactic priming with Broca's aphasics, but only in a subset of the conditions were normals showed these effects (i.e., not when the prime target sequence formed a single constituent phrase).

In the remainder of this section we present three possible accounts for the stronger priming effect with Brocas, observed in the present study. We must note beforehand however that our study was not designed to show these enhanced priming effects. Thus, each of the three accounts is, out of necessity, *post hoc.* Nevertheless, we think it important to provide an account of that interesting finding, and we attempt to construct accounts that follow from general principles of activation models, either connectionist activation models (McClelland & Rumelhart, 1981) or rule-based activation models (Just & Carpenter, 1992).

The first account entails that priming asymptotically increases the activation level of a node. Assume that priming entails sending input to a node representing a given item (see, e.g., Milberg et al., 1995, in the context of semantic priming in aphasia). Assume further that normals have activation levels that are closer to the threshold. In effect, their activation levels approach the ''asymptote of activation.'' Therefore, any input (as a result of

priming) has limited effects on the activation level. It is important to note that the assumption of attenuated effects of input with increased activation level of a node has been made in interactive activation models (e.g., McClelland & Rumelhart, 1981).

A different account of the finding that Brocas are more susceptible to priming than normal controls follows from the observation that Broca's aphasics have a reduced variety of grammatical form (Gleason et al., 1975). Suppose that this reduced variety of syntactic form in overt speech reflects a reduced variety of syntactic form at the level of planning a sentence. A consequence of that reduction is 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 Brocas 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 and 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 Brocas 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 Brocas 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 account of the enhanced priming effect follows from the hypothesis that the amount of priming is inversely related to the amount of computational resources. That hypothesis follows from the capacity theory of sentence comprehension proposed by Just and Carpenter (1992), assuming that similar mechanisms of (re)allocating activation apply to sentence production. The hypothesis is based on the fact that initially both competing structures (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 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 et al., 1997; 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 Brocas being unable to simultaneously maintain two competing structures. Normal controls, on the other hand, having many more computational 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 et al., 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 more from priming; (ii) the consequences of changes in this activation level for demand of computational 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; and (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

1. a tractor pulling a car
2. a bullet hitting a bottle
3. lightning hitting a golf player
4. a bicycle pulling a cart
5. a flyswatter killing an insect
6. a tripod hitting a farmer
7. a wave flushing a ship
8. smoke dazing a man
9. an avalanche destroying a house
10. a magnet attracting a coin
11. a ball hitting a vase
12. an arrow hitting an apple
13. lightning hitting a church
14. a tank killing a soldier
15. a ball hitting some cans
16. a wave flushing a girl
17. a bicycle bumping into a pedestrian
18. a train killing a woman
19. an ambulance bumping into a mailman
20. a rocket destroying an airplane
21. a torpedo hitting a ship
22. a tow truck pulling a car
23. a bat hitting a ball
24. a tornado lifting up a girl
25. a ball hitting a boy
26. an arrow hitting a bird
27. an avalanche burying skiers

Datives

1. a boy handing another boy a hammer
2. a child showing his wounded arm to his mother
3. a girl handing flowers to a teacher
4. children handing flowers to a man
5. a girl giving a tulip to another girl
6. a police officer handing a ticket to a car driver
7. a girl handing a paintbrush to a boy
8. a girl handing a plant to a boy
9. a boy handing a ball to a girl
10. a waitress showing the menu to a customer
11. a little boy giving a valentine to a girl
12. a woman showing a dress to a man
13. a boy giving a ball to another boy
14. a lawyer showing a letter to a judge
15. children showing a drawing to their teacher
16. a girl handing a cup to a boy
17. a waitress presenting drinks to some men
18. a boy giving a valentine to a girl
19. a cowboy showing his hat to a clown
20. a nurse handing a glass of water to a patient
21. a child handing a pear to her teacher

22. a boy handing a guitar to a singer
23. a girl showing a report card to a boy
24. a girl giving a present to a boy
25. a girl handing a ball to a boy
26. a girl handing a bone to a dog
27. a librarian handing a book to a boy

Transitive Prime Sentences in Different Animacy Conditions (Presented Here in the Active Voice, Followed by Literal English Translation)

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 bicyclist/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 jewel/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
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 disturbs 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 pane/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 throws the pin/goalkeeper around
    ''The ball/player overthrows the pin/goalkeeper''

Dative Prime Sentences Followed by Literal English Translation

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 Santa 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

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