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What's Beat got to do with it? The Influence of Meter on Syntactic Processing: ERP Evidence from Healthy and Patient populations

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Contents

Part I

Introduction

"*Eckstein, Eckstein, alles muss versteckt sein!*" [1]

Nursery rhymes like the one cited above are very frequent in German and in other languages as well. They all have one commonality: They were repeated in a strictly metric and monotonous sense. But meter is not only present in such a nursery rhyme: It is a phenomenon which we encounter daily: we dance in step to music, we approximately clap in time to music, rhythm facilitates sequence-learning like telephone numbers or vocabularies, when we ride a bicycle, we pedal in a certain tactus (1-2-1-2), and we try to "rhythmatize" even monotonous regular sounds such as the drops of a faucet, as the first of two or more following drops is perceived more stressed than the others. One could list many more examples to substantiate the enormous impact of the ability to perceive rhythmic or rather metric structures - it is without controversy that rhythm is very important in our life. Thus, the following statement of Jousse (1974) is absolutely appropriate: "Je rhythme, donc je suis."
With respect to speech perception, the role of rhythm is not so self-evident at first glance. Intuitively speech seems to be - unless one thinks of poems - totally unsystematic and without any underlying metric structure compared to a piece of music. However, put yourself in the shoes of a native German speaker, listening to a native French speaker speaking German. Quite often it is difficult to understand this non-native speech as French has a different speech meter than German. It is not only the pronunciation which is unfamiliar to Germans but also the foreign speech rhythm may make the sequencing of a sentence difficult. Further evidence for the importance of speech rhythm with respect to speech perception comes from language acquisition. Already nine-months old children are able to discriminate their mother tongue from other languages solely by an extracted rhythm (Jusczyk, Cutler, & Redanz, 1993; Nazzi & Ramus, 2003).
With regard to speech production it has been demonstrated that participants that were instructed to produce short phrases to the tap of a metronome were only able to do this in certain relations (1/3, 1/2, 2/3). These proportions fit with the relations measured in motoric tasks (Cummins & Port, 1998).
The results of previous studies indicate that speech perception and production respectively are to a great extent related to metric processing. The focus of the present thesis explores the relationship of auditory syntactic processing and metric processing. Metric structures seem to be critically linked to syntactic processing as both (meter and syntax) structure the incoming speech stream and are therefore important for sequencing speech. An example for syntactic and metric structures going hand in hand would be the following question "*Kannst Du nicht gehen?*". This question has two completely different syntactic structures and meanings dependent on the used stress pattern. If the speaker places the accents on the

[1] *Headstone, headstone, everyone has to be hidden!* (lit. transl.)

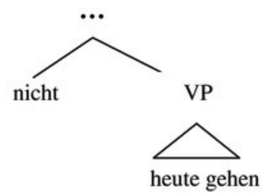

Figure 1: Syntactic tree diagram for the syntactic structure meaning that the listener should go.

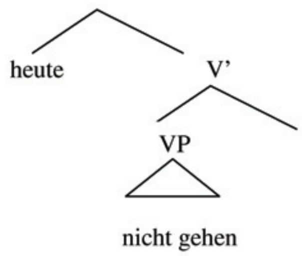

Figure 2: Syntactic tree diagram for the syntactic structure meaning that the listener is called to stay.

verb "gehen", the percipient would propably leave the location. If instead the speaker puts stress on the adverb "nicht", the listener is called to stay a bit longer. This is due to the fact that different syntactic hierarchies are underlying this sentence. This can be well demonstrated by putting an additional adverb into the sentence, the adverb "heute". While it is no problem to say *Kannst Du nicht heute gehen?* which means that the addressee should go, putting stress on the negation "nicht" to indicate that the addressee should stay, is no more acceptable (**Kannst Du* <u>*nicht*</u> *heute gehen?*). To ask the listener to stay, one has to put the negation 'nicht' after the adverb 'heute', e.g. adjacent to the main verb 'gehen' (*Kannst Du heute* <u>*nicht*</u> *gehen?*). If one assumes that the adverb 'heute' marks the left edge of the VP, 'nicht' has to be placed inside the VP if 'nicht' is stressed, whereas it is placed outside the VP when 'nicht' is unstressed. This results in two different syntactic structures which are simplified demonstrated in Figures 1 and 2.

