PLATFORM SESSION 2

1. Syntactic ERP Effects in Broca's Aphasics with Agrammatic Comprehension

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Introduction. Although some aphasic patients have been described who are agrammatic in language production but unimpaired in sentence comprehension (e.g., Kolk, Van Grunsven, & Keyser, 1985), the majority of patients with Broca's aphasia have syntactic problems when comprehending language. This phenomenon of agrammatic comprehension has been intensively studied, mainly by employing paradigms in which patients were asked to match sentences with pictures or to manipulate toys in acting-out tests (e.g., Caplan & Hildebrandt, 1988). Such paradigms, in contrast to on-line methods, are less suited to tap the processes involved in syntactic comprehension as they unfold in real time. An on-line method which is useful for studying syntactic comprehension processing in Broca's aphasics is the recording of event-related brain potentials (ERPs). One particular ERP-component, the Syntactic Positive Shift (SPS), has been found to be sensitive to on-going syntactic processing. The SPS is a positive polarity brain potential that starts at about 500 ms following relevant stimulation and has been observed in response to a number of syntactic violations (e.g., Hagoort, Brown, & Groothusen, 1993). In the current study the SPS is used as a tool to study syntactic comprehension problems in patients with Broca's aphasia. Next to the SPS, the N400 is a well-known ERP component, related to semantic processing. The N400 component is also relevant for this study.

Method. The ERP experiment focused on syntactic integration processes within and across phrasal boundaries. The subjects were presented with spoken sentences in Dutch containing violations of (1) phrase structure rules (transpositions of adverbs and adjectives in Adv–Adj–N sequences), and (2) violations of subject–verb agreement (both in a simple and complex constituent structure, in order to vary syntactic complexity). For example (critical regions are italicized; literal English translations in brackets):

(1a) Mijn broer gebruikt een *nogal oude* computer voor zijn studie.
(My brother uses a *rather old* computer for his studies.)

(1b) *Mijn broer gebruikt een *oude nogal* computer voor zijn studie.
(My brother uses an *old rather* computer for his studies.)

(2a) De vrouwen betalen de bakker en *nemen* het brood mee naar huis.
(The women pay the baker and *take* the bread home.)
(2b) *De vrouwen betalen de bakker en *neemt* het brood mee naar huis.
(The women pay the baker and *takes* the bread home.)
(2c) De vrouwen die de bakker betalen, *nemen* het brood mee naar huis.
(The women who pay the baker, *take* the bread home.)
(2d) *De vrouwen die de bakker betalen, *neemt* het brood mee naar huis.
(The women who pay the baker, *takes* the bread home.)

The subjects were asked to listen attentively to the sentences. No additional task demands were imposed.

Subjects. Ten patients with aphasia secondary to a single CVA in the left hemisphere, and twelve normal elderly control subjects participated in the experiment. All patients were diagnosed as Broca's aphasics on the basis of the standardized Dutch version of the Aachen Aphasia Test and on the basis of a transcribed sample of the patients' spontaneous speech. Agrammatic comprehension was further examined by an off-line sentence picture matching test for syntactic sentence comprehension. This test consists of five different sentence types, namely: (1) active, semantically irreversible sentences, (2) active, semantically reversible sentences, (3) simple passive sentences, (4) sentences with a relative clause containing a prepositional phrase, and (5) embedded passive sentences. The different sentence types assess the influence of (increasing) syntactic complexity on sentence comprehension.

On the basis of their performance on this off-line test, the aphasic patients were divided into two groups (High versus Low Comprehenders; see Fig. 12). Both the High ($N = 5$) and Low Comprehenders ($N = 5$) showed a significant decrease in comprehension with increasing syntactic complexity, with the Low Comprehenders performing significantly worse than the High Comprehenders. Twelve normal control subjects, matched in age and education to these patients, were also tested.

Results and discussion. In the normal elderly control subjects SPS effects were found for the phrase structure and subject–verb agreement violations. The latter effect was not modulated by syntactic complexity. The ERP results of both the High and Low Comprehenders deviated from the results of the elderly controls. The High Comprehenders showed an SPS with the same latency but a smaller amplitude than the control subjects for both the phrase structure violations and the agreement violations in the simple constituent structure. The effect for the agreement violations in a complex constituent structure failed to reach significance. This pattern of results indicates that

