MAX-PLANCK-INSTITUTE OF COGNITIVE NEUROSCIENCE

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It was a joint committee of the Medical-Biological Section (Medizinisch-Biologische Sektion) and the Humanity Section (Geisteswissenschaftliche Sektion) of the Max-Planck-Gesellschaft that conceived the idea of an institute for cognitive neuroscience (MPI of Cognitive Neuroscience) in the „Neue Bundesländer“. That the founding fathers voted for Leipzig (Lipsia) as site of the new institute was mainly due to the rich scientific environment in this up-and-coming Saxonian city and in particular with its well-structured university offering manifold neuroscience, medical, linguistic, and psychological facilities. The great tradition of Leipzig in the field of brain research is bound up with the names of Brodmann, Flechsig, Weber, Fechner and Wundt, the latter being considered as one of the pioneers of experimental psychology.

Professor Zacher, president of the MPG, formally established the institute on September 12, 1995 in the presence of the Saxonian Minister of Science and Arts, Professor Meyer, the president of the University of Leipzig, Professor Weiss, and many other dignitaries representing German scientific, cultural, and political institutions.

The basic concept of our institute commits us to multidisciplinary research on cognitive (i.e. language and memory) processes and their cortical/cerebral representation. For this particular purpose, the MPG endowed us with a 3-Tesla nuclear magnetic resonance tomograph (MRT), a 150 channel magnetencephalograph (MEG), several high-quality multi-channel EEG devices and other technical equipment (e.g. speech and reaction time laboratories, computer facilities including a parallel computer) necessary for this kind of non-invasive, “in vivo” brain-behavior research in humans.

At the time being, the Max-Planck-Institute of Cognitive Neuroscience consists of two closely interacting departments (Arbeitsbereiche), the Neuropsychology (NPS) and the Neurology (NEU) department. In addition, there is also a Day-Care-Clinic for 25 neurological patients, which was opened on February 5,1996, and is established under the roof of the University of Leipzig. Since many fundamental questions in cognitive neuroscience ask for complementary investigations with both healthy volunteers and brain-injured patients we are happy to have basic and clinical research facilities at our disposal.

The NPS department consists of three working teams (Language, Memory, MEG) dealing with behavioral measurements as well as measurements of language- and memory-related brain activity with particular emphasis on EEG and MEG providing a high temporal resolution. We expect the MEG to be implemented in May/June 1996.

The NEU department is divided into four groups (MRT, Signal and Image Processing, Experimental Neuropsychology and Clinical Neuropsychology). As a pivotal research tool for this department, and for the entire institute, functional magnetic resonance imaging (fMRI) has to be established with top priority. We are prepared to start with fMRI studies in August 1996.

A common interest of both departments concerns language processing, the language group providing psycholinguistic theorizing, neuropsychological and neurophysiological modeling; the Clinical Group offering diagnostic and therapy data from neurological patients with various language disorders. A second field of mutual interest refers to working memory processes which are pursued in the temporal (electrophysiological) and the spatial (neuroimaging) domain considering both verbal and nonverbal modalities. As soon as MRT and MEG are installed, all working teams will be involved in these two major research areas. A future focus is to use a combination of fMRI, MEG and EEG data to identify normal and pathologically altered language and memory subsystems.

The immediate installation of our EEG laboratories and the swift continuation and broadening of work that one of us (A.F.) had done at the Free University of Berlin, allow us to report on first results and, as we believe, interesting perspectives for the future work in our fast developing institute.

We decided that the NEU department should not contribute to this annual report since at present we could only “philosophize” on plans and intentions rather than present data. As soon as the MRT and appropriate stimulation devices are installed, a bunch of carefully planned research programs will get under way, the implementation of which will be documented in our next annual report.

The structure of this institute should give us an excellent opportunity to explore both the “outer shell” of cognitive functions and the “inner shell” of neurobiological processes and their mutual interactions. Major progress, however, will crucially depend on multiprofessional cooperation and transdisciplinary understanding.

We recommend this first of a hopefully long series of annual reports on our work in the MPI of Cognitive Neuroscience to the attention of our gentle readers.

Angela D. Friederici
D. Yves von Cramon

Leipzig, February 1996

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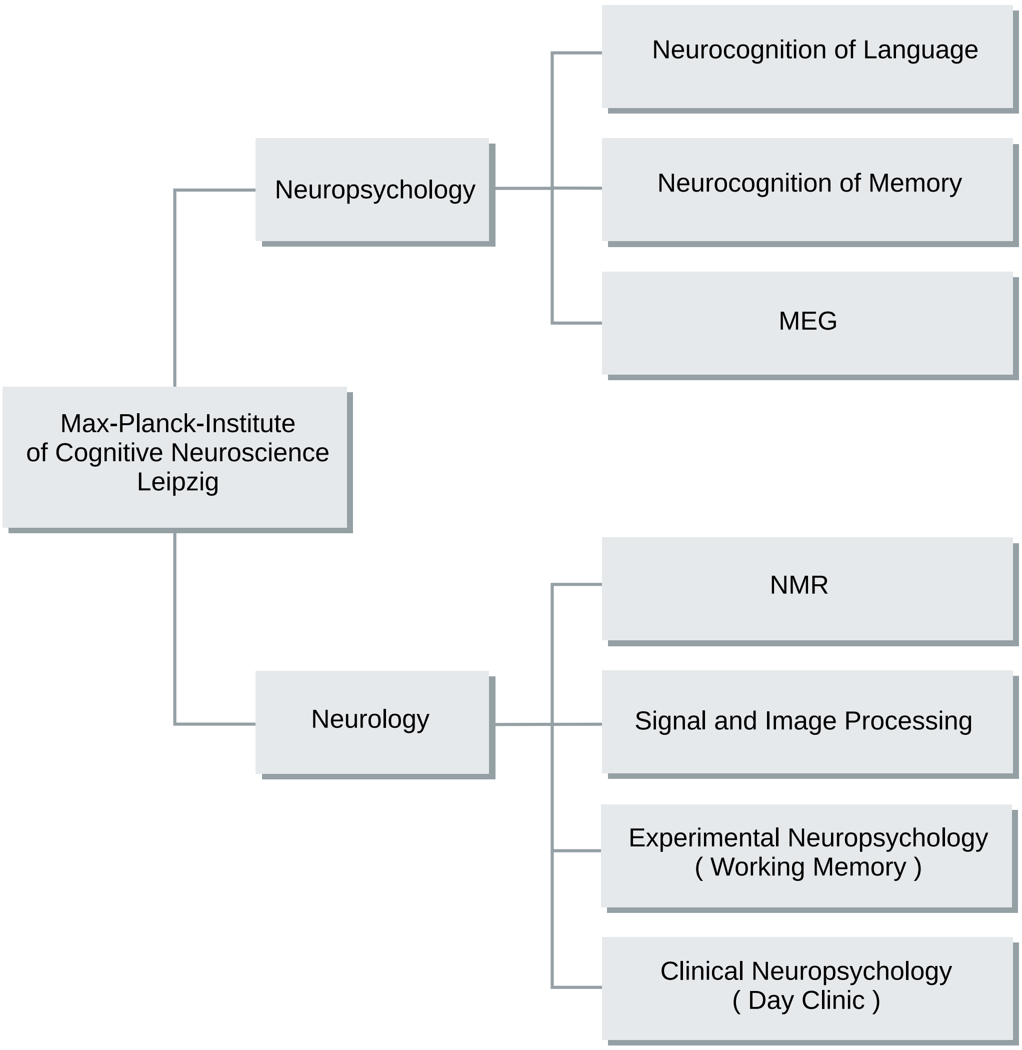
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NEUROCOGNITION OF LANGUAGE 3.1

Language processing and its functional representation in the brain is a major research area in our institute. Psycholinguistic theorizing, neuropsychological and neurophysiological modeling, together with empirical data from patients with circumscribed brain lesions, as well as from normals, are considered in building a picture of the language-brain relationship. Behavioral measurements, as well as measurements of the language-related brain activity (EEG, MEG, fMRI), are used to specify the processes and systems underlying language comprehension. The focus of on-going research is the relation between syntax, syntactic processing (parsing), and sentence comprehension in general. That is, we isolate structural factors in sentence comprehension and inquire into their relation to other factors such as lexical, semantic, and discourse information.

3.1.1 The time course of syntactic activation during language processing: A model based on neuropsychological and neurophysiological data

Friederici, A.D.

Friederici (1995) formulated a model describing the temporal and neurotopological structure of syntactic processes during comprehension which is based on morpho-psychological as well as neurological data. The model postulates three distinct phases of language comprehension, two of which are primarily syntactic in nature. During the first phase the parser assigns the initial syntactic structure on the basis of word category information. These first-pass parsing processes are assumed to be subserved by the anterior parts of the left hemisphere, as event-related brain potentials show this area to be maximally activated when phrase structure violations are processed and as circumscribed lesions in this area lead to an impairment of the on-line structural assignment. During the second phase, lexical-semantic and verb-argument structure information is processed. This phase is neurophysiologically manifest in a negative component in the event-related brain potential around 400 ms after stimulus onset. It is distributed over the left and right temporo-parietal areas when lexical-semantic information is processed, and over left anterior areas when verb-argument structure information is processed. During the third phase, the parser tries to map the initial syntactic structure onto the available lexical-semantic and verb-argument structure information. In case of an unsuccessful match between the two types of information, reanalyzes may become necessary. These processes of structural reanalysis are correlated with a centro-parietally distributed late positive component in the event-related brain potential. The different temporal and topographical patterns of the event-related brain potentials, as well as some aspects of aphasics' comprehension behavior, support the view that these different processing phases are distinct and that the left anterior cortex, in particular, is responsible for the on-line assignment of syntactic structure. This model, as well as psycholinguistic considerations by Gorrell (1995), serve as the theoretical background for the current research in the language processing domain.

3.1.2 Mechanism of Reanalysis

Gorrell, P.

Although structural factors are well established in first-pass parsing, their role in reanalysis is less clearly understood. It may be that the case that structure is not a significant factor at all in reanalysis operations, or, perhaps, is only indirectly implicated, as suggested by recent work of Fodor & Inoue (1995). That is, first-pass operations require the close coordination of distinct processors (one of which is a specifically *structure*-based mechanism) but reanalysis operations are the product of a more interactive mechanism. But a more parsimonious hypothesis is that structural factors play a similar role in first-pass and reanalysis operations. This is the approach taken in Gorrell (in press, 1995 a,b,c), where it is argued that incremental parsing involves a continuous reanalysis of the previous structure as each new word of the input is analyzed. One generalization which emerges from this approach is that reanalysis is less complex when it simply requires adding structure to the computed representation than when this representation must be altered in some fundamental way (e.g. its basic geometry). This view is consistent with that of Friederici (1995), who observes that the latency of the positvity associated with reanalysis in ERP studies may be affected by type of reanalysis. That is, Friederici contrasts hierarchical restructuring (associated with longer latencies) with reindexation (associated with shorter latencies). What Friederici terms reindexation can be analyzed as structural addition, given certain specific assumptions concerning syntactic structure and processing.

3.1.3 First-pass versus second-pass parsing processes in a Wernicke's and a Broca's aphasic: electrophysiological evidence

Friederici, A.D., Hahne, A. & von Cramon D.Y.

Friederici, Hahne and von Cramon used an electrophysiological approach to evaluate the claim that a prominent feature of Broca's aphasia is the absence of automatic first-pass parsing processes. Electrophysiological studies of language parsing in normals seem to indicate that first-pass parsing processes are correlated with an early left anterior negativity, whereas second-pass parsing processes are reflected by a late positivity (Neville et al., 1991; Friederici et al., 1993).

Based on these findings, we predicted that a Broca patient should show no early left anterior negativity during sentence parsing, but only the late positivity, as the latter reflects controlled processes which are supposed to be intact in Broca's aphasia. Moreover, under the assumption that semantic processes are intact in Broca's aphasia, we expected to observe the N400 component usually found to correlate with semantic integration processes. In contrast, Wernicke's aphasia has been claimed to either suffer from a deficit of lexical representation (Grober et al., 1980), a delay in lexical integration (Hagoort, 1993) or from a loss of controlled processes in general (Milberg et al., 1987). Under the first hypothesis, we would expect the N400 component to be absent in a Wernicke patient, under the second we expect the N400 to be delayed and under the third, we would expect the early negativity to be present while the late positivity should be absent.

We tested these predictions in two aphasic cases: a Broca patient and a Wernicke patient. The individual case history is displayed below.

Patient	sex	Patient Age	Type of aphasia on AAT	Token test	Comp. in AAT	Ethiology	Lesion site
W.S.	m	62	Broca (100%)	9	114	CV	Left anterior
G.R.	f	37	Wernicke (72%)	36	93	CV	Left posterior

The material used was identical to that used with normal subjects (for details see Friederici, Pfeifer, & Hahne, 1993). It consisted of sentences which were either correct

(1) or in which the final word (target) did not match the previous sentence context (prime) (2-4). The target either violated the prime fragment (2) in the lexical-semantic domain (selectional restriction violation), (3) in the phrase-structure domain or (4) in the domain of morpho-syntax.

(1) Correct sentence:
The finder was rewarded./ Der Finder wurde belohnt.

(2) Semantic violation:
The cloud was buried./ Die Wolke wurde begraben.