Consequently, syntax and meter are really in a close relationship. The definition of syntax used in this thesis is based on a definition by Patel (2003). This definition was originally formulated by Jackendoff (2002) and describes syntax as a set of principles governing the combination of discrete structured elements into sequences. Thus, syntax as an organization principle in speech perception carries a feature which is highly correlated with rhythm and meter, respectively, namely the *organization of sequences*. Meter in this thesis is defined as an instance of a stable structure in time (Cummins & Port, 1998), while metrical accents arise at temporal locations where beats of many hierarchical levels come into phase (Large, 2000). Thus, meter functions as a complex form of temporal expectation.

In the first part of this thesis the theoretical background will be described. In Chapter 1, I will give an overview about meter research and the used terminology. Furthermore, I will introduce a meter perception theory which builds the theoretical framework of this thesis with regard to metric processes. In Chapter 2, the method used in this thesis as well as the underlying language perception model is introduced. The role of the basal ganglia and their high impact on metric and syntactic processing are outlined in Chapter 3.

In the second part of this thesis a series of five experiments will be presented. In Experiment 1a and 1b the role of external 'taktgeber' on syntactic processing in healthy populations has been investigated, whereas in Experiment 2a and 2b the impact of speech immanent beats on syntactic processing is in the focus of interest. The fifth and last Experiment 3 is conducted to further investigate the role of the basal ganglia in this topic. Therefore, patients with focal lesions of the basal ganglia were confronted with the same material used in Experiment 2a, in order to check the effect of speech internal metric cues on their syntactic processing competence.

Part II

Theoretical Background

Chapter 1

Meter - Definition and Theory

In this chapter I want to give a brief review on meter research and to clarify why this part of language is so important in auditory language processing. In the first part I will introduce the problem that very different definitions of the term *meter* or *rhythm* exist. In the second part of this chapter I will discuss some theories of meter perception and the relevance of meter in auditory language processing.

"*Every investigator... in his definition of rhythm is very certain and unequivocal as to its complexity. This is practically the only point that all are agreed on.*" (Isaacs, 1920)

1.1 Terminology

Isaacs's statement is more than 80 years old, however, it has not lost its actuality. The literature provides evidence that the term 'speech rhythm' is used in very different ways. So first of all a precise terminological differentiation is inevitable to investigate this phenomenon.
In doing so, some authors define speech rhythm as temporal patterns or grids in which speech is produced. For instance, Cummins and Port (1998) showed by means of a speech cycling task [1], that language underlies the same rhythmical constraints as other motor activ-

[1] The Speech Cycling task is designed to see if constraints applying to rhythmic production of speech are similar to motoric constraints. Subjects repeat a short phrase, such as "big for a duck", in time with a regular series of metronome beeps. Then the authors look for regularities in the speech timing as a function of the inter-beep interval (they call this the Phrase Repetition Cycle), rate, etc.
Targeted Speech Cycling is a development of this basic idea, in which the metronome series consists of alternating high and low beeps. Subjects have to try to align the beginning of the phrase with the high beep, and the onset of the second stress ("duck") with the low beep. By varying the relative timing of the high and low beeps, the authors were able to see whether subjects are constrained in the form of speech timing they can produce.

ities, e.g. fingertapping. This gives rise to the notion that patients with motor deficits such as patients with basal ganglia damage may also show language deficits as well as perceptual regularity deficits such as in meter perception.
In contrast, other authors use the term speech rhythm to describe a part of prosody, namely an interplay of pause duration, transitions, vowel reductions, stress successions, etc. which differentiates language sounds across languages. Therefore, some authors have proposed that the languages of the world can be divided into different rhythmical classes. Even though Abercrombies' (Abercrombie, 1967) original idea of syllable- and stress-timed languages and 'measureable isochrony' has been abolished, language sounds of the world may differ based on such a phenomenon. 'Stress-timed languages' like German or English seem to have another durational pattern of vocal and intervocal intervals and do have a greater degree of vowel reduction (Ramus, Nespor, & Mehler, 1999), as well as more complex syllables compared to 'syllable-timed' languages such as French. Some authors (Thiessen & Saffran, 2003; Jusczyk et al., 1993) investigated the importance of rhythm in language acquisition showing that even 5-days old newborns (Nazzi & Ramus, 2003) are able to discriminate their native language from other language solely based on rhythm.
Thus, one is confronted with the problem that different linguistic aspects correlated with temporal processing are labeled *speech rhythm*. Up to now neither concrete parameters defining speech rhythm were pointed out nor a unique definition has been put forward. It seems - as already noticed by Handel (1989) - that *meter* is what most people characterize as *rhythm*. To avoid confusion, I will give a brief review of the terminology of this area of language research and come up with a working definition for the current thesis.