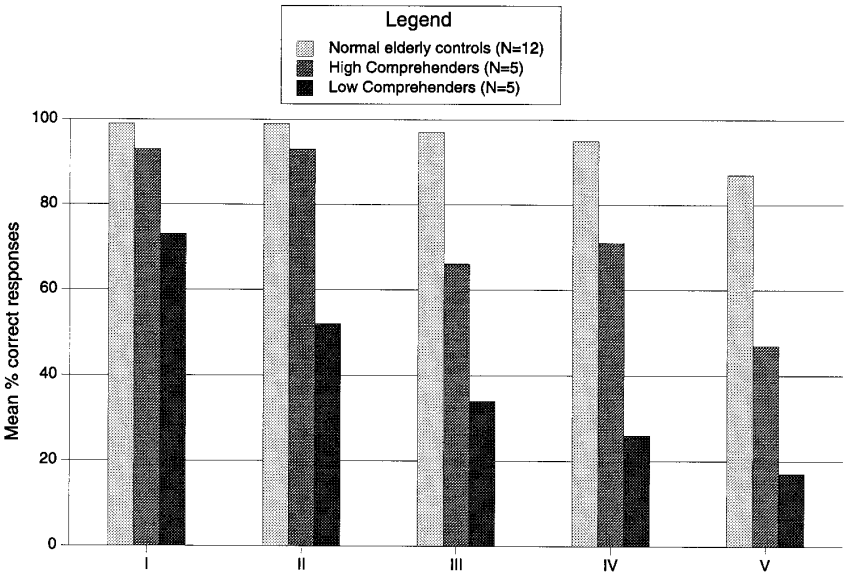

FIG. 12. Static off-line test. Mean percentage correct responses for Normal elderly Controls, High Comprehenders and Low Comprehenders for 5 different sentence types: (I) Active, semantically irreversible; (II) Active, semantically reversible; (III) simple passive; (IV) relative clause containing a prepositional phrase; (V) embedded passive.

the High Comprehenders still have available, at least in part, the processing machinery for the assignment of syntactic structure.

In contrast to the High Comprehenders, some Low Comprehenders showed a delayed positive shift for the phrase structure violations, which might indicate a considerable delay in the time course of their syntactic integration. Other Low Comprehenders showed no SPS but an N400 effect instead, suggesting the use of a compensatory semantic strategy for sentence interpretation. In the Low Comprehenders no effects were found for the agreement violations.

In summary, the quantitative difference in the off-line test performance of the High and Low Comprehenders was accompanied by a qualitative difference in their ERP data, with either reductions or delays of syntactic ERP effects, or no such effects but instead modulations of the semantic N400 component.

REFERENCES

Caplan, D., & Hildebrandt, N. 1988. Disorders of syntactic comprehension. Cambridge, Mass.: MIT Press.

Hagoort, P., Brown, C., & Groothusen, J. 1993. The Syntactic Positive Shift (SPS) as an ERP Measure of Syntactic Processing. *Language and Cognitive Processes*, **8,** 439–483.

Kolk, H. H. J., Grunsven, M. J. F. van, & Keyser, A. 1985. On Parallelism between Production and Comprehension in Agrammatism. In M.-L. Kean (Ed.), *Agrammatism.* New York: Academic Press.

2. The Role of Working Memory in Sentence Processing: Evidence from Parkinson's Disease

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Many psycholinguists have been interested in the role that working memory plays in language processing and in the possibility that reductions in the capacity of this system may underlie certain types of language disorders. Data from patients with Parkinson's Disease (PD) have been taken as evidence for a relationship between an impairment in syntactic processing and a reduction in working memory capacity, since these patients have been found to have both impairments in executive functions and impairments in structuring sentences syntactically. However, the nature of the sentence comprehension impairments seen in PD and their relationship to impairments in executive functions and processing resource reductions is far from clear.

Most studies of sentence processing in PD have used sentence comprehension tasks that have heavy post-interpretive demands and so may have led to an exaggerated view of the deficits these patients have in assigning syntactic form and understanding the literal meaning of a sentence. In addition, in many studies the syntactic complexity of the stimulus materials is confounded with other factors, such as length and propositional density, and so it is likely that these other factors may account for the results. Finally, most studies have not measured working memory in the PD patients whose sentence processing was tested. Even if PD patients do have impairments in structuring sentences syntactically, it is necessary to demonstrate that these patients have an impairment in working memory and to relate this impairment to their processing of syntactic form to examine the relationship between these two cognitive domains. This study reconsiders the relationship between working memory and syntactic processing in PD, using tasks and materials that address these issues.

Method. Subjects: The subjects were 23 PD patients and 15 controls. The mean ages of the PD patients and controls were 70.1 and 71.6 years respectively and the mean number of years of education were 14.9 and 13.5, respec-

tively. The patients were recruited from Neurologists associated with Movement Disorders Clinics in Montreal and Boston. The control subjects were chosen from a pool of healthy elderly volunteers in each of these cities. Both patients and controls were tested on a battery of Neuropsychological tests to rule out dementia. All subjects were also tested on a variant of the Daneman and Carpenter test (Waters & Caplan, 1996) as a measure of verbal working memory capacity. The mean working memory span for PD patients was 1.8 and for controls was 3.4.