(3) Syntactic violation:
The friend was in the visited./ Der Freund wurde im besucht.

(4) Morpho-syntactic violation:
The treasure was guard./ Der Schatz wurde bewache. (1. Pers. Sing.)

There were a total of 240 sentences with 40 sentences in each category and additional filler sentences to balance the amount of correct and incorrect sentences.

Subjects seated in a comfortable chair were requested to carefully listen to sentences of the type described above and to indicate after each sentence whether the sentence heard was correct or not. Fifteen scalp electrodes were placed according to the 10-20 system (Jaspers, 1958) and additional sites of Broca's area and Wernicke's area on the left and the homologous areas on the right.

Performance data: Both subjects performed well on the judgement task. W.S. classified nearly all incorrect sentences (sem, 40; phrase, 39; morpho, 40) and correct sentences (corr: 37) correctly. G.R. classified most of the incorrect sentences (sem, 38; phrase, 39; morpho, 35) correctly, but was at chance level for the correct sentences (21).

ERP data: For W.S. we observed for the semantic condition, a N400 component between 500 and 950 msec, a late central positivity for the phrase structure condition (400-1100 msec), and a late positivity centroparietally (900-1500 msec) for the morpho-syntactic condition. There was no early left anterior negativity for the phrase-structure violation condition. For G.R. we observed an early left anterior negativity between 200 and 350 msec, followed by a very late positivity with a maximum at Pz (1200-1500 msec) for the phrase structure condition. For the morphosyntactic condition there was a late positivity between 1100 and 1500 msec. The N400 component for the semantic condition was absent, but there was a late posterior positivity starting as late as 1250 msec.

As predicted, the Broca patient W.S., unlike normals, showed no early left anterior negativity for the syntactic condition but, similar to normals, showed a late positivity.

This pattern could be taken to support the claim that this patient has lost the automatic first-pass parsing processes, but has retained secondary parsing processes which support his performance. Similar to normals, we observed a N400 component for the semantically incorrect sentences, suggesting that this patient's access and integration processes for lexical-semantic information are intact. The Wernicke patient G.R., in contrast, showed no N400 component suggesting that lexical processes are disrupted in this patient. Most interestingly, patient G.R., similar to young normals, showed an early left anterior negativity for the phrase structure condition indicating that the automatic first-pass parsing processes are intact.

This double dissociation is taken to support the view that first-pass parsing processes are not only functionally distinct from second-pass parsing processes, but that these are moreover subserved by different brain systems.

3.1.4 Neuromagnetic recordings during auditory sentence perception: Syntactic processes and the left anterior brain region

Maeß, B., Groß, J., Dammers, J., Barnes, G., Ioannides, A. A., Müller-Gärtner, H. W. & Friederici, A.D.

We report an event-related magnetic field study of auditory sentence perception focusing on semantic and syntactic aspects of language processing. Earlier ERP studies had shown differential patterns for the processing of semantic and syntactic aspect in auditory language perception with the first-pass syntactic processes inducing a particularily localized activity over the left anterior brain region (Friederici, Pfeifer & Hahne, 1993).

Five normal male volunteers who were healthy, right-handed and native speakers of German participated in the study. Their age ranged from 25 to 35 years. The sentence material presented as connected speech included correct sentences (50%), semantically incorrect sentences (25%) and syntactically incorrect sentences (25%). Semantic incorrectness was realized as a selectional restriction error (1) and the syntactic incorrectness was realized as a word category error (2).

(1) Semantic violation:

The honey was murdered./ Der Honig wurde <u>ermordet.</u>

(2) Syntactic violation:

The president was in murdered./ Der Präsident wurde in <u>ermordet.</u>

Subjects listened to 520 sentences presented in 4 blocks. 1000 ms after the offset of each sentence a probe word was presented and subjects were required to indicate whether this word had appeared in the previous sentence or not. Biomagnetic activity was recorded with a dual 37-channel magnetometer (Magnes BTi) positioned symmetrically over fronto-lateral sites of the left and the right hemisphere. The sampling rate was 1041 Hz (frequency band DC to 250 Hz). EOG, ECG and EMG were recorded to control for artifacts. MR images were taken for each of the five subjects and are included in analysis currently carried out.

Preliminary analysis for the individual subjects revealed similar brain responses between the subjects. For four out of five subjects, we observed a clear effect induced by syntactic incorrect sentences between 150 ms and 180 ms after onset of the critical word. The magnetic deflections were prominent over the anterior brain regions, more pronounced over the left hemisphere. Semantically incorrect sentences produced a more widespread magnetic deviation over both probes consistent with either deep or parietal generators.

The analysis conducted so far are in partial agreement with earlier results from studies using ERP measures. The present finding of a particular MEG pattern in correlation with the processing of syntactic parameters characterized by a left anterior dominance and an early presence supports earlier ERP findings (Friederici, Pfeifer & Hahne, 1993). The absence of a local MEG effect for the semantic processes is probably attributed to the fronto-lateral positioning of the probes. Earlier EEG studies have shown widespread activities in the parietal areas (Friederici, Pfeifer & Hahne, 1993; Kutas & Hillyard, 1980). An advantage of this probe positioning is that it makes easier the identification of deep activities, and hints of such activities for the semantic violation condition have been obtained using signal combinations from both probes. More detailed analysis to disentangle superficial and deep activities associated with either syntactic or semantic violations is now in progress.

3.1.5 The processing of syntactic and semantic violations: Do syntax negativity and N400 interact?

Friederici, A.D., Steinhauer, K. & Frisch, S.

In a recent ERP study it was demonstrated that the so-called phonological mismatch negativity (PMN, at about 150-350 msec) and the semantic N400 component (at about 350-600 msec) are elicited independently from each other and that both negativities can co-occur if the target word is both phonologically unexpected and semantically anomalous, thus indicating independent stages of word processing (Conolly & Philips, 1994). The present study was designed in order to find out whether a similar pattern could be observed for the relation between the early negative going waveform assumed to reflect the detection of syntactic violations during first-pass parsing, namely the early left anterior negativity (Neville et al., 1991; Friederici, Pfeifer & Hahne, 1993) the semantic N400. If these two components do not influence each other, first-pass parsing and semantic integration have to be viewed as independent processes during sentence comprehension. An influence of first-pass parsing processes on semantic integration, in contrast, could be taken to reflect serial, dependent processes.

Four types of sentences (with 80 trials in each condition) were presented word-by-word on a computer screen (300 msec of presentation, 200 msec ISI) and ended with the target word (past participle) which either was a correct sentence completion (1), or indicated a structural violation of a prepositional phrase (2) or a semantic anomaly (3), or both violations (4):

(1) Correct sentence:

Das Haus wurde bald gebaut.
The house was soon built.

(2) Syntactic violation:

Das Haus wurde vom gebaut.
The house was by built.

(3) Semantic violation:

Das Haus wurde bald gegessen.
The house was soon eaten.

(4) Synt. and sem. viol.:

Das Haus wurde vom gegessen.
The house was by eaten.

In order to balance the number of correct and incorrect sentences, filler sentences were added. To make sure that subjects actually processed the sentences, a probe identification task had to be performed (probe presentation began 800 ms after the sentence final word). EEG was recorded continuously at 15 electrodes sites. 16 German native speakers, university undergraduates with a mean age of 27 years (range = 21 - 33 years), participated in this study and were grouped according to their ‘Reading Span’ (Daneman & Carpenter, 1980) in subgroups of 8 low span (RS £ 3.0) and 8 high span readers (RS ≈ 4.0), respectively.

Performance data: For the response times, we found a main effect of syntactic violation ($p<.01$) in both subgroups, but neither a main effect of semantic violation nor an interaction. Effects of error rates only occurred in the low span subgroup, i.e. main effects of semantic ($p<.05$) and syntactic ($p<.05$) violation, but no interaction between the factors.

ERP data: The critical word for the evaluation of the ERP data was the sentence final past participle, because it was the only word to indicate whether a sentence was syntactically or semantically incorrect, or both. The time window of the auxiliary *wurde / was* was chosen as baseline. Analyses of variance (ANOVAs) included the factors SYN (syntactic violation), SEM (semantic violation) and RS-group (reading span) and were computed separately for three midline (FZ, CZ, PZ) and twelve lateral electrodes. The results were as follows (see also the grand average for all 16 subjects in Fig. 1):

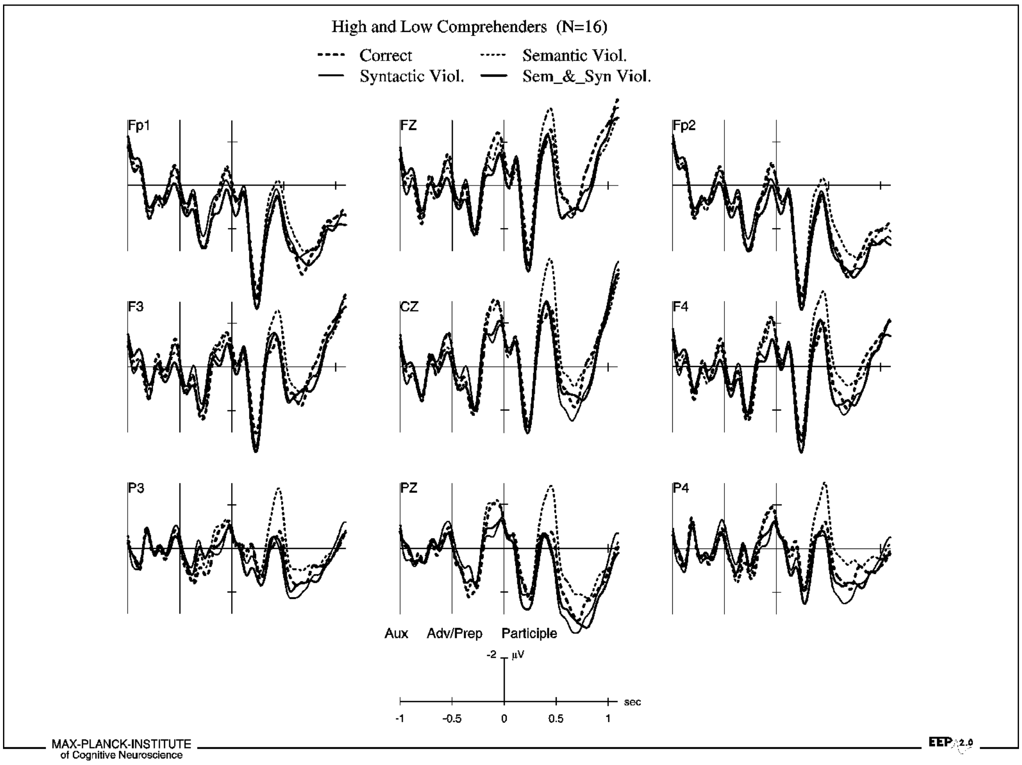

Figure 1: Average ERPs across all 16 subjects for 9 scalp electrodes and the four sentence types. Stimulus onset of auxiliary (-1000 ms), adverb/preposition (-500 ms) and target word (past participle; 0 ms) are indicated by vertical lines. The waveforms are plotted with negative amplitude up.

- Adverbs preceding the participle in conditions (1) and (3) elicited a larger N400 amplitude than prepositions in (3) and (4). Although this effect was completely confounded with the structural ‘SYN’ factor in statistical analyses, it should rather be attributed to differences in word category or word class, respectively (open vs. closed class elements).
- At lateral electrode sites an early frontal negativity (100 to 150 ms after onset of the past participle) for the syntactic violation conditions (2, 4) was found to be co-occurring with a posterior positivity in the same time interval. Since an early negativity was predicted for these conditions, we assume the component to reflect the detection of the structural violation. It must be noted, however, that a spill-over effect of the word class N400 from the preceding adverb and preposition, respectively as well as the presence of the offset-P200 of the preceding elements render such an interpretation more difficult.
- The most interesting result was that in both subgroups the N400 on the sentence final word as a correlate of semantic anomaly was only elicited in the pure semantic violation condition (3 vs. 1), but not in the combined violation condition (4 vs. 2: $F < 1$).

These data are in support of a serial model of language comprehension in which a first-pass syntactic parse not only precedes semantic integration, but in which the execution of the latter process is not independent of the former.

On the automaticity of syntactic processing

3.1.6

Gunter, Th. C., Friederici, A.D. & Mecklinger, A.

When reading a sentence, both a syntactic (structural) and semantic analysis is carried out in order to arrive at an understanding of the sentences (to achieve thematic role assignment). One of the most influential theories on syntactic processing (Frazier, 1987) hypothesizes a two stage model of syntactic parsing. When a word is processed, the initial analysis is strictly syntactic. Then, in a second step, this initial syntactic representation is evaluated on the basis of other sources of information such as semantical and pragmatic information. If there is an inconsistency between an initial selected syntactic structure and other information sources, the parsing system will carry out an additional syntactical re-analysis. One major question in psycho-physiological linguistics is how both processes are reflected in the electrical activity of the brain. At the moment there are two candidates for these syntactic processes namely the LAN (left anterior negativity) and the P600 component which can, for instance, be elicited by syntactic violations. Earlier experiments, which were carried out in Dutch, seem to suggest that the LAN reflects more automatic processes while the P600 seems to reflect more controlled processes. This experiment explores the automaticity issue using a levels of processing approach (see for instance Chwilla et al. (1995) who used a similar approach to explore the N400 component in priming). In particular, we were interested in the processing of syntactic violations under shallow and more demanding processing conditions.