Rhythm, Beat, and Meter According to Lehrdahl and Jackendoff (1983) *rhythm* is the whole feeling of motion in time, including pulse, phrasing, harmony and meter. Generally speaking, the term 'rhythm' designates the temporal pattern of event durations in an auditory sequence, i.e. a psychological construction consisting of beat, meter, timing and a random variation.
Thereby *beats* are perceived pulses which mark regularly distributed - that means isochronous - points in time, either in form of sounds (like stressed syllables) or purely hypothetical points in time, i.e. accents that are perceived without an existing physical correlate. The beat of a succession of auditory events arises from aiming points in the temporal sequence. These aiming points will not be real until cognitive processing has taken place (Bruhn, 2000). Considering the 'isochrony' hypothesis, isochrony has been rejected as

For English speakers, three (and only three) patterns were commonly found, each of which corresponds to a 'simple' rhythmic pattern in which the stress foot (interval between the onsets of stressed syllables) is neatly nested an integral number of times within the Phrase Repetition Cycle.

purely hypothetical points in time cannot be measured physically. However, they are perceptually realized and thus an underlying isochronous grid may influence the processing of an incoming acoustic event.
Beats form the metrical grid of an auditory sequence in language as well as in music, because beats group single events to perceptive chunks (e.g. two successive stressed elements could never belong to one phrase in a language). Thus, *meter* is an abstract structure in time and is based upon a periodical recurrence of pulses (Gasser, Eck, & Port, 1999). The simplest meter is a regular metronome pulse (this comes up to isochrony). However, there is meter with two ore three nested periodicities in integer frequency ratios. For instance, in the case of a waltz-meter different individual beats are formed into groups of three - every third beat being more strongly accentuated than the others. Regarding this meter there is one faster periodical cycle (every beat) and a slower one (on the measure-level). Rhythmic groups with an initial prominent element are preferred even if the physical stimulus is a regular succession of identical elements (Hyman, 1977). The underlying claim is that meter helps to organize a sequence.

However, *rhythm* does not have to be temporarily regular (like meter). Temporal patterns are always separated into temporal (perceptual) groups, but even a random pattern contains a certain rhythm. Making a sequence rhythmical is the degree to which it can be separated in perceptual groups. Making a sequence metrical is the degree of perceived temporal regularity. For instance in a purely isochronous sequence rhythmicity is minimal. For the purposes of this thesis I will adhere to the definition of 'speech rhythm' formulated by Todd and Brown (1994): "The term *speech rhythm* refers to the perception of a regular ordering of stressed and unstressed speech sounds; this is equivalent to the notion of *metre* in music...". Consequently, speech rhythm and meter can be traced back to the temporal ordering of beats in a speech stream.

1.2 Meter Perception

Meter and Predictability

Consequently, Cummins and Port (1998) in their speech cycling experiment probably have investigated meter rather than rhythm in speech production. In reference to Liberman and Prince (1977) they state that rhythm constitutes an organizational principle. Liberman and Prince describe that every temporarily ordered behavior is metrically organized. This means that rhythm, or better meter, becomes manifest as temporal binding of events to specific and predictable phases of a higher-ordered circuit. Furthermore, Cummins and Port propagated meter in speech to be functionally determined and therefore emerging under those linguistic conditions which require a narrow temporal coordination of events encompassing more than one syllable. Meter as a coordinative strategy has the advantage that those parts which group together to form the meter are determined in their relative timing and therefore the number of degrees of freedom is reduced. This means the more metrical an auditory sequence is the more predictable and easier to process.

In reference to Abercrombie (1967), a certain rhythm (meter) is manifested because of emerging motion whereby an expectancy of continuity in a sequence is generated. Speech rhythm should be perceived as motion rhythm, i.e. to perceive speech rhythm speaker and listener have to speak the same mother tongue, otherwise "phonetic empathy" cannot emerge.

A Model of auditory Meter Processing

In following section I will sketch a theoretical model of meter perception, that will be the framework for the empirical data of the current thesis.