Stimuli and Procedure: The stimulus sentences consisted of six different sentence types—active conjoined theme (Acth), Dative (D), Cleft Object (CO), Object Subject (OS), Conjoined (C), and Subject Object (SO). These sentence types were chosen since they allowed three comparisons of sentences that are matched for length and number of propositions but differ in terms of syntactic complexity (Acth vs CO; OS vs SO; C vs SO) and three which are matched for length and syntactic complexity but differ in terms of the number of propositions (Acth vs OS, Acth vs C, CO vs SO). Three versions of this test were administered. In each, the sentences were read aloud by the examiner. For each sentence, the subject indicated whether the target picture matched the sentence (one picture version) or selected the target picture from among two or three alternatives (two and three picture versions).

Results. Separate Group (PD vs Control) × Sentence Type (Acth, D, CO, OS, C, SO) ANOVA's were carried out for each of the three tasks. The PD patients performed extremely well overall on the three versions of the task (91.9%, 95.2%, 93.7% for the one, two, and three picture versions) and their performance did not differ significantly from the controls on any of the tasks (controls = 94.5%, 96.8%, 94.7%). There was a main effect of sentence type on all three tasks. Post hoc analysis showed that none of the comparisons testing the effect of syntactic complexity were significant in any task, and that two of the three comparisons testing the effect of number of propositions were significant in all tasks. In addition, in the analysis of the one-picture version there was a significant group × sentence type interaction which was due to all three comparisons testing the effect of number of propositions being significant in the patients and only two in the controls.

Given that chance differs across the three versions of the task due to the differing number of pictures, it was not possible to simply directly compare subjects' overall performance across the three versions of the task. Composite scores of the magnitude of the effect of syntactic complexity were calculated for each task by averaging across the three comparisons designed to examine the effect of complexity to yield a syntactic complexity index. Composite scores of the magnitude of the effect of number of propositions were calculated similarly. These data were analyzed in a Group (PD vs Control) × Task (1 vs 2 vs 3 pictures) × Comparison Type (Complexity vs Proposition) ANOVA. The main effects of group and comparison type were significant. PD patients showed bigger effects than did controls. Examination of the

means for each index for each group showed that there was no effect of syntactic complexity in the PD group (PD complexity index = .04) while controls performed slightly better on the syntactically more complex sentences (normals' complexity index = −.22). Both groups showed effects of number of propositions (proposition indices = 1.37 and .71 for patients and controls, respectively). The magnitude of the proposition effect was greater than of the syntactic complexity effect. The Task × Comparison Type was also significant. Post hoc analysis showed that the magnitude of the proposition effect was greater in the one- than in the two-picture version of the task.

Discussion. The results of this experiment show that nondemented Parkinson's patients with reduced verbal working memory capacities do not have disturbances of syntactic processing, as measured by a sentence–picture matching task. Their problems with sentence comprehension emerge on sentences with more propositions. This result is consistent with previous results in our lab that relate working memory capacity to the ability to use the meaning of a sentence to accomplish a task, but not to the efficiency with which the syntactic form of a sentence is constructed and used to determine that meaning (Waters et al., 1995).

REFERENCES

Waters, G. S., & Caplan, D. 1996. The Measurement of Verbal Working Memory Capacity And Its Relation to Reading Comprehension, *Quarterly Journal of Experimental Psychology,* **49A:** 51–79.

Waters, G. S., Caplan, D., & Rochon, E. 1995. Processing Resources and Sentence Comprehension in Patients with Alzheimer's Disease, *Cognitive Neuropsychology,* **12:** 1–30.

3. Effects of Syntactic Structure and Number of Propositions on Patterns of Regional Cerebral Blood Flow

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Introduction. The question of the localization of the processing involved in both comprehending sentence meaning on the basis of syntactic form and in using that meaning to accomplish tasks remains open. In the following two studies, we explored this question using PET. In experiment 1, we measured changes in rCBF in normal subjects that are associated with processing more vs less syntactically complex sentences. In experiment 2, we measured changes in rCBF in normal subjects that are associated with processing sentences that differ in their propositional density. These two variables primarily increase processing load at interpretive and postinterpretive stages of sen-

TABLE 8

Location	Max *Z*-score	Number of pixels	Location {*X*, *Y*, *Z*}
Areas of increased rCBF for subtraction of PET activity associated with right branching sentences from center embedded sentences			
Medial frontal gyrus	3.8	131	10, 6, 52
Cingulate gyrus	3.5	173	−2, 6, 40
Broca's area, pars opercularis	3.0	47	−42, 18, 24
Areas of increased rCBF for subtraction of PET activity associated with sentences with one proposition from sentences with two propositions			
Occipital and	3.8	575	−32, −66, 0
inferior temporal	3.3		−22, −84, −4
Inferior temporal	3.7	54	46, −40, −4
Medial temporal	3.1	66	−52, −64, 20

tence processing, respectively, and therefore changes in rCBF associated with them are relevant to the question of the neural basis for these two functional capacities.