The participants had to read sentences which were either correct or contained a syntactic violation at the sentence final word. In addition, the ending was either written in upper or lower case letters. In the experiment the participants had to carry out two different type of tasks which were presented in different taskblocks. In the first task they had to indicate whether or not the sentence was syntactically correct. In the second task, they had to indicate if one of the words in the sentence was presented in UPPER or lower case letters. During the first task, the subjects will have to process the syntactic information completely in order to give a correct answer. In the second task (UPPER/lower case) there is no need for processing the syntactic information. To state it in automaticity terms; in the first task one would expect reflections of both automatic and controlled syntactic processes while only more automatic processes should be reflected in the second task.

A total of 400 experimental sentences were created such that each sentence contained 7 words and ended with a verb. Of each of these sentences two further versions were made up which contained a syntactic error. The first type of syntactic error was a morpho-syntactic violation (2) which was realized by replacing the correctly inflected verb (i.e. past participle) with an incorrect form (i.e. infinitive). The second type of syntactic error (3) was realized by replacing the noun in the prepositional phrase by a verb. This type of error could be viewed as a word category error as the preposition *vom/by* requires a noun as a correct continuation. This particular preposition which was used in all sentences, moreover, signals the thematic role of an agent.

(A) Correct sentence:

Die weißen Zähne wurden vom Kind geputzt.
The white teeth were [by the] child brushed.

(B) Morpho-syntactic violation:

Die weißen Zähne wurden vom Kind putzen.
The white teeth were [by the] child brush.

(C) Syntactic violation:

Die weißen Zähne wurden vom geputzt.
The white teeth were [by the] brushed.

The sentences were allocated to 2 x 5 task blocks in which either a syntactic or a physical judgement has to be given for each sentence. Each task block contained 40 experimental sentences. The experimental sentences were divided such that there were 20 correct sentences, 10 morpho-syntactic violations and 10 syntactic violations. The assignment of an experimental sentence to a particular condition in a specific block was random. Half of the experimental sentences ended with upper case, the other half with lower case. From each block 16 versions were created which depended on correctness, upper/lower, and instruction such that across all subjects each sentence was presented in all of the possible conditions.

All sentences had a word-by-word presentation format (300 ms per word with a blank screen of 200 ms between the words). After the presentation of the sentence ending (period included) a blank screen (700 ms) and a fixation asterix (1500 ms maximal) were presented. Subjects were instructed to give their response after the fixation asterix had appeared. On the basis of this response a feedback stimulus was presented for 300 ms immediately after the occurrence of a response (i.e. correct, incorrect, 'faster' if the response was not within 1500 ms). Then the presentation of the next sentence started.

The sentences were presented to thirty-two native German speaking students (20 female, mean 21.7 years, age range 19 - 25 years) which were right handed and had normal or corrected-to-normal vision. The EEG was recorded with 60 Sn electrodes (electrocap) which were evenly distributed across the head. Each EEG-electrode was referred to the right mastoid. Bipolar horizontal and vertical EOG was recorded and used to identify trials containing eyemovement artifacts. The signals were amplified, bandpass filtered between .5 and 35 Hz and digitized at a rate of 250 Hz.

Because the data analysis is still in progress, we present preliminary and statistically untested ERP results. The ERPs of the morpho-syntactic violation show a clear N400 and P600 component compared to the correct ending in the syntactic judgement condition. This is in agreement with earlier findings from an auditory language processing ERP study which also found an N400, P600 complex for morpho-syntactic violations in German (Friederici, Pfeifer & Hahne, 1993). Both effects disappear in the physical judgement condition. These results suggest that the P600 (and N400) component elicited by morpho-syntactic violations do not reflect highly automatic processes. The data rather suggest that in morpho-syntactic violations the P600 indeed reflects more controlled syntactic processes.

The syntactic violation showed no left anterior negativity in either task. In the syntactic judgement task. In contrast to the morpho-syntactic violations however, these effects do not disappear in the physical judgement task. The syntactic violation also shows a N400 and P600 component. The absence of a early left anterior negativity is unexpected on the basis of earlier results from studies using word category violations (Friederici, Pfeifer & Hahne, 1993; Neville et al., 1991). In contrast to the present study these earlier experiments included a wide variety of prepositions. The present study only included the preposition *vom/by* signaling the thematic role of an agent. Given the fact that this was the only preposition used throughout the experiment, the ERP pattern may not primarily reflect structural aspects of processing but rather aspects of thematic role assignment. This type of violation, moreover, may have so salient that readers were not able to ignore it in the physical judgement task. Further experiments will have to show whether violations of thematic roles (independent of word category violations) generate similar N400 - P600 pattern.

3.1.7 Developmental aspects of language processing as revealed by ERPs

Hahne, A. & Friederici, A.D.

Hahne and Friederici are working on a project investigating functional brain organization processes during language development. Recent aphasia and ERP research suggests that fast and automatic syntactic processes are subserved by left anterior parts of the brain while left temporal/posterior parts of the brain may be responsible for the representation of grammatical (including lexical) knowledge. Reaction time data (Friederici, 1983) showed that children below the age of 9 do not seem to have established fast and automatic syntactic processes. A review and meta-analysis of childhood aphasia (Friederici, 1994) supported the idea that syntactic automaticity develops rather late as children younger than about age 9 do not show a fluent aphasia even with left temporal lesions. Based on this evidence, we hypothesize that there is a major functional reorganization of language-relevant brain areas during development: as syntactic processing becomes more and more automatic, left anterior parts of the brain become more involved in processing this type of information. In this project we test our hypothesis using electrophysiological measures.

In a first step we constructed stimulus materials adequate for children at primary school age including correct, semantically incorrect and syntactically incorrect sentences. The materials were tested in an extensive pretest involving a judgement task. 55 individually tested children listened to the sentences and judged for each of them whether it was correct or not. Children’s performance was near perfect for most items. There were only a few “outliers”, when children did not know the meaning of a single word. Subsequently, the stimulus materials were revised accordingly.

The experimental procedure for the EEG recording was adapted to children and a first set of ERP sessions was run. It turned out that, on behalf of the children, the testing situation requires much motivation as well as their ability to concentrate for quite a long time. While the eight year olds managed to do very well, it seems to be fairly difficult for 6 year old children. Nevertheless, Preliminary data analysis from 8 and 6 years old children indicates some clear developmental changes in ERP responses, in particular for the syntactic aspects of language processes.

3.1.8 Parsing preferences and their revisions as revealed by the late positivity in the ERP: Influences of revision complexity and of the point of disambiguation

Friederici, A.D., Steinhauer, K., Mecklinger, A. & Meyer, M.

A number of ERP studies investigating syntactic parsing have reported a late positivity as one of two ERP components in correlation with syntactic processes. The late positivity can be considered to reflect additional syntactic processes, be it that a phrasal structure has to be revised in so-called ‘gardenpath’ sentences or be it in the case of outright structural violations (Osterhout & Holcomb, 1992; Osterhout et al., 1994; Hagoort et al., 1993). Whereas this component usually occurred with a peak latency of about 600 ms (‘P600’), a recent study by Mecklinger, Schriefers, Steinhauer & Friederici (1995) reported a positivity with a latency of only 345 ms when the disambiguating sentence final auxiliary required the recovery from the initially preferred subject relative reading to the non-preferred object relative (1b) reading, in German. Theoretical considerations suggest that, in contrast to most other gardenpath sentences used in ERP studies, the revision processes required in German object relative clauses are less complex since only a change of the grammatical function of an already identified filler (i.e., the relative pronoun) but no rebuilding of the hierarchical phrase structure is necessary. This led us to the hypothesis that not only the amplitude of the late positivity is correlated with the ‘cost of processing’ (Osterhout et al., 1994), but also the latency might vary as a function of the complexity of revision processes (i.e., longer latencies for more complex revisions).

Relative Clauses (SR = subject relative, OR = object relative)

(1a) SR: *Das sind die Professorinnnen, die*$_1$ *[*t_1*] die Studentin gesucht haben.*

These are the professors that the student sought have.

(1b) OR: *Das sind die Professorinnen, die*$_2$ *die Studentin [*t_2*] gesucht hat.*

These are the professors that the student sought has.

Verb Complement Clauses (SF = subject-first, OF = object-first)

(2a) SF: *Er wußte, daß die Professorinnnen die Studentin gesucht haben.*

He knew that the professors the student sought have.

(2b) OF: *Er wußte, daß die Professorinnen*$_1$ *die Studentin* $[t_1]$ *gesucht hat.*

He knew that the professors the student sought has.

In order to test this hypothesis, Friederici, Steinhauer, Mecklinger, and Meyer ran an experiment using subject (1a) and object relative (1b) as well as subject-first (2a) and object-first (2b) complement clause sentences. Note, that all sentences contained feminine case ambiguous noun phrases and could only be disambiguated between subject and object relative reading at the number marked sentence final auxiliary. The revision of a complement clause in favor of the non-preferred object-first structure is much more complex than that required by an object relative clause because the parser has to posit a filler-trace relation where a filler has not yet been identified. We therefore predicted the late positivity's latency to be increased compared to object relative clauses.

Two additional factors relevant for the parsing of these sentence types were investigated: (a) a linguistic factor concerning the point of disambiguation and (b) a psychological factor, namely the subject's working memory capacity as measured in a reading span test (Daneman & Carpenter, 1980). As the local ambiguity in the sentences displayed above results from the absence of overt case marking in the feminine pronoun and NPs, the factor of case marking was tested by replacing the unmarked feminine pronoun (*die* [NOM & ACC] NPs (*die Studentin* [NOM & ACC] by case marked masculine pronouns (der [NOM] / den [ACC]) and NPs (*der* Student [NOM] / *den Studenten* [ACC]) which allow a very early disambiguation of the sentence structure during reading. In these sentences we expected the late positivity to be elicited by the disambiguating object relative pronoun or first NP in the object first complement clause, respectively, whereas it should be absent at the sentence final auxiliary. The impact of working memory was examined since in an earlier study only high span readers had shown reliable ERP effects of immediate structure revision (Mecklinger, Schriefers, Steinhauer & Friederici, 1995).

10 high span and 10 low span subjects had to read 512 sentences (64 per condition) which were presented word-by-word on a computer screen, followed by a simple 'yes/no'-question (e.g., '*Was the professor sought?*'). EEG was recorded continuously at 25 electrode sites.

Performance data: Analyses of the performance data revealed that object-first complement clauses, which require the complex revision process, led to dramatically increased error rates and RTs in all subjects and that early disambiguation due to overt case marking generally results in a better comprehension (less errors and shorter RTs), especially for low span readers. High span subjects made less errors and responded slightly faster than low span subjects.

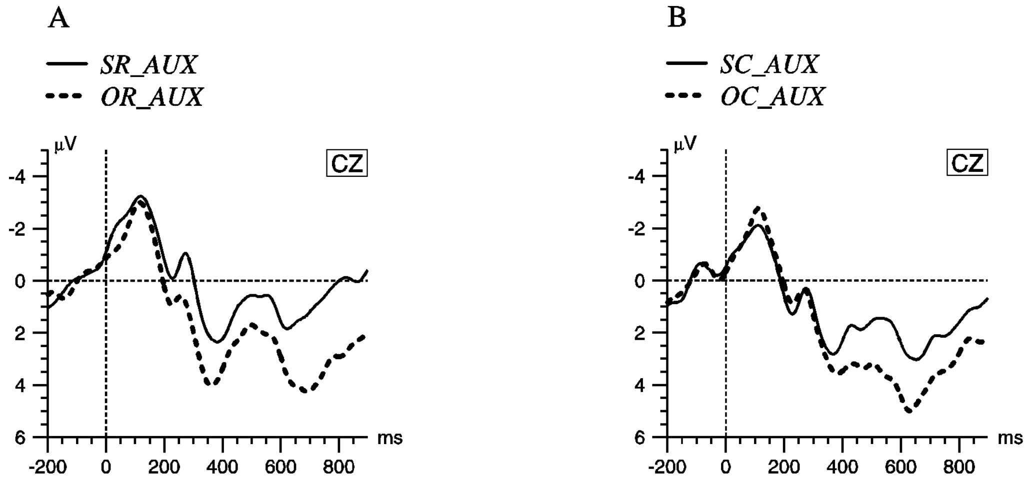

Figure 1: Grand average ERPs for the high span group elicited at CZ by the disambiguating auxiliary. A: ERPs for subject and object relative clauses with case ambiguous NPs. B: ERPs for subject- and object-first complement clauses containing case ambiguous NPs.

ERP data confirmed our hypotheses. First, in case ambiguous clauses the non-preferred object-first readings showed a late positivity elicited by the disambiguating auxiliary sentence final. Second, the latency of this positivity was increased in object-first complement clauses compared to object relative clauses, i.e. an early effect (300 - 400 ms) was significant only in the relative clauses, whereas a late effect (600 - 900 ms) occurred in both relative and complement clauses (Fig. 1a,b). These effects were found only for high span but not for low span readers.