As far as I know, no speech comprehension model so far explains the perception and relevance of metric structures. Therefore, it is necessary to make use of models outside of language research. The "Dynamic Attending Theory" proposed by Large and Jones (1999) seems to be promising, as it does not assume that metric structures have to be isochronous acoustic events to be perceived as metrical, e.g. if one imagines a horse's hoof beats when it gallops faster and faster. The model explains the phenomenon of meter preception with so-called 'internal oscillations' or 'attending rhythms', that allow to entrain to an external event and to direct the attentional energy to expected points in time. Meter is therefore defined as a general attention mechanism, that gives rise to a certain expectancy.

The Dynamic Attending Theory consists of 2 systems: 1) external rhythms and 2) internal rhythms. External rhythms include a sequence of related events whose onsets are localizable in time. They build up a sequence of timed intervals as the successive sounds of hoof beats. The attended rhythm localized in the perceiver is a self-sustaining oscillation, which generates an expectancy. If an individual is confronted with an external rhythm, phase and period of the oscillations of the internal rhythm (which Port, Tajima, and Cummins also label 'cognitive oscillation') are coupled to the oscillations of the external rhythm via entrainment (see Figure 1.1). Thus, stable *attractor states* arise and elements that fall into the attractor state are in the focus of attention and thus should have perceptual advantage.

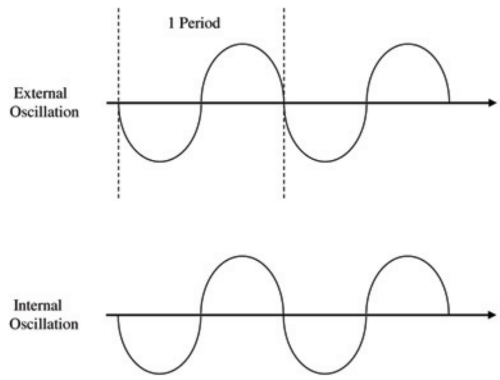

Figure 1.1: Synchronization of external and internal oscillations.

The resulting patterns are stable and yet flexible, as they can persist in the absence of an input and they also can be reorganized given potent indication of a new temporal structure (Large, 2000).

The period of the oscillation is reflected by the overall tempo or rhythmic rate, whereas the phase-relationship between the coupled internal and external attending rhythms is expressed by the listeners expectancy when to hear the next external beat. Changes in the beat should be handled as follows: 1) If the external rhythm is only momentarily disturbed, phase relationships are desynchronized but they can easily be adjusted if the perturbation is not too large. That is to say, if the perturbation is relatively minor entrainment can be continued by small phase adjustments (see Figure 1.2). 2) If the external rhythm is changing into a completely new rate then the attending rhythm must also be changed in rate. Thus, it is not sufficient to adjust the phase as beats would always be expected at wrong points in time because the phase relationsship is no longer correct (see Figure 1.3). This means, period coupling enters the overall rate while phase coupling prevents synchrony between external and internal attending rhythms. Data from Cummins and Port (1998) evidenced that such attractor states do exist in speech production as well as the authors could show in their speech cycling experiment that speaker could not place the second accent of the target phrase at will. Instead three attractors were formulated (1/3, 1/2, 2/3), which is called the 'Harmonic Timing effect'. Thus, the general rules and constraints of cyclical or rhythmical acting motoric and cognitive systems do also apply for speech production (Port et al., 1999).

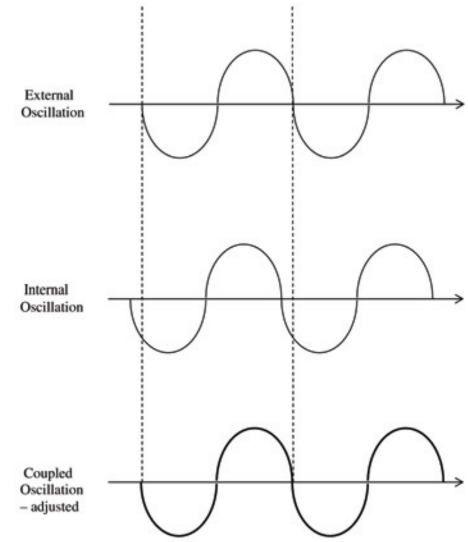

Figure 1.2: Phase-adjustment in the case of small deviations between the phase of external and internal oscillations.