Experiment 1. Subjects were scanned during 2 experimental conditions. Sentences in condition 1 contained syntactically more complex center-embedded relative clauses (e.g., *The juice that the child spilled stained the rug*) and sentences in condition 2 contained syntactically simpler right-branching relative clauses (e.g., *The child spilled the juice that stained the rug*). Half the sentences in each condition were plausible and half were not. Subjects made timed plausibility judgments after each sentence. Eight right handed female subjects between the ages of 21 and 31 participated.

Behavioral results: RT data corrected for outliers for correct responses were analyzed in ANOVAs for the effects of block, syntactic structure, and semantic plausibility. There was a main effect of sentence structure (F_{1RT} (1, 7) = 5.3, $p = .05$; F_{2RT} (1, 284) = 31.6, $p < .001$) favoring less complex sentences. No other main effects or interactions were significant.

rCBF results: Table 8 shows the location of increases in rCBF associated with z scores of 3 or greater based on statistical parameter mapping derived by contrasting PET activity in condition 1 (center-embedded sentences) with PET counts in condition 2 (right-branching sentences). A significant increase in rCBF occurred in two medial frontal structures, the anterior cingulate gyrus and the immediately superior medial frontal gyrus, and in Broca's area, where the center of activation was in the rostal part of the pars opercularis, Brodmann's area 44.

Experiment 2. Experiment 2 sought to document changes in rCBF that might be associated with processing sentences that contained two, as opposed to one, proposition. Sixteen college students were scanned during 2 experimental conditions. Sentences in condition 1 contained two propositions (e.g.,

The boy read the book and finished the newspaper) and sentences in condition 2 contained one proposition (e.g., *The boy read the new book and the newspaper*). Half of the sentences in each condition were plausible and half were implausible. Sixteen native, monolingual English-speaking college students, 8 males and 8 females mean between the ages of 22 and 30 participated.

Behavioral results: RT data corrected for outliers for correct responses were analyzed in ANOVAs for the effects of block, syntactic structure, and semantic plausibility. There were significant main effects of the number of propositions ($F_{1RT}(1, 15) = 52.7$, $p < .001$; $F_{2RT}(1, 282) = 54.0$, $p < .001$), favoring one-proposition sentences, and plausibility ($F_{1RT}(1, 15) = 5.6$, $p = .03$; $F_{2RT}(1, 282) = 2.7$, $p < .1$), favoring plausible sentences. No other main effects or interactions were significant.

rCBF results: Table 8 shows the location of significant increases in rCBF based on statistical parameter mapping derived by contrasting PET activity in condition 1 (two propositions) and condition 2 (one proposition). A significant increase in rCBF occurred in a large contiguous posterior region that included the occipital poles and inferior temporal cortex bilaterally. Additional regions of activation were found bilaterally somewhat more anteriorly in the posterior and inferior temporal region. No increase in activation was found in any perisylvian structure traditionally associated with language processing.

Discussion. Experiment 1 replicates the results reported by Stromswold et al. (1996). rCBF increased in the pars opercularis (Brodmann's area 44) for the more difficult syntactic sentences compared with the simpler ones. The anterior cingulate and immediately adjacent medial frontal gyrus also showed increases in rCBF, likely to be the result of increased attention or processing load. The results partially contrast with those reported by Just et al. (1996), who found increased rCBF associated with syntactically more complex sentences in Wernicke's and Broca's areas bilaterally, using a question answering task. Differences in tasks may be responsible for the rCBF differences between the studies.

Experiment 2 shows a very different pattern of rCBF than previously reported in any experiment in which sentence types were contrasted. There was no increase in rCBF in either perisylvian cortex associated with language processing when PET activity associated with the one-proposition sentences was contrasted with activity associated with the two-proposition sentences. All increased activation arose in areas of the brain associated with the ventral stream of visual processing. One plausible account is that this activity is due to visual mental imagery processes that the subjects may have used to determine the plausibility of these sentences (Kosslyn, 1993), which may increase with the number of propositions.

In summary, this study provides evidence for a distinction in the neural tissue that increases its blood flow in sentence comprehension as a function

of the syntactic complexity versus the propositional density of a sentence. This pattern is compatible with the existence of partially distinct neural systems underlying the construction of syntactic form in the determination of sentence meaning and the use of that meaning to accomplish a task.

REFERENCES

Just, M. A., et al. 1996. *Science,* **274,** 114–116.
Kosslyn, S., et al. 1993. *Journal of Cognitive Neuroscience,* **5,** 263–287.
Posner, M. I., et al. 1989. *Science,* **240,** 1627–1631.
Stromswold, K., et al. 1996. *Brain and Language,* **52,** 452–473.

ARTICLE NO. BL971911