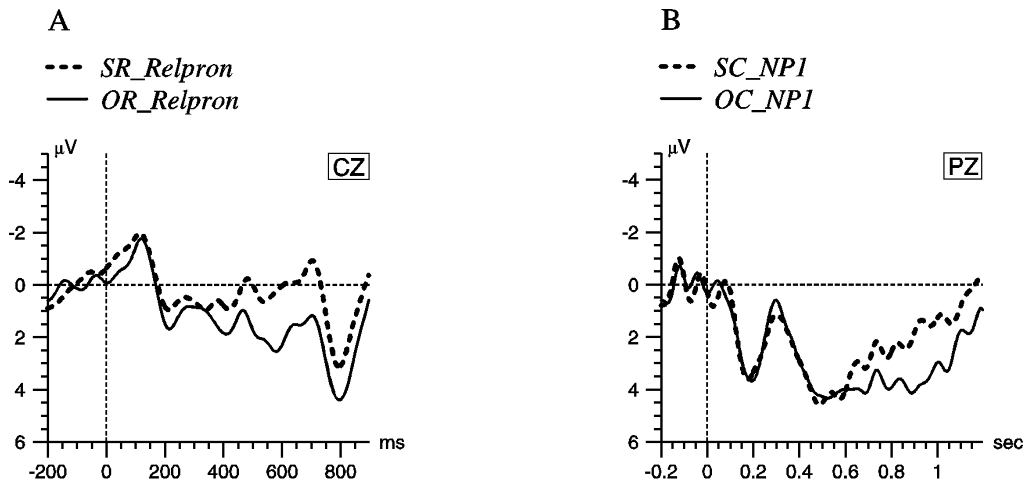

Figure 2: Grand average ERPs for all 20 subjects. A: ERP elicited by the disambiguating case marked relative pronoun in subject and object relative clauses at CZ. B: ERPs elicited by the disambiguating case marked first NP in subject- and object-first complement clauses at PZ. In the case marked sentences, high span readers did not show any effects at the sentence final auxiliary. Instead, as predicted, a late positivity was elicited by the disambiguating relative pronoun (600 - 900 ms; Fig.2a) or by the noun phrase (900 - 1100 ms; Fig.2b), respectively, when initially preferred subject-first structures had to be revised in favor of an object-first reading. These latter effects of early disambiguation were also found for low span readers.

Taken together, the results confirm the notion that revision processes are always reflected by a positivity in the ERP and that it's latency varies as a function of the complexity of these processes. High span readers generally use disambiguating information as soon as possible in order to assign a structure on-line. Low span readers are sensitive to the disambiguating information, but do not seem to use this information for ultimate assignment. They seem to complete their assignment not before the sentence final auxiliary is processed.

3.1.9 The impact of probability on late positivities co-occurring with syntactic revision processes

Friederici, A.D., Steinhauer, K., Mecklinger, A. & Meyer, M.

Some researchers view the late positivities elicited during the parsing of syntactic anomalies to be specifically linked to additional syntactic processing (Osterhout & Holcomb, 1992; Hagoort, 1993), whereas others challenged this interpretation by showing that the 'positive syntactic shift' behaved very similarly to the non-linguistic P300 component, reflecting domain unspecified processes of context updating in working memory (Gunter et al., 1995; Coulson et al., 1995). That is, the amplitude decreased with increasing probability of occurrence for the syntactic anomalies.

The present experiment addresses two major questions: First, two different types of syntactic anomalies requiring either a very easy (object relative clauses) or a very complex (object complement clauses) revision process were introduced in order to examine if the probability effect occurs independently from such differences. Second, a recent study (Mecklinger, Schriefers, Steinhauer & Friederici, 1995) reported that two late positivities with different latencies (i.e., P350 and P600, respectively) were generated during the recovery from the preferred subject relative reading to the non-preferred object relative reading. If these two components reflect different cognitive processes, we expect them to be differentially influenced by probability variations.

Four locally ambiguous sentence types were used, namely preferred subject-first and non-preferred object-first structures of both, relative and verb complement clauses, the latter requiring the more complex revision. (For examples and details concerning presentation mode and tasks see Friederici, Steinhauer, Mecklinger & Meyer, section 3./.8) Subjects were 16 university undergraduates with a high reading span (RS $\approx$ 4.0) according to the reading span test (Daneman & Carpenter, 1980). A total of 768 sentences were constructed (192 per sentence type) and distributed over 12 blocks of 64 sentences each: Six of these blocks were composed of 75% subject-first sentences and 25% object-first sentences (hereafter: S-blocks), the other 6 blocks were composed of 75% object-first sentences and 25% subject-first sentences (hereafter: O-blocks). Thus, each of the four sentence types occurred with either a high probability or a low probability depending on the respective block. Every subject participated in three sessions comprising two subsequent S-blocks followed by two subsequent O-blocks, or vice versa. That is to say that in each session the probability changed only once (i.e., from 25% to 75%, or the reverse). The sequence of blocks was counterbalanced across subjects.

Preliminary data of 8 subjects revealed the following results: Performance was much better for subject-first than for object-first structures. A main effect of probability demonstrated that all sentence types led to less errors an shorter response times if the respective sentence type occurred with a high frequency (e.g., an object-first structure in an O-block). Object-first complement clauses which required a complex revision process, showed the highest error rates and longest RTs in all three sessions, also contributing to a main effect of sentence type (relative clauses < complement clauses). In the ERP we found a frontal positivity co-occurring with a bilateral temporal negativity at approximately 350 msec after onset of the disambiguating sentence final auxiliary for the 25% conditions compared to the 75% conditions. This result suggests, that probability does have an effect at least in the time domain of the P350. Further data evaluation is in progress.

3.1.10 Processing temporary ambiguous sentences: Effects of case marking and verb argument structure

Schriefers, H., Friederici, A.D. & Scharfenberg, C.

The present study was designed to investigate parsing preferences in locally ambiguous sentences. The particular type of syntactic structures makes use of a particular type of ambiguity in the German case marking system: (genitive and dative for feminine singular nouns like *der Studentin* [genitive or dative]. We compare the processing of locally ambiguous sentences like (1), (3), (5), (7) with corresponding sentences not containing an ambiguous case marking like (2), (4), (6) and (8), (e.g., *des Studenten* [masculine singular, genitive] vs *dem Studenten* [masculine singular, dative]).

Subjects were presented with 16 variations of sentences of the following type:

(1)	Er wußte daß	die Professorin	der Studentin	dem Mitarbeiter	den Scheck	gab.
	He knew that	*the professor*	*the student*	*the coworker*	*the cheque*	*gave.*
(2)	Er wußte daß	die Professorin	des Studenten	dem Mitarbeiter	den Scheck	gab.
	He knew that	*the professor*	*the student*	*the coworker*	*the cheque*	*gave.*
(3)	Er wußte daß	die Professorin	der Studentin		den Scheck	gab.
	He knew that	*the professor*	*the student*		*the cheque*	*gave.*
(4)	Er wußte daß	die Professorin	dem Studenten		den Scheck	gab.
	He knew that	*the professor*	*the student*		*the cheque*	*gave.*
(5)	Er wußte daß	die Professorin	der Studentin	den Mitarbeiter		vorstellte.
	He knew that	*the professor*	*the student*	*the coworker*		*introduced.*
(6)	Er wußte daß	die Professorin	dem Studenten	den Mitarbeiter		vorstellte.
	He knew that	*the professor*	*the student*	*the coworker*		*introduced.*
(7)	*Er wußte daß*	*die Professorin*	*der Studentin*		*den Scheck*	*sah.*
	He knew that	*the professor*	*the student*		*the cheque*	*saw.*
(8)	*Er wußte daß*	*die Professorin*	*des Studenten*		*den Scheck*	*sah.*
	He knew that	*the professor*	*the student*		*the cheque*	*saw.*

In the sentence (1), (3), (5), (7), the NP *der Studentin* is ambiguous between a genitive attribute of the NP *die Professorin* and an indirect object (dative) of the verb. We assumed that the NP *der Studentin* will in first instance be interpreted as an indirect object (as should be predicted by the parsing principle "minimal attachment"). In (1), this first analysis will turn out to be incorrect when reading the NP *dem Mitarbeiter* which is unambiguously marked as a dative. In (3), this first analysis as an indirect object is not undermined by the next NP *den Scheck* that is unambiguously marked as an accusative, and thus will be assigned to the function of direct object. If this direct object is indeed followed by a verb allowing for a direct and an indirect object (like (3) and (4)), then this analysis is correct. However, if this sentence is continued by a strictly transitive verb like *sah* in (7), the indirect object analysis of the NP *der Studentin* turns out to be incorrect. In (5) by contrast, the ambiguous NP *der Studentin* is first followed by a noun phrase in accusative case, and the following verb discolors that the ambiguous NP *der Studentin* has to be analyzed as a NP in dative case. In (2), (4), (6) and (8) the reading of the sentence is disambiguated early by the case marking in the second NP (e.g. *des Studenten* or *dem Studenten*). Thus, these conditions serve as two unambiguous control conditions against which the performance in the respective ambiguous condition can be compared.

In Experiment 1 we used sentences of the type (1) through (4). 16 subjects participated in the experiment. Each subject received 32 sentences, each sentence being presented data each of the conditions exemplified in (1) through (4).

Subjects read the sentences in a so-called self-paced reading paradigm. By pressing a push-button, the subjects requested the first word of a sentence. With the next press of the push-button, this word was replaced by the second word of the sentence, and so on, until the subject had read the final word of the sentence. With the next button press two question marks appeared on the screen. 500 msec after appearance of the question marks, a yes / no question concerning the preceding sentence appeared on the screen. Subjects answered this question by pressing either the left (= yes) or the right (= no) button of a two-push-button-panel. After having answered the question, the subject requested the first word of the next sentence.

Table 1 gives the mean reading times per word for six reading zones for sentences with a correct answer to the subsequent question.

	Zone 1: *Er wußte, daß*	Zone 2: *die Professorin*	Zone 3: *der Studentin* *des Studenten* *dem Studenten*	Zone 4: *dem Mitarbeiter*	Zone 5: *den Scheck*	Zone 6: *gab*
(1)	367	392	408	460	432	555
(2)	360	381	408	423	401	535
(3)	362	374	402	/	432	527
(4)	363	380	401	/	392	516

The reading times for Zone 1 do not differ significantly between the conditions (1) trough (4). The same holds for the reading times for Zone 2 and Zone 3. Reading times for Zone 4 show significantly longer latencies for condition 1 (i.e. the condition with the case-ambiguous NP *der Studentin* in Zone 3) than for condition 2 (i.e. the condition with the unambiguous NP *des Studenten* in Zone 3). The same pattern is obtained for Zone 5 and, at least in tendency for Zone 6.

At first sight this result appears to confirm the idea that readers first analyze the case-ambiguous NP in Zone 3 of condition 1 as a dative as predicted by the principle of minimal attachment, the dative NP (e.g. *dem Mitarbeiter*) appears to enforce a revision of this first analysis to a genitive interpretation, and this is reflected in longer reading times in Zone 4 through 6 of condition (1) as compared to the unambiguous control condition (2).

However, in condition (3) the material contained in Zone 5 and 6 requires an analysis of the ambiguous NP of Zone 3 as a dative NP. If the initial syntactic analysis of the ambiguous NP in Zone 3 would be "dative", there should be no prolongation of reading times in Zone 5 and 6 of condition 3 as compared to the unambiguous control condition (4). In contrast to this prediction, also the comparison of conditions (3) and (4) reveals longer reading times for the disambiguating Zones 5 and 6 of condition (3) relative to the Zones 5 and 6 of condition (4).
Taken together, the results of this first experiment suggest that readers do not commit themselves to either a dative or a genitive "analyses on reading a case-ambiguous NP like *der Studentin*". Rather it appears as if readers are considering both options. The choice for one of these two options that is made on reading Zone 4 through 6 then leads to a cost in terms of reading time in the locally ambiguous conditions (1) and (3) as compared to their respective unambiguous control conditions (2) and (4).

Closer consideration of the conditions of Experiment 1 might give rise to the suspicion that subjects were using a strategic approach for coping with the case-ambiguous noun-phrase. After all, it is the case that if the case-ambiguous noun-phrase is followed by a noun-phrase in accusative case (condition (3)) the ambiguous noun-phrase will eventually be analyzed as dative case. On the other hand, if the case-ambiguous noun-phrase is followed by a noun-phrase in dative case, the ambiguous noun-phrase is eventually analyzed as genitive case.

The fact, that the noun-phrase immediately following the ambiguous noun-phrase does, in the context of the whole experiment, provide a reliable cue as to the eventual analysis, subjects might have refrained from making any immediate commitment concerning the syntactic analysis of the case-ambiguous noun-phrase. As a consequence, the overall ambiguity effect observed in experiment 1 might be a reflection of some strategy induced by the composition of experimental conditions.

Therefore, in Experiment 2 we included four additional conditions that should prevent subject from adopting such a potential strategy. In particular, by introducing conditions (5) through (8), subjects can not "guess" the eventual analysis on the basis of the fact that a noun-phrase in accusative case is following the case ambiguous noun-phrase.

Twenty-four subjects (6 male, 18 female, between 20 and 36 years old, mean about 26,3 years) participated in the experiment.

Sixteen sentences were constructed for Experiment 2. Each subject saw each of the sixteen sentences in the eight experimental conditions exemplified above. In all other respects of the experimental procedure the experiment was identical with Experiment 1.

Table 2 gives the mean reading times per word for the eight experimental conditions. The mean reading times are based on only those sentences to which subjects had given a connect response on the subsequent yes / no question.

	Zone 1:	Zone 2:	Zone 3:	Zone 4:	Zone 5:	Zone 6:
	Er wußte daß	*die Professorin*	*der Studentin (1,3,5,7)* *des Studenten (2,8)* *dem Studenten (4,8)*	*dem Mitarbeiter (1,2)* *den Mitarbeitern (5,6)*	*den Scheck*	*gab (1-4)* *vorstellte (5,6)* *sah (7,8)*
(1)	484	554	604	691	647	930
(2)	497	571	582	647	605	912
(3)	514	571	620	/	617	965
(4)	497	572	604	/	569	884
(5)	495	574	618	658	/	1153
(6)	495	566	602	653	/	1072
(7)	498	574	623	/	648	1258
(8)	498	564	579	/	606	907

First of all, the pattern of results for conditions (1) through (4) is identical with the pattern obtained in Experiment 1. Thus, the inclusion of conditions (5) through (8) does not influence the result pattern, identicating that the results of Experiment 1 are not due to a strategic component that has been induced by the composition of experimental conditions.
However, in contrast to Experiment 1 we are now also obtaining a slight effect on Zone 3, with case-ambiguous noun phrases leading to longer reading times than their unambiguous counter parts. Furthermore, conditions (5) through (8) also show a general slowing of reading times in the zones disambiguating a case-ambiguous noun phrase, as compared to the same reading zones following an unambiguous noun phrase in Zone 3. For conditions (5) vs (6) this effect occurs on Zone 6 (the verb). For conditions (7) vs (8), the corresponding effect occurs in Zone 5 and 6.

In general, Experiment 2 confirms the results of Experiment 1. We obtain an overall “ambiguity effect” for the reading times of zones disambiguating a locally ambiguous noun phrase (in Zone 3). There is no evidence for a particular preference for an initial commitment towards either a genitive or a dative analysis of the case-ambiguous noun phrase. In this respect, the results are in conflict with the “minimal attachment principle” that would predict an early commitment towards a dative analysis on reading the case-ambiguous noun phrase. Rather, the results appear to favor a model in which both possible analyses are considered in parallel. Later resolution towards one of these analyses induces a processing lost that is reflected in longer reading times on the disambiguating zones.

One aspect of the results of Experiment 2 deserves special mentioning. The comparison of the verb reading times (Zone 6, verbs like *sah*) for condition (7) and (8) reveales a particularly large ambiguity effect (1258 msec vs 907 msec). This might be due to the fact that subjects, on reading a accusative noun phrase like *den Scheck* in Zone 5 first make a commitment to analyzing the ambiguous noun phrase in Zone 3 as a dative (*dem Scheck*) by misreading the case marking in the article. However, the following verb (e.g. *sah*) in Zone 6 then enforces a re-reanalysis as it now turns out that the preceding ambiguous noun phrase has nevertheless to be analyzed as a genitive.

3.1.11 Information types and first-pass parsing

Gorrell, P.

Previous experimental work using event-related potentials (Mecklinger, Schriefers, Steinhauer & Friederici, 1995) and a self-paced reading task (Schriefers, Friederici & Kühn, 1995) yielded results consistent with first-pass attachment preferences being governed by a syntactic parsing strategy (the *Active Filler Strategy* [AFS] of Frazier & Flores d'Arcais, 1989) rather than by information concerning semantic plausibility. But other experimental studies using different structures and a different language (English) suggest that plausibility information can influence first-pass operations. It may be that, as Schriefers *et al.* suggest, this is due to the fact that, unlike the English studies, in the German relative-clause structures tested by Schriefers *et al.* and Mecklinger *et al.*, the relevant semantic information occurred late in the sentence or clause, after the point at which an incremental, serial parser is forced to make structural commitments.

Gorrell designed a self-paced reading experiment to test the hypothesis that semantic plausibility information can influence first-pass operations, provided that it is available prior to the parser making an attachment decision based on structural factors. The Mecklinger *et al.* and Schriefers *et al.* studies contrasted temporarily-ambiguous subject and object relative clause structures and found an AFS-predicted preference for subject relatives. In both structures the noun head of the relative clause was [+ animate]. In the designed experiment, the head of the relative will be either [+ animate] or [- animate]. Inanimate nouns are less-likely subjects than animate nouns. If the previously-observed subject preference is evident in the [- animate] condition, then we have evidence that the AFS exerts a stronger influence on early parsing decisions than plausibility information. On the other hand, if the AFS effect is not observed in this condition, we will have evidence that syntactic parsing strategies can be influenced by plausibility information that is available prior to structure-based commitments.

Processing of locally ambiguous sentence structures in aphasia

3.1.12

Hofmann, M. & Friederici, A.D.

Recent research in Broca's aphasia provided evidence for preserved grammatical capabilities in agrammatic aphasics. Therefore, the hypothesis of a general breakdown in syntactic processing may not explain the patients' disturbances. In the last few years limitations of processing resources (e.g. temporal mismatches or reductions of short term verbal memory) are taken into account. But some authors argued that agrammatic behavior is the product of strategies rather than a reflection of the underlying deficit itself.

One aim of the present study conducted by Hofmann and Friederici was to examine whether aphasics employ semantic and/or syntactic information to interpret locally ambiguous sentences, or whether their behavior is dominated by the use of strategies like the actor-first-principle. A second purpose was to investigate whether the performance is influenced by the mode of stimulus presentation or the patients' memory capacity. To address these questions an off-line paradigm was used.

Well-formed sentences which contained either a subject relative (a) or an object relative clause (b) were presented. Each sentence was followed by a question on the thematic roles expressed in the relative clause (c) that had to be answered with yes or no. There were two different modes of presentation. In the auditory condition subjects only heard the sentences as running speech. In the auditory-plus-visual condition they additionally received a printed version of the stimuli which allowed a permanent availability of the input. In both cases they had as much time as they needed to answer the question.

The nouns, their definite articles and the relative pronoun of each sentence were ambiguous with respect to case because of the absence of overt case marking (nominative vs. accusative) in German feminine noun phrases. Therefore, in the neutral condition (1) both nouns are equally likely to be the agent of the relative clause until the auxiliary occurs. In the bias condition (2), the past participle of the main verb introduces semantic/pragmatic information. Thus, before syntactic disambiguation is possible one of the two noun phrases is more likely to be the agent.

(1) NEUTRAL CONDITION

(a)	*Das ist*	*die Polizistin,*	*die*	*die Diebinnen*	*gesehen*	*hat.*
	This is	the police officer,	that	the thiefs	seen	has.
(b)	*Das sind*	*die Diebinnen,*	*die*	*die Polizistin*	*gesehen*	*hat.*
	These are	the thiefs	that	the police officer	seen	has.

(2) BIAS CONDITION

(a)	*Das ist*	*die Polizistin,*	*die*	*die Diebinnen*	*verhaftet*	*hat.*
	This is	the police officer,	that	the thiefs	arrested	has.
(b)	*Das sind*	*die Diebinnen,*	*die*	*die Polizistin*	*verhaftet*	*hat.*
	These are	the thiefs	that	the police officer	arrested	has.

(c) *Wurde(n) die Polizistin (Diebinnen) gesehen/verhaftet?*
Was (were) the police officer (thiefs) seen/arrested?

In addition, all subjects participated in a verbal memory span test involving three different types of word lists (concrete nouns, abstract nouns and function words). All lists contained one-syllable words. The word lists were of different size varying from one to eight items. There were ten different item lists at each size. The lists were read to the subjects who were required to recall the words in the exact order of appearance.

Six Broca's aphasics, six Wernicke's aphasics and a group of twelve age-matched controls served as subjects. Patients were selected according to classification (Aachen Aphasia Test) and CT lesion information (left anterior vs. left posterior lesions).

In the auditory condition the Broca's aphasics as well as the age-matched controls showed a significant main effect of semantic bias in their answering performance. Independent of syntactic structure semantically biased participles led to less errors than neutral participles. For the Wernicke's aphasics, in contrast, no such semantic effect was observable. Moreover, for both patient groups there was a tendency for subject relative clauses to be easier than object relative clauses.

In the auditory-plus-visual condition a significant effect of semantic bias was found for the Broca's aphasics as well as the control subjects. Additionally, these groups showed a weak interaction of syntax structure and semantic bias. For the Wernicke's aphasics we found a significant effect of semantic bias, but also a marginal syntax effect.

Verbal memory span for aphasics was decreased in both, Broca's and Wernicke's patients compared to age-matched controls. The controls were able to recall at least six items. The aphasics, in contrast, were able to recall only two to four items. Broca's and Wernicke's aphasics showed a very similar pattern of verbal memory performance. There was no significant difference for the three types of word lists.

A correlational analysis of subjects performance on sentences of the main experiment and the mean memory span revealed one single significant correlation. For Broca's aphasics the performance on neutral object relative clauses correlated with the memory span in the auditory condition.

The results showed that in both presentation conditions Broca's aphasics did profit from the presence of a semantic bias. Furthermore, the data reflected their sensitivity to syntactic information. Qualitatively, the patterns of Broca's aphasics and age-matched controls were quite similar. This could be interpreted as a further indication that the comprehension deficit in Broca's aphasics observed in some on-line task may be due to the on-line nature of language input in these studies. The data moreover show that the patients' performance is not determined by their verbal short term memory capacity.

3.1.13 The role of prosodic information in normal and aphasic processing of temporary ambiguous sentence structures

Höhle, B., Hofmann, M. & Friederici, A.D.

Höhle, Hofmann and Friederici carried out an investigation of the function of prosodic information during sentence processing. Prosodic information seems to play a crucial role in the marking of the syntactic boundaries of the speech signal. This has been shown for syntactically ambiguous sentence where the ambiguity results from different possible positions for phrase boundaries. Acoustic analyses of the different interpretations of those sentences show differences in F0-contour, in pausing and segment length in the critical domains (Lehiste, 1973; Scott, 1982). The results of recent on-line experiments suggest that this information is used immediately in the syntactic structuring of the incoming speech signal (Marslen-Wilson et al., 1992; Nagel, Shapiro & Nawy, 1994).

Until now the knowledge about neuropsychological aspects of processing of prosodic information has been very fragmentary. Results of an investigation using the dichotic listening technique indicate that the right hemisphere is more important for the processing of prosodic information than for other types of linguistic information (Blumstein & Cooper, 1972). On the other hand, experiments with aphasics suggest that aphasics perform worse than normals, and even worse than patients with right-hemisphere damage in tasks where prosodic information has to used to differentiate between two possible syntactic structures of an utterance (Baum et al., 1982; Blumstein & Goodglass, 1974; Emmorey, 1987; Weniger, 1979). Furthermore, Weniger (1989) investigating prosodic aspects at the lexical level showed that this impairment is not associated with an inability to differentiate prosodic patterns per se. This result could mean that aphasics are sensitive to prosodic features but that they are impaired is using this information in its structuring function. This, in turn could be related to agrammatics' well-known problems of understanding sentences. The aim of our study was to get a clearer picture of the abilities of aphasic patients to use prosodic information during the processing of spoken language.

The sentence materials consisted of 12 pairs of sentences with local syntactic ambiguities. All sentences contained a main clause and an infinitive clause. The members of one pair differed in respect to the nonfinite verb. In one sentence (1) the nonfinite verb was transitive. In these cases the second NP of the sentence is the object of the nonfinite verb and the boundary between matrix and infinitive clause lies before the second NP. In the other sentence (2), the nonfinite verb was intransitive. In these cases the second

NP of the sentence is the object of the finite verb and the boundary between matrix and infinitive clause lies after the second NP.

(1) Peter versprach Anna zu lieben und sie heiraten zu wollen.
Peter promised Anna to love and to marry her.

(2) Peter versprach Anna zu kommen und ihr Blumen mitzubringen.
Peter promised Anna to come and to bring her some flowers.

The two sentences of each pair were lexically identical and syntactic ambiguous up to the nonfinite verb, which resolved the ambiguity of the sentence. All stimulus sentences were recorded by a female speaker. Afterwards the members of each pair were cross-spliced. Each sentence was spliced after the infinitival marker *zu*. Then the first part of the sentence type (1) was combined with the second part of the sentence type (2) and vice versa. In the experiment a word monitoring task was used. While listening to the sentences the subjects had to press a button whenever they heard the word *und* which appeared in all critical sentences just after the nonfinite verb. Our assumption was the following: If prosodic information is used to build up a syntactic structure for the incoming signal immediately, the nonfinite verbs in the cross-spliced sentences cannot be integrated into the built-up structure. This should cause reanalysis, which is expected to result in a delay of monitoring latencies in the cross-spliced sentences.

First, the experiment was run with 24 students. A clear effect of splicing only appeared in monitoring latencies for the sentences with intransitive nonfinite verbs. The difference between the spliced and unspliced versions of the sentences with transitive nonfinite verbs was not significant. This result shows that the difference between the original and the spliced versions of the sentences was not only a general effect of splicing but, it suggests that prosodic information is used for syntactic structuring of spoken language. The reason that this effect did not appear in the sentences with transitive verbs could have to do with the fact that in German most transitive verbs can also be used as intransitive verbs.

The same experiment was run with a group of 7 agrammatic Broca's aphasics and a group of 6 Wernicke's aphasics. The only difference in procedure between the aphasics and the normal participants was a longer inter-stimulus-interval for the aphasics than for the students. For both aphasic groups a reaction time pattern similar to the students was found. Both groups showed marginally significant longer reaction times for the cross-spliced sentences with an intransitive nonfinite verb compared to the original sentences, but not for the sentences with a transitive nonfinite verb.
The results suggest that aphasics as well as normal listeners use prosodic information on-line. The finding that left hemisphere damage does not affect the use of prosodic information could be a further indication that the right hemisphere plays a special role in processing prosodic information. The fact that prosodic information can be used as a guide for syntactic structure even by agrammatic patients is a result that merits further investigation.

Intonation modulates syntactic parsing and syntactic ERP components

3.1.14

Hahne, A. & Friederici, A.D.

Hahne and Friederici investigated the effect of intonation in auditory sentence comprehension. Earlier studies exploring the temporal structure of syntactic parsing during language comprehension (Friederici, Pfeifer & Hahne, 1993; Friederici, Hahne & Mecklinger, in press) had shown an early left anterior negativity to be correlated with violations of the required syntactic structure. In the new study, we used similar stimulus materials as in the previous experiments, but systematically varied their acoustic realization. Sentences were either correct or contained a phrase structure violation, that is a case inflected preposition followed by a verb instead of a noun phrase.

(1) Correct sentence: *Der Fisch wurde geangelt.*
The fish was catched.

(2) Syntactic violation: *Der Fisch wurde im geangelt.*
The fish was in the catched.

The critical variable in this experiment was the auditory realization of the incorrect sentences. All sentences were spoken by a female speaker trying to produce them with natural intonation. But what is a natural intonation for a violation of the phrase structure? As there is no obvious a priori answer to that question, we approached it empirically by comparing two ways of realizing such a violation. In one condition (the so-called unspliced condition) our speaker tried to produce the sentences in analogy to correct sentences containing a complete prepositional phrase but without actually producing the noun itself. In a second condition (the so-called spliced condition) the speaker actually produced a complete noun phrase (as in *Der Fisch wurde im Gebrumm geangelt. / The fish was in the noise catched.*) and this additional noun was later spliced out of the speech signal using a speech-wave editing tool. This manipulation of the acoustic signal worked quite well as we used the same phonological transitions from preposition to noun as from noun to verb (both starting with the prefix *ge*-). The resulting two versions of the incorrect condition in fact differed: the preposition was more stressed in the unspliced condition than in the spliced condition, as indexed by a mean length difference of 59 ms.

When presenting correct and both versions of incorrect sentences to the subjects in random order (i.e., mixed) during the experiment, we obtained marked differences in the ERP patterns for the two incorrect versions. Only the spliced version yielded a clear early negativity over anterior electrode sites. The unspliced version, by contrast, did not elicit a negativity at the anterior electrodes. Both sentence versions elicited a late posterior positivity though it was much more pronounced for the spliced condition. This result pattern indicates that the early negativity as well as the late positivity may be modulated by intonational properties of the utterance. These findings clearly demonstrate the parsing system’s sensitivity to intonational cues, and indicate the necessity to control for these when working with acoustic stimuli.

3.1.15 The time course of semantic and syntactic activation in word recognition

Jescheniak, J., Friederici, A.D. & Schriefers, H.

To complement the ERP research on the temporal structure of processing structural and semantic information, Jescheniak, Friederici and Schriefers investigated time course of semantic and syntactic activation during word recognition in a reaction time study. They employed a new experimental paradigm adopted from Sudevan & Taylor (1987, JEP: HPP).

The experimental task requires the participants to perform a (binary) decision on some property of a stimulus by giving a push button response. The stimuli have to be evaluated on one of two possible dimensions, the actual one being specified by a cue. Of particular interest is the effect of response compatibility. A condition is said to be compatible if the two judgement dimensions require the same response, and incompatible if the two judgement dimensions require different responses. A Sudevan & Taylor have shown, incompatibility of responses leads to prolonged response latencies, i.e., interference. Most important, this interference is asymmetric. While a relatively fast process can interfere with a relatively slow process, the reverse does not hold.
A variant of this paradigm was applied to the study of lexical processing. Any word, such as *pill* can be evaluated on a number of different linguistic dimensions. It can be evaluated with respect to its semantic properties: *pill* denotes an inanimate entity. If preceded by a (minimal) context, such as the article *the* or the pronoun *I* can also be evaluated whether it forms a correct or an incorrect continuation. Whether it does depend on its syntactic properties, i.e. its word category. The noun *pill* can follow the article *the* but it is not permitted after the pronoun *I*.

In the experiments, participants saw sequences of two words, like *DIE TABLETTE* (*the pill*) and performed either a semantic task or a syntactic task. Participants responded by pressing one of two push buttons. The semantic task involved an animacy decisions on the target word *TABLETTE*, and the syntactic task involved a decision on whether the target word is grammatically acceptable in that context or not. In all trials the context word was either the article *DIE* (*the*) or the pronoun *ICH* (*I*), and the target word was either a noun or a verb. All nouns were of feminine gender (and hence acceptable following the article *DIE*), and all verbs appeared in 1. Person sg. present tense form (and therefore acceptable following the pronoun *ICH*). As the targets were restricted to nouns, it was possible to apply the semantic as well as the syntactic task to the same set of stimuli. Verbs appeared in filler trials only.

Within a trial, context word and target word were presented in succession. In Experiment 1, flanking characters cueing the actual judgement dimension were displayed simultaneous with target onset.

If processing of syntactic category information starts earlier and/or is faster than semantic processing, compatibility of the syntactic judgement should affect the semantic judgement, but not vice versa. In contrast, if processing of syntactic category information is slower and/or starts later than semantic processing, the reverse pattern should hold.

The data of Experiment 1 revealed a reliable interaction of the factors compatibility and judgement dimension, reflecting the fact that compatibility had virtually no effect on the semantic judgement but a powerful impact on the syntactic judgement. At first glance, this particular pattern of asymmetric interference appears to be at odds with the idea of early syntactic (word category) activation. However, overall response latencies were fairly long (well over 1,000 msec), and this might in part be due to the complex experimental task. After all, participants not only had to recognize the target word but also had to identify the cues specifying the actual judgement dimension. If participants would first process the target word and only thereafter identify the actual judgement dimension, any effect of early and possibly short-lived syntactic (word category) activation could have been missed.
For this reason, the cues appeared simultaneously with the context word in Experiment 2. This allowed participants to identify the actual judgement dimension prior to target presentation. While this change in procedure yielded a substantial decrease in overall reaction times (by some 150 msec), response incompatibility still led to longer reaction times. But in contrast to Experiment 1, this interference effect was symmetric: the amount of interference for the semantic decision was just as pronounced as it was for the syntactic decision.
The symmetric interference pattern from Experiment 2 seems to reflect a phase during which semantic and syntactic (word category) information are simultaneous available. The finding that the interference pattern becomes asymmetric with increasing reaction times, as in Experiment 1, may then suggest that the two types of lexical information, once activated, have different decay rates with syntactic information being subject to more rapid decay. Under this interpretation, asymmetric interference, as obtained in Experiment 1, could result from the process of reaccessing syntactic information during a phase at which semantic activation still persists.

It is likely that the reaction time paradigm used here was not able to tap into an early processing stage in which only the syntactic information is activated, but not the semantic information. This stage which is assumed to reflect fast initial syntactic processes may more likely to be observable using event-related brain potentials measurements.

3.1.16 Monitoring the processing and memorizing of semantic and syntactic information with high density ERP recordings

Mecklinger, A., Friederici, A.D., Naumann, P. & Gunter, Th.

Recent ERP studies provided evidence for the notion that different brain systems are involved in the processing of syntactic and semantic information. Most of these studies, however, either focused on sentential processing or on the processing of isolated content or function words which not necessarily requires the activation of syntactic knowledge. The objective of this experiment was to develop a paradigm which could be used with different imaging techniques those with a high temporal resolution (EEG, MEG) and those with a low temporal resolution (SPECT, PET, fMRI) as the latter provide high spatial resolutions. The experiment was designed to examine syntactic and semantic aspects of language processing while subjects listened to and memorized semantic or syntactic information. (see Friederici, Klemm, Biersack & Pavic (1995) for the use of a similar paradigm in a SPECT study). The semantic conditions comprised list with abstract or concrete nouns presented in a segmentable and non segmentable form (e.g. *Auftakt, Takt, Beiblatt, Blatt*). The syntax conditions were comprised of short phrases of two function words (e.g. *auf euch; dank euch*) with the first word being either a spatial or functional preposition (syntactic conditions).

ERPs were recorded from 64 channels during the presentation of the word lists and were also averaged as a function of subsequent memory performance (recalled vs not recalled).

Performance data: Recall performance was highest for concrete nouns, intermediate for abstract nouns and lowest for the two syntax conditions.

ERP data: Pronounced N400 components were evoked in the semantic conditions but not in the syntactic conditions. Moreover N400s were larger for concrete than for abstract nouns and delayed for about 200 ms for segmentable compared to nonsegmentable nouns. For the functional but not for the spatial syntax condition a positive component most pronounced over left anterior brain regions was found in close temporal relationship with the onset of the functional preposition.

For all semantic conditions, ERP activity at the initial presentation of words was predictive for later recall performance. That is, nouns that were later recalled evoked an enhanced positivity as compared to nouns not recalled. Several aspects of this ERP difference related to memory are noteworthy: First, the difference between subsequently recalled and not recalled nouns started in the N400 latency range and extended several 100 ms thereafter. Second, it was largest for concrete nouns which also evoked largest N400 components. Third, the ERP differences related to memory yielded different scalp topographies as a function of noun type, being more posteriorly distributed for the abstract as compared to the concrete nouns. These results suggest that different brain regions could be engaged in elaborative encoding of abstract and concrete nouns.

Event-related potentials (ERPs) have been widely used as a tool for studying the neuronal basis of cognitive processes in humans. ERPs are multidimensional, that is, they can be distinguished by characteristics like latency, scalp topography and polarity. In contrast to functional imaging techniques with good spatial resolution like SPECT, PET or fMRI, ERPs have an excellent time resolution for analyzing cognitive processes operating on a sub-second time scale. The primary focus of this research program is to use ERPs and behavioral measures to examine the temporal structure of memory processes for specific stimulus features. A secondary future focus is to use fMRI and SPECT to identify the memory systems and its subsystems neuroanatomically. Of present interest are the neurotopological and temporal patterns underlying memory processes for object ('what'), spatial ('where') and temporal ('when') information.

3.2.1 Recognition memory for object and spatial information: An analysis with event-related potentials

Mecklinger, A. & Meinhausen, R.

Recent research suggests that the processing of object and spatial information in the primate's visual system involves functionally and anatomically different systems, a 'what' and a 'where' system, respectively. An important question on the neuro-anatomical basis of memory is whether the functional and anatomical dissociation in the visual processing of 'what' and 'where' information can be extended to memory processes. For example, recent models of recognition memory assume that the same neuronal pathways involved in perceptual processing of these two types of information are also active during storage and retrieval of these information types.

In a large variety of studies, in which recognition judgements were monitored by ERPs, correctly identified old items were found to elicit more positive going waveforms than correctly identified new items. This old-new effect in the ERP waveforms is assumed to reflect the retrieval of information from memory traces. Its topographical distribution allows inferences about the neuronal configurations mediating memory retrieval. In a series of experiments, we examined to what extent old-new differences in the ERP waveforms during the retrieval of object identity and spatial location information from the same memory trace can be dissociated with respect to timing and scalp topography. In these experiments a modified study-test paradigm is used in which subjects are asked to memorize abstract geometric objects and their spatial positions within a 3 x 4 spatial matrix. Prior to the test phase a cue informs the subjects about the stimulus feature which will be relevant in the upcoming test phase (i.e., object identity or spatial location). This task enables us to examine ERP activity in the preparatory phases after cue presentation as well as old-new differences as a function of recognition task.

In a recent recognition memory experiment employing this paradigm, presentation of the task cues evoked an anterior focused negative slow wave for the object recognition task and a parietal-occipital dominant negative slow wave for the spatial recognition task, with both components starting 700 ms after cue onset. Moreover old-new effects were most pronounced at the frontal recording sites for object identity and at the parietal-occipital recordings for spatial information in the 300 to 600 ms time interval. In a later time interval (i.e. 1200 to 1800 ms after stimulus onset) pronounced old-new effects were found at right anterior recording sites for both recognition tasks.

In this experiment, however, responses were found to be faster and more accurate in the spatial recognition task than in the object recognition task. This pattern of results raises the possibility that the topographic differences in ERP activity as a function of recognition task reflect differential task difficulties rather than differences in the retrieval of object and spatial stimulus features. To test this latter assumption we designed an experiment in which performance was identical in the object and spatial memory tasks. In this experiment, subjects were required to make old-new judgements with respect to the mirror position of a previously studied object, rather than responding to the position of the object itself. Similar to the first experiment, the task cues evoked differential slow wave activity as a function of task. Although less pronounced in the spatial recognition task, the scalp topography of the old-new effects was highly similar to the one obtained in the previous experiment. Again, old-new effects were anteriorly focused in the object task and posteriorly focused in the spatial task in the 300 to 600 ms time interval, with both tasks yielding pronounced old-new differences in the late time interval. Based on this pattern of results any interpretation of the ERP effects based on differential task difficulty can be ruled out.

The results are consistent with the notion that memory retrieval is a multicomponent process which involves a network of structures. For spatial memory operations it is conceivable that during recognition memory similar brain areas are activated which are also involved in perceptual processing of spatial information. At present we test the assumption that the frontally oriented old-new effects in the object memory task are caused by the particular form of object features used in the experiment (i.e., abstract geometrical objects) which might be more susceptible to interference than spatial stimulus features.

3.2.2 Spatiotemporal dynamics of working memory processes for 'what' and 'where' information as revealed by slow potentials in the ERP

Mecklinger, A., Pfeifer, E. & Güssow, Th.

Working memory refers to a system that provides temporary storage and manipulation of information necessary for a large variety of cognitive tasks. It is conceptualized as consisting of two components specialized for the processing of phonological or visuo-spatial information (i.e. an articulatory loop and a visuo-spatial sketch pad) and a central executive controlling conscious processing.

Recent studies have shown that negative slow waves in the ERP are specific to working memory operations. For example different slow wave topographies have been found as a function of the type of material held in working memory, e.g. phonological vs. visual materials. Based on recent research that suggests a functional and anatomical dissociation in the processing of spatial and object information, in this study we used ERP slow waves to examine whether there are different subsystems within the visuo-spatial sketch pad specialized for the processing of object and spatial information.

16 subjects performed two tasks in which they were required to maintain either simple geometric objects or spatial configurations in working memory for a 6.8 sec retention interval. Memory load was manipulated in both of the tasks. The EEG was DC-recorded continuously from 29 electrodes throughout the retention interval and slow wave activity was quantified in successive time intervals of 500 and 1000 ms duration.

Pronounced differences in timing and topography of the ERP components elicited by these two working memory tasks were obtained: Starting at about 3000 ms post-stimulus we found a memory-load-sensitive negative slow wave over frontal brain areas in the object memory task, that extended throughout the retention period. For the spatial memory task memory-load-sensitive negative slow wave activity was obtained over the occipital recording sites starting as early as 800 ms and extending to 3300 ms after stimulus onset. Two additional results were obtained by between-task comparison of absolute slow wave amplitude: First, more pronounced negative slow activity in the spatial task was found at parietal and occipital recordings throughout the recording interval, whereas this between task difference was inversed in polarity at the inferior right temporal recordings. Second a negative component peaking at 240 ms (N240) was obtained at right anterior temporal recordings in the object memory but not in the spatial memory task.

The results are consistent with the view that working memory for object and spatial information is mediated by different brain areas. Maintaining objects in working memory is correlated with negative slow wave activity most pronounced at inferior right temporal and frontal recording sites whereas retention-related slow wave activity in the spatial memory task was dominant at posterior parietal recordings more than 2000 ms earlier. Consistent with results obtained by other brain imaging techniques the present data suggest a differential involvement of frontal, right temporal and posterior parietal brain areas in spatial and object working memory tasks and in addition underline the importance of considering differential temporal dynamics of working memory processes.

3.2.3 Objects and spatial locations in the figural and verbal modality: Evidence for supramodal memory systems?

Mecklinger, A., Bosch, V. & Friederici, A.D.

The identification and processing of visual stimuli is performed by different subsystems in a serial fashion. Recent neuroscientific research supports the notion that there are functionally and anatomically distinct systems for object- ('what') and spatial ('where') information. Moreover, psycholinguistic studies show a comparable distinction in the verbal domain (e.g. noun phrases vs. prepositional phrases). The goal of the present study is to investigate the temporal structure and the neurotopological organization of processing 'what' and 'where' information with both figural and verbal coding by means of event-related potentials (ERP). One assumption to be tested is, that there is a coincidence of spatial-feature processing and ERP-variations in the parietal region whereas object-feature processing is assumed to be correlated with temporally focused ERP activity. A basic question under investigation is whether these two postulated subsystems to process 'what' and 'where' information are unimodal (visual) or supramodal (visual and verbal).

In order to examine these questions, a modified S1-S2 paradigm was developed. A study-picture (S1) is presented to the subject for 200 mses, containing two geometric objects presented in a virtual 3-D space. After 2 seconds a cue is presented that defines the type of the requested decision for the S2 stimulus (position vs. object). 2 seconds later follows the test picture (S2) which can be either figural (like the study picture) or verbal (a brief written description of the objects and their spatial locations). The subject is requested to respond by pushing an 'old' or 'new' button. The figural-verbal conditions are blocked in order to precue the subject about this modality. In the position conditions the subject has to decide whether or not one of the two positions has changed regardless of the object features. In the object conditions the subject has to decide whether the objects are the same as before regardless of their spatial locations.

Hence, eight experimental conditions are under investigation: [figural-verbal] x [position-object] x [unchanged-changed]. Data acquisition is still in progress. So far a variety of pilot studies have been run in order to adjust several stimulus parameters (e.g. presentation times, object and spatial features for new trials at S2 etc.) for a better comparison of performance measures across modalities and conditions. Additional to performance measures, 72 EEG channels will be recorded to obtain a good database for both encoding ERP analyses and spatio-temporal dipole analyses.

3.2.4 Selective attention to ‘what’ and ‘where’ information: An MEG analysis of enoding spatial and objects features of a stimulus

Mecklinger, A., Maeß, B., Pfeifer, E. & Opitz, B.

Mecklinger and Müller (in press) reported ERP differences at posterior recording sites as a function of attentional set to object or spatial features of visual stimuli. That is, when subjects directed their attention to a stimulus’ spatial characteristics, a pronounced N2 component emerged at posterior parietal recording sites whereas attending to object features of the same stimuli elicited a right posterior-temporal P2 component. These ERP components might reflect enhanced processing of a stimulus’ spatial and object features. In this project we examined the functional, temporal and topographical characteristics of these electrophysiological signs of selective attention to specific stimulus features in more detail using a 64-channel MEG recording device (CTF Instruments, Vancouver, Canada).

Similar to the study by Mecklinger and Müller, a visual discrimination task was designed in which subjects were required to attend to either object features, spatial features, or to a conjunction of both. In the object discrimination task simple geometric objects were presented consecutively on one of 16 positions of an imaginary 4 x 4 spatial matrix. The subjects’ task was to respond to rare ($p = .25$) target objects. In the position discrimination task the subjects were presented with the same visual stimuli and were required to respond to rare target locations. In a third block, responses were required to rare target objects presented at target locations. The MEG was recorded from 64 channels continuously for each of the three discrimination conditions. Analysis of performance measures (RT and accuracy) so far indicates that discrimination was easier in the object than in the spatial discrimination task, while for conjunction discrimination intermediate performance levels were obtained.

The MEG analysis is in progress. Examination of the RMS functions for 9 subjects so far indicates more pronounced and temporally more focused electromagnetic activity in the 150 to 600 ms range in the object condition as compared to the other two conditions. The topographic distribution of electromagnetic activity in the object and the spatial condition so far suggests pairs of lateralized dipoles which are differentially activated as a function of discrimination condition. When spatial stimulus features have to be discriminated there is more pronounced activity of the right hemisphere dipole in early (i.e. 320 to 400 ms) time intervals. In contrast, discrimination of object features is associated with an earlier onset and temporarily more focused activity (i.e., 400 to 600 ms) of the left hemisphere dipole. At present spatio-temporal dipole model analyses are performed in order to obtain more precise descriptions of various dipole parameters.

3.2.5 Dissociation in the processing of spatial and temporal information in working memory after frontal tumour excisions

Hälbig, Th. D., Friederici, A.D. &. von Cramon, D.Y.

Different experimental approaches suggest that basic informational dimensions in memory are processed by different modular (i.e. domainspecific and neurostructural specific) subsystems. There is converging evidence for a ‘what’-system specialized for the processing of object information and a ‘where’-system specialized for the processing of dynamic spatial information. Both systems consist of distinct neuronal pathways, with the ‘where’-system running from the occipital lobe to the posterior parietal lobe.

In contrast there is little knowledge of the cognitive processes underlying the memory for temporal information. In a first study Hälbig, Mecklinger, Schriefers and Friederici (unpublished) set out to investigate if the modularity assumption holds as well for the processing of temporal information. Assuming that behavioral data provide the framework to address the issues of neural implementation it was tried to test the domain specificity of the memories for temporal duration and spatial location information. Based on the assumption that modular processes of the same neurocomputational level show as breakdown pattern a double dissociation the selective interference paradigm was used to find behavioral evidences for a functional dissociation of the processing of spatial and temporal information in the visual working memory of intact human subjects. According to the selective interference paradigm two cognitive processes interfere when they are simultaneously realized by the same neuronal circuitry. Performance on a temporal memory test should be selectively degraded by a secondary temporal task, and performance on a spatial memory test should be selectively impaired by a secondary spatial task.

In order to test these assumptions an experiment was designed in which 24 right-handed students were tested in two experimental sessions. In each session subjects performed either a temporal or a spatial memory primary task, each comprised of a study and a test phase. The subjects were required to indicate whether the study and the test stimuli were same or different in duration (temporal memory) or in location (spatial memory). Both primary tasks were combined with three types of interference tasks, to be performed in between the study and the test phase of the primary task: A spatial and a temporal interference task and a non-interference baseline task. In the interference tasks subjects were required to judge the identity in duration (temporal) or in location (spatial) of two consecutively presented stimuli, whereas in the non-interference task they simply waited.

Data provided evidence that temporal and spatial working memories are subject to selective interference. Memory for temporal duration was shown to be impaired by a temporal classification memory task, but not by a spatial discrimination memory task; memory for spatial position showed the opposite pattern of impairment. For both task the non-selective interference is similar to the non-interference baseline task. The selective interference pattern expresses a functional dissociation in the processing of temporal and spatial information in working memory in intact human subjects. This result is consistent with the assumption that short-term-memory for temporal information is degraded specifically by parallel on-line processing of temporal information and not by the processing of spatial information because, both cognitive functions have at least to a certain extent indepent neurocognitive substrate.

In order to clarify this issue, the current work tries to support this line of argumentation by lesion data. Based on studies that indicate the importance of the integrity of the frontal lobes for the processing of temporal information a group of five patients with unilateral frontal-lobe excisions restricted to the superior or middle frontal gyri was tested using the same tasks as in the previous study. Each of the patients aged between 20-40 years was right-handed and had undergone tumour surgery. The patients were tested one year post-injury.
Data analysis, which is still in progress, already reveals the following preliminary results: Frontodorsal lesions of either hemisphere impaired memory for temporal duration in the primary tasks as well as in the interference tasks, whereas patients had only slightly more difficulty then normal subjects in performing spatial primary and secondary tasks. Moreover these frontal lobe lesions lead to an overall memory performance which was degraded to a larger extent when patients had to perform both the temporal primary and the secondary task, as compared to performance on primary and secondary spatial tasks. Finally patients' overall temporal memory performance was impaired to a greater extent as compared to normal subjects' temporal memory. In contrast frontal lobe lesions lead only to a slightly degradation of overall spatial memory performance as compared to normal subjects.

These results seem to confirm the interpretation of the selective interference pattern of the first experiment. They are consistent with the assumption that working memory for temporal information is degraded specifically by parallel on-line processing of temporal information and not by the processing of spatial information because, both cognitive functions have at least to a certain extent an independent neurocognitive substrate. Moreover the processing of temporal duration information seems to rely on the integrity of the frontal lobe. To provide further evidence for the double dissociation in the processing of temporal and spatial information patients with focal posterior parietal lobe lesions are currently tested.

3.2.6 Double dissociation in the processing of spatial and temporal information in working memory

Schubotz, R. & Friederici, A.D.

Neurophysiological and neuropsychological research suggests that basic informational dimensions are processed separately by domain specific visual subsystems. There is supportive evidence for a ‘what’-system specialized for the processing of object information and a ‘where’-system specialized for the processing of dynamic spatial information.

In the present study, Schubotz and Friederici set out to investigate whether there is a third system specialized for the processing of temporal information, a ‘when’-system. Based on neuropsychological studies that indicate the importance of frontal lobe structures for the processing of temporal information (see section 3.2.5), we tried to find further behavioral evidence for a functional dissociation for the processing of spatial and temporal information in working memory of intact human subjects, thereby revealing evidence for the modular organization of the working memory.

The basic assumption was that two cognitive processes interfere to the extent to which they make simultaneous demands on the same processing system. The performance in the spatial memory task should be selectively impaired by a secondary spatial task, because both tasks rely on posterior parietal areas and/or the inferior convexity in the prefrontal cortex, and in analogy, performance of a temporal memory task should be selectively affected by a secondary temporal task because both tasks might rely on frontal lobe structures. Given that the two systems for processing temporal and spatial information are independent, any non-selective interference due to a secondary task should be smaller than the selective interference.

In order to test these assumptions a first experiment was designed in which 18 right-handed students were tested in three experimental sessions. In each session subjects performed either a primary temporal task or one of two different primary spatial memory tasks, each comprised of a study and a test phase. The subjects were required to indicate whether the study and the test stimuli were the same or different in regard to *duration* (temporal memory), *location* or *spatial relation* (spatial memory). The three primary tasks were combined with four types of interference tasks to be performed in between of the study and the test phase of the primary task: two different spatial and one temporal interference task and a non-interference baseline task. In the interference task subjects were required to judge the identity in duration (temporal), in location (spatial) or in spatial relation (spatial) of two consecutively presented stimuli, whereas in the non-interference task they simply waited.

The analyses of the reaction times revealed a priming effect in the conditions where primary task and secondary task were of the same category (“duration-duration”, “location-location” and “relation-relation”). These conditions had the shortest reaction times within each primary condition.

The error analyses for the answers revealed a significant interference effect in the conditions where primary task and secondary task were of the same category: “duration-duration”, “location-location” and “relation-relation” were the conditions where the subjects made the most errors within each primary condition. These findings support our assumption that two cognitive processes interfere to the extent to which they make simultaneous demands on the same processing system.

The priming effect observed in reaction times when primary and secondary task are of the same category could be a reflection of the fact that the task stays the same (“knowledge of how”). The interference effect in correctness of answer for these conditions appears to reflect the fact that the information is of the same type in both the primary and secondary conditions (“knowledge of what”).

The secondary temporal task interfered remarkable with the primary spatial relation task, in which the subjects had to perform a mental rotation in order to answer the question of same or different relation. The interference effect of a secondary temporal task seems to indicate that mental rotation (as movement in time) involves a performance not only of spatial but also of temporal memory, too.

In the first experiment only the judgement of *duration* was used as a temporal task. Following, the question was raised whether the judgement of *temporal order* is to be conceived as temporal task requiring demands on the same subsystem as the duration task. Furthermore, verbal encoding strategies - applied by the subjects during the primary tasks of the first experiment - should be controlled in the interference tasks. We, therefore, developed one verbal encodable and one only visual encodable temporal order task. These two tasks together with slightly modified versions of the three tasks of the first experiment were applied in a second experiment.

In this second experiment 16 right-handed students were tested in five experimental sessions. In the primary tasks, the subjects were required to indicate whether the study and the test stimuli were the same or different in regard to duration, location, spatial relation or temporal order. Like in the first experiment, the five primary tasks were combined with interference tasks to be performed in between of the study and the test phase of the primary task: two different spatial, one temporal and two different temporal order tasks and a non-interference baseline task. Preliminary analyses show that the results for the three tasks also used in the first experiment basically repliate those of the first experiment. Detailed analyses of the additional tasks are currently carried out.

3.2.7 A spatio-temporal dipole model analysis of the P300 to novel and target events

Mecklinger, A. & Ullsperger, P.

Recent research indicates that infrequent and attended target events and unexpected novel events elicit two varieties of P300 activity. When a low frequent and task relevant target event is detected a parietal maximal P300 is generated. In contrast, uninstructed novel events, to which no response is required generate an earlier latency fronto-centrally distributed P300. Recent neuropsychological studies suggest that the frontal lobes have an essential influence on the generation of the 'novel P3' but not on the 'target P3'.

In the present study we examined to what extent the novel and the target P3 arise from different combinations of neuronal sources by using a spatio-temporal source analyses, Subjects performed an auditory oddball task in which rare target tones (p=.10) embedded in frequent standard tones (p=.80) had to be counted. Novel stimuli, randomly selected from 150 unique sounds, were presented with p=.10. Event-related potentials were recorded from 29 electrode positions.

P300s elicited by novel events were substantially larger at all recording sites than those elicited by the target events. Moreover the novel P3 was largest at the central recording sites whereas the target P3 displays a maximum at parietal electrodes. A dipole localization algorithm, Brain Electrical Source Analysis (BESA), was used to estimate the time course and the localization of the neuronal generators that could have generated the scalp recorded electrical fields in the novel and target conditions. A triple dipole configuration was found to describe the scalp recorded P300 activity for novel and target events with less than 2.5 % residual variance. For the novel, but not the target dipole configuration a frontaly oriented dipole was obtained whose temporal activity function suggests that the brain areas involved in the processing of novel events are engaged earlier than those relevant for target processing.

These results add to the converging evidence that frontal brain structures mediate the generation of P300 activity evoked by rare and unexpected information but not the generation of P300 activity elicited by target information. The dipoles' temporal activity functions further suggest that some of the brain areas relevant for the processing of novel events are engaged 70 ms earlier than those involved in target processing. The ambiguity related to the precise localization of activated brain structures which is inherent in this modeling approach, could be overcome by using high density electrode configurations and by combining the spatio-temporal modeling approach with structural imaging techniques providing neuroanatomical constraints for various dipole parameters.

SOFTWARE FOR EEG / ERP EVALUATION 4.1

Pfeifer, E., Novagk, R. & Maeß, B.

The EEG data acquired in our labs is currently evaluated using the PC-based software package EEP (ERP Evaluation Package; Pfeifer, 1992), which initially was being developed in response to the requirements of an EEG lab equipped with a 32 channel amplifier. The change from the 32 to a 128 channel system and the growing size of data blocks had to be met by an upgrade of all program modules. New ERP experiments with extended evaluation needs required a couple of modifications and improvements concerning available algorithms, data presentation options and the user interface.

Currently the software package consists of the main modules briefly described below and several utility programs for various purposes (module names in capitals):

Data preprocessing

FILTER — Linear phase FIR (Finite Impulse Response) filtering for raw continuous EEG data. Any filter type can be realized (low pass, high pass, etc.). The module COEFF is normally used to compute the required filter coefficients.

REJECT — Automatic checking for artifacts like eye movements, eyeblinks, body movements, etc. The contaminated data areas are marked so the subsequently run program AVERAGE can determine which epochs to reject from an ERP average. A raw data point is considered contaminated if either the amplitude or the standard deviation within a certain window exceeds a predefined threshold, the latter criterion being especially useful when working with DC recordings. Any combination of electrodes can be used for artifact detection.

DETREND — Removal of DC drift artifacts by means of linear regression techniques (especially important in topographic analyses of slow potentials). The epoch size used in the estimation and correction of linear trends is user-adjustable with the epoch boundaries being automatically aligned to selectable stimulus events. Amplifier DC resets and other discontinuities are treated correctly. Robust statistics estimation is applied to provide reliable trend estimates even in the presence of signal distortions.

REREF — Computes a new virtual reference channel as a combination of any set of original electrodes from a unipolar montage. Bipolarly recorded electrodes (typically the EOG) can be excluded from the computation. The subtracted waveform may optionally be stored as an extra channel so the effect of rereferencing can easily be undone.

Data analysis / ERP evaluation

AVERAGE — Computes single subject ERP averages from continuous or epoched raw data. An event file (see EVENTS) is required for the program to locate the epochs to be averaged. The artifact rejection marks set by REJECT are used to determine which trials to include. For each experimental condition there has to be a separate event code; it is possible, however, to pool several codes into one average. The baseline values which have been subtracted are stored in a file for subsequent statistical analyses of condition specific differences. The single trial waveforms may be exported in ASCII format and can be printed as a trial overview diagram in PostScript format (for selected channels), which proves helpful for visual artifact monitoring.

GRAND_AV — Calculation of grand average over a set of single subject averages. Mean amplitude values can be requested for specific areas of the ERP to test for statistical differences in an ANOVA design. An appropriate header structure can be generated automatically to interface with the SAS Institute statistics package. Normalization over electrodes (similar to the procedure suggested by McCarthy and Wood, 1985) is provided that allows for the ANOVA interaction term condition x electrode to be interpreted as a topographical difference in the experimental effect.

PICKVAL — General purpose viewing program for average data. Any experimental conditions, electrode positions or individual subjects can be superimposed to compare the ERP curves. The user interface provides specialized features for interactive or semiautomatic picking of peak amplitudes, latencies and other ERP measures of interest. The measurements are written to an ASCII file for further statistical analyses.

POWER — FFT-based spectral power analysis for the frequency domain evaluation of raw EEG data. Available options include: averaging of spectra to reduce noise, event-related spectra, multiple FFT windowing techniques, artifact checking, linear or logarithmic scaling and a variety of diagram types like spectrogram, 2D and 3D line chart or bar chart.

PCA — Principal components transformation of average data based on channel covariances over time. The components can be interpreted as virtual topographic sources which are for example useful to investigate the dimensionality of scalp potential distributions. In addition to the eigenvectors and -values, the source waveforms and their projection onto the electrode positions can be computed and stored in average file format.

Viewing / Data presentation

SCAN	General purpose multichannel viewing program for raw EEG data with sequential or event-controlled scanning mode. Can be used to visually monitor for artifacts, set and delete rejection marks, insert and remove events or control triggers. The channels to display, the time window, the amplitude scaling and the highlighting of events etc. is configurable.
VIEW	Another viewing program for raw data. In contrast to SCAN there is both a whole-session overview display and a zoom-in window, making it especially suited for determining optimal artifact rejection thresholds.
VIEW_A	Main module to view and print ERP average data with various layout options. Multiple experimental conditions can be superimposed for comparison; difference waves, variances and 'running t-tests' may be displayed, the latter ones being useful to illustrate statistically significant differences. Screen hardcopies and publication-quality PostScript printouts can be created with optional color support.
MAP	Computes and plots potential and current source density maps using spherical splines (Perrin et al., 1989) for interpolation. A menu driven user interface allows to adjust the time slices to plot the projection angle and method, the map size and rendering colors, etc. Data can be imported in ASCII or binary average format. The maps can be exported in Bitmap graphics format and may be printed as color hardcopies.

Tools

COMPAND	Utility to reduce storage space with special compression/expansion algorithm for EEG-type data, based on a simple linear prediction approach. Depending on the smoothness (frequency content) of the data, compression ratios of up to 5:1 may be achieved.
COEFF	Universal filter design program for FIR-filters. The program calculates the coefficients that are required to run the FILTER module. The Fourier series method and the REMEZ exchange algorithm (McClellan and Parks, 1973) have been implemented. The user specifies the desired transfer function in terms of stopband attenuation, width of transition band and maximum ripple amplitude in the passband.

LAYOUT	Module to create ERP diagram layouts, generating configuration files for use with the module VIEW_A. A graphical user interface is provided to adjust the placement of electrodes, the size and labeling of the individual curves, legend, caption etc.
ASCII	Conversion utility to export average data in ASCII format. Useful as an interface to other evaluation packages.
EVENTS	Extracts trigger events from a raw data file. The events (time and code) are written to an ASCII file which is used by AVERAGE and other modules to access the appropriate parts of the raw data. Events are normally created by the stimulus presentation software and are recorded on-line together with the EEG. However, event files may be edited off-line making it possible to recode existing events, insert new events and so on.
EPOCH	Cuts raw data epochs out of a continuously recorded data block. Control triggers are used in the original file to mark the onset and end of the epochs to be cut out. This way, artifact contaminated areas or pauses can be thrown away to reduce the storage capacity required.
FILTER_A	Filter module for average data similar to the module FILTER that is used for raw data. To avoid filtering artifacts it is advisable to extend the averaging window on both sides by half the FIR filter length.
ARTFSTAT	Module to compute descriptive statistics on artifacts. Histograms show the frequency distribution of artifacts relative to selected event codes. The module is preferably used to detect unwanted synchronicity between artifacts (e.g. eye movements) and the events to average. ARTFSTAT doesn't detect artifacts itself, but reads them from an event file. The detection may be done by visual inspection or by using the automatic detection/classification module CLASSIFY.

Improvements currently in progress

An integrated evaluation environment is being developed that will facilitate data viewing and processing and the related file handling. A pulldown-menu controlled user interface with integrated editor, context sensitive help, hotkeys, history lists, etc. will provide support for both interactive and automatizable evaluation tasks. A small automatically updated database for each experiment will help to keep track of files, evaluation steps and other information. An easy to learn macro language that goes beyond the capabilities of simple DOS batch file programming will make it more convenient to automatize typically non-interactive evaluation tasks. Several pretesting functions will help to trap typical user mistakes before a complex and time consuming evaluation job is started that wouldn't complete.

An eyeblink / eye movement artifact correction program is being implemented based on the linear regression approach as for example applied in EMCP (Eye Movement Correction Procedure; Gratton et al., 1982). Some minor extensions have been added, such as orthogonalization of horizontal and vertical EOG and an improved blink / movement detection and classification procedure. Currently, artifact contaminated trials have to be excluded from an average when using EEP, occasionally leaving an insufficient number of trials. Critically applied, eye artifact correction will help to improve the signal-to-noise ratio in experiments where the number of trials is limited for one or the other reason.

In a typical multichannel ERP experiment 50-100 MBytes of raw data are recorded for each subject and session. Archiving costs and the desire to have as many data sets as possible on-line for evaluation make it profitable to devise an efficient way of compressing EEG data, even though storage media are becoming less and less expensive.

Especially in multichannel recordings there is a lot of redundancy across channels as neighboring electrodes pick up similar EEG. Principal components transformation (PCA) can be used to reduce the original data to a small number of independent channels that carry most of the information. Using these principal components the original channels can be recomputed with only small residual errors that need less bits to store. The principal components themselves can be further compressed by linear predictive coding (LPC) taking advantage of the autocorrelation in the signal. Both the LPC and the PCA residuals typically show an unequiprobable distribution of magnitude, allowing even further shrinkage by storing frequent values in a smaller number of bits than less frequent ones. This is optimally done using arithmetic compression.

Based on these three principles a program is being implemented that yields substantially improved (losses) compression compared to the currently available utility program COMPAND.

Recently, a project has been started to port the complete PC-based ERP evaluation package to the UNIX platform to overcome some PC-specific limitations and to increase performance in general.

5 TEACHING

SOMMERSEMESTER 1995

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