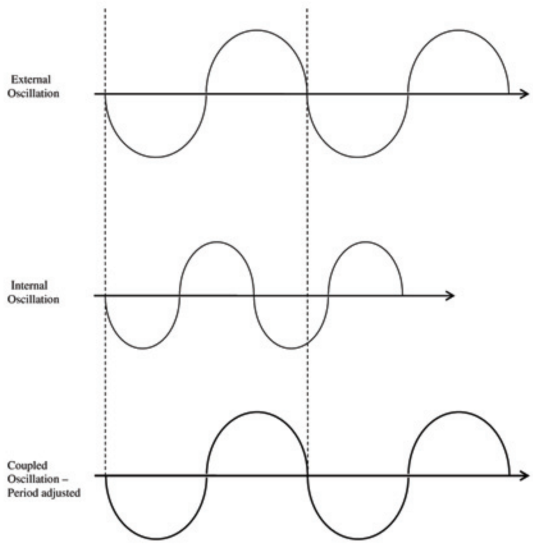

Figure 1.3: Period-adjustment of the internal oscillation in the case of a completely changing rate of the external oscillation.

During speech meter perception cognitive oscillations are phase-locked with the external speech flow (Cummins & Port, 1998). Thus, to elicit a certain meter in speech there has to be a sufficient number of successive cues establishing periodicity. These cues marking meter are inter alia intensity and duration.
The theory of Large and Jones (1999) has the advantage of being also plausible in a greater biological context. The assumption of internal oscillations being dynamic and to adapt to external rhythms is in accordance to the observation that other cyclical behavior in biology is adaptive as well, e.g. the circadian cycles. Furthermore, the model hypothesizes that the better incoming acoustic events can be predicted, the better and easier they can be processed. Consequentely, speech processing is inter alia facilitated for the listener if he/she is familiar with the speaker and his preferred intonational and rhythmic pattern.

1.3 Conclusion

As described above, *meter* is something predictable as it arises due to the regular succession of physically real as well as purely perceptive beats. In music this is called tactus, in language this becomes manifested in a succession of stressed and unstressed syllables. The pattern in speech is more deviant as it does not induce beats similarly to music. However, the listener perceives a certain regularity in speech so that the mother tongue can be differentiated from other languages. This is supported by the observation that listening to a non-native speaker of ones own mother tongue is often more difficult if the non-native speakers mother tongue adheres to a different stress pattern. In such cases another metric pattern is often superimposed onto a language.
Furthermore, *meter* is the precondition for rhythm to arise whereas rhythm is defined by grouping and phrasing within the range of a given meter. Additionally, rhythm is influenced by the succession of speech segments including the fact that in German vowel reduction is more common and consonant cluster are more complex than e.g. in French.
Most important though, *meter* serves as an organization principle in music as well as in speech as has been noted by Magne et al. (2004): "Rhythm [meter] seems to be part of all human activities and may be considered as an organizing principle that structures events". It is used to segment the ongoing speech stream (Cutler, 1994) and facilitates the use of speech in some way (Bell, 1977). According to Liberman and Prince (1977) this linguistic meter is manifested by stress patterns.
As "syntax may be defined as a set of principles governing the combination of discrete structural elements (such as words or musical tones) into sequences" (Jackendoff, 2002), Patel (2003) has described syntactic knowledge to allow the parser a remarkable transformation

of the incoming linear sequence of elements into perceived hierarchical relations that convey organized patterns of meaning. Thus, both meter and syntax function as organization principle, which may constitute the common principle for both mechanisms.

Chapter 2

A Neurocognitive Perspective on Language Processing

2.1 Method: EEG and ERP

In the following section I will give a brief introduction into the method I have chosen for my research, namely event-related potentials (ERP).

Berger (1929) gave a first report on the electroencephalogram (EEG). This method is used to measure electrical voltage fluctuations of the human cortex. These recorded waves vary in their amplitude from 1 to 200 μV. The EEG-waves are summed excitatory postsynaptic potentials of the upper cortical layer, although they may be induced by subcortical activation as this activation could be transmitted to the cortex as so-called *far-field* potentials. The electrical potentials build a well-regulated pattern cohering strongly to mental processes. The organization of the EEG-waves is based on the regular organization of the cytoarchitectonic structure of the neocortex.
Consequently, ERPs are patterned voltage changes in the on-going EEG which are time-locked to specific processing events. They occur previous to, during, or after a motor, sensory or mental event. It is important to note that these event-related voltage fluctuations are very subtle compared to the spontaneous EEG and thus are invisible. That is why a lot of signal segments relating to events of the same type have to be averaged in order to get the typical ERP-waveform (see Figure 2.1). This is based on the assumption that the underlying mental process remains equal across several stimuli of the same type while background activity is random.

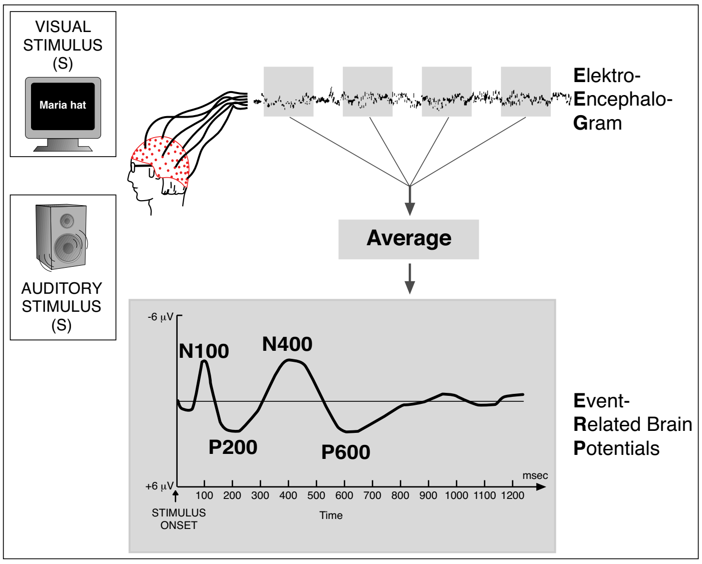

Figure 2.1: EEG measurement and averaging and idealized ERP components

The ERP-waveform is a sequence of negative- or positive-going peaks that are also labeled as components, deflections, peaks, or waves. They are described in terms of their polarity, distribution, latency and experimental variability. Traditionally, ERP-components are subdivided into *endogenous* and *exogenous* components. Exogenous components are reactions to simple physical stimuli occurring between 0 and 100 ms after stimulus-onset, altering due to the physical features of a stimulus. All components arising 50 and more milliseconds after stimulus-onset are reactions related to mental changes thus do not only occur because of physical differences. These components are called endogenous. Up to 300 ms after stimulus onset processing steps are thought to be non-attended.

What motivates the choice of ERPs in the current thesis? The non-invasive ERP-method has a great advantage, namely its high temporal resolution. Speech processing is characterized by its high speed as well as its complexity. Thus, many types of information, namely phonetic, prosodic, semantic and syntactic information have to be processed within a minimum of time. Amazingly, this is effortless in healthy participants.

ERPs are a convenient method to study these subprocesses of language as they can be subdivided within milliseconds. This means, language subprocesses can be separated from decoding the acoustic signal to the understanding of an utterance. Especially with regard to a potential interaction between two processes or language levels (in the current case meter and syntax), the aspect of time plays an important role to separate processes. Using ERPs to study the interaction between meter and syntax renders it possible to look at these processes separately and to examine if these processes run the same time course or if one of them varies in latency, respectively. Other methods, such as behavioral measures or imaging methods may only provide information about variance in the output, but not about variance in the time course.

All ERP studies in this thesis used an electrode-setup that followed the upgraded 10-20 system (Pivik et al., 1993). This standardized system specifies electrode places in terms of their proximity to particular regions of the brain. Frontal placements are labeled with F, temporal placements are labeled with T, central ones with C, parietal ones with P and occipital ones with O. Odd numbers indicate left electrode placements, even numbers indicate electrodes placed over the right hemisphere and Z is used for electrodes places along the midline (please, see Figure 2.2). For data reduction and power enhancement, electrode-sites are summed into regions of interest (ROIs) for statistical analyzes. As the scalp distribution of effects varied, especially depending on the utilized paradigms and ERP deflections of interest, ROIs are determined individually for each ERP-study.

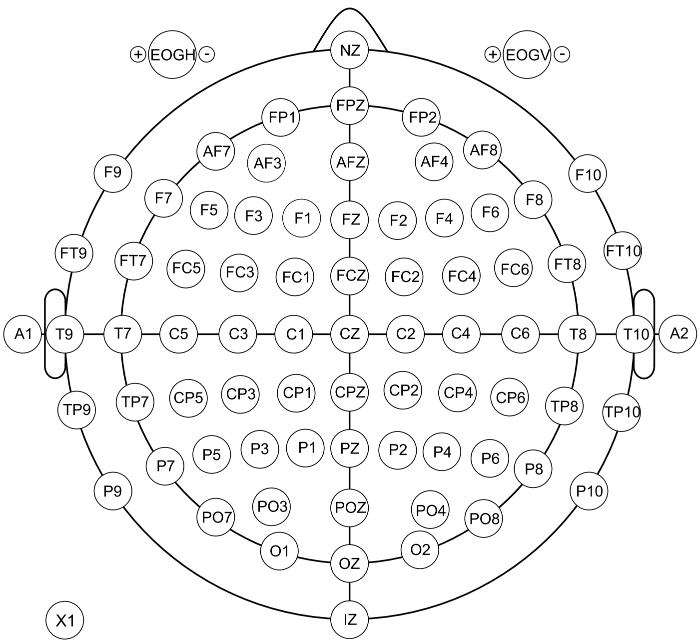

Figure 2.2: 10-20 system for electrode placement

In the following the main ERP components elicited by **auditory** stimuli will be introduced. As exogenous components are not in the focus of the current thesis, they will be described very briefly, while the focus of this overview is directed towards the P600, a late positive component. As this component is mainly discussed in the context of syntactic processing and seems to be sensitive to metric processing as well, the P600 is in the focus of the current thesis.

Early components

N100/P200 Component Both the N1 (75-150 ms after stimulus onset) and the P2 component (150-250 ms after stimulus onset) are very early EEG-components elicited by auditory stimuli. As they always occur together they are also labeled as the N1-P2-complex (see Näätänen and Picton (1987) for a review). Both components reflect physical stimulus features and can be elicited when stimuli are attended or unattended. Thus, they are thought to be exogenous. However, this explanation is controversial for the P200 as it also varies as a function of higher cognitive processes (Luck & Hillyard, 1994; Dunn, Dunn, Languis, & Andrews, 1998).

MMN The MMN is an endogenous auditory ERP component occurring approximately 100 ms after stimulus onset (Näätänen, 1992). This negativity can be elicited pre-attentively and is measureable over centro-frontal electrodes. It is evoked by physically deviant stimuli which appear randomly in a series of standard stimuli. Originally, it was reported in relation to changes in acoustic features such as fundamental frequency, intensity, or duration.

ELAN & LAN Both components, the ELAN as well as the LAN are connected to the detection of syntactic violations. Several studies reported an early anterior negativity (ELAN) in response to phrase structure violations (Friederici & Mecklinger, 1996; Friederici, Pfeifer, & Hahne, 1993; Hahne & Friederici, 1999; Maess, Friederici, Damian, Meyer, & Levelt, 2002; Neville, Nicol, Barss, Forster, & Garrett, 1991). Consequently, based on ideas of Frazier (1987) initial sentential structure building is assumed to be based on word category information. The ELAN onsets approximately 100-200 ms after stimulus onset (Hahne & Friederici, 1999) and is followed by a posterior positivity (P600), thus, it is part of a biphasic pattern (ELAN - P600). Without doubt this component seems to be automatic in nature as neither the predictability of a violation condition, nor the context or the task influences the amplitude of the early negativity (Maess et al., 2002; Hahne & Friederici, 1999, 2002). Thus, the ELAN is independent of attentional factors (Friederici, Cramon, & Kotz, 1999). Nevertheless, the ELAN is not completely independent of input conditions, as could be shown by Gunter, Friederici, and Hahne (1998). This study revealed the absence of the ELAN as soon as a visual contrast is to low. Furthermore, some studies

reported that the ELAN is time sensitive. This implies that the ELAN is not evoked when the inter-stimulus-interval is too long (Neville et al., 1991; Kotz, Cramon, & Friederici, 2005). As Neville et al. (1991) stated automatic processes are not initiated to build up a phrase structure if the input is slowed down.
Source candidates of the ELAN are the deep frontal operculum and the anterior superior temporal gyrus as could be manifested in several studies (Knösche, Maess, & Friederici, 1999; Friederici, Hahne, & Saddy, 2002; Friederici, Rueschemeyer, Hahne, & Fiebach, 2003). However, although this component has first been reported to have an anterior distribution, an MEG-study conducted by Friederici, Wang, Herrmann, Maess, and Oertel (2000) indicates that generator sources of the ELAN are rather temporal than frontal. Furthermore, Müller (2005) reported a wholehead distributed early negativity in response to auditory presented phrase-structure violations (using the same material as Hahne and Friederici (1999)). Thus, the exact structural nature of the ELAN remains under discussion.

The LAN, a component elicited about 300 to 500 ms after onset of the critical item (Friederici, 1999) has been observed in response to morpho-syntactic violations, such as gender, number and tense agreement (Coulson, King, & Kutas, 1998; Deutsch & Bentin, 2001; Gunter, Friederici, & Schriefers, 2000; Friederici et al., 1993; Penke et al., 1997). Like the ELAN it is almost always frontally distributed and is more pronounced over left than right electrodes. This component often occurs in a biphasic pattern as it is followed by a late posterior positivity (P600). The LAN has been discussed to be sensitive to working memory load (Coulson et al., 1998; Kluender & Kutas, 1993; King & Kutas, 1995) as well as being a pure 'morpho-syntactic' component (Friederici, 1995). A recently conducted study by Hoen and Dominey (2000) revealed a LAN in response to an abstract sequence violation indicating that this component is not really language specific, but rather a reflection of a general rule-based sequencing mechanism as a function of error detection in a hierarchically structured sequence (independent of being a language or a non-language sequence).

P300

The P300 (300-500 ms after stimulus onset) is the most studied component of all event-related brain potentials. It was first reported by Sutton, Braren, Zubin, and John (1965). One can distinguish between two sorts of P3 waves - the P3a and the P3b. The onset of the P3a is somewhat earlier than the onset of the P3b and it seems to reflect the cognitive processes which identify the stimulus as a target (Squires & Donchin, 1976) and the orienting of the response towards new events (Yamaguchi & Knight, 1991). Its maximum is over frontal and central electrode sites and its onset changes with respect to stimulus repetition (Solanti & Knight, 2000). The P3b wave is evoked in an oddball-paradigm. During this task subjects attention is directed to a series of frequent stimuli (standard) while sometimes a deviant stimulus is randomly presented. The subject has to react to the deviant stimuli by pressing a button (active) or silently counting the deviants (passive). The amplitude of the P3b varies as a function of task relevance, stimulus meaning and probability. There is an ongoing debate whether the P3b reflects context updating in working memory (Donchin, Gratton, Dupree, & Coles, 1988; Ruchkin, Johnson, Canoune, Ritter, & Hammer, 1990) or inhibition processes in the processing of expected targets (Heit, Smith, & Halgren, 1990; Schupp, Lutzenberger, Birbaumer, Miltner, & Braun, 1994).

N400

The N400 is a negativity that occurs about 200 to 700 ms after the presentation of a critical stimulus (Coulson, 2004). The N400 is distributed over the scalp, however, it is mostly pronounced over centro-parietal electrodes with a slight rightward shift (Kutas & Hillyard, 1980a). This component is affected by a large number of manipulations: It is sensitive to word frequency as less frequent words elicit a larger N400 than frequent words (Smith & Halgren, 1989), it is sensitive to repetition (Rugg, 1985; van Petten & Kutas, 1991) and to words with close probability (Kutas & Hillyard, 1984); its amplitude size decreases with increasing probability of a certain word in a given context. Furthermore, an amplitude decrease of the N400 has been reported for semantic priming (Bentin, McCarthy, & Wood, 1985; Holcomb, 1988; Holcomb & Neville, 1990) as the N400 amplitude becomes smaller when the target word is preceded by a related word. Additionally, pseudowords as well evoke an N400 while nonwords do not (Kutas & Hillyard, 1980b). Recently conducted studies reveal the N400 to be sensitive to syntactic contexts, as this negativity can be evoked when thematic role assignment is impossible (Bornkessel, Schlesewsky, & Friederici, 2002; Frisch & Schlesewsky, 2001; Friederici & Frisch, 2000; Frisch, Hahne, & Friederici, 2004). Thus, the N400 has been interpreted as an index of processing difficulty "the more demands a word poses on lexical integration processes, the larger the N400 component will be" (Coulson, 2004).

P600

The P600 is a late positivity with centro-parietal distribution and with a maximal peak latency of 600 ms. This positivity has been connected to several types of syntactic violations namely subject-verb-agreement (Hagoort, Brown, & Groothusen, 1993; Osterhout & Holcomb, 1992; Vos, Gunter, Kolk, & Mulder, 2001), verb inflection (Friederici et al., 1993; Gunter, Stowe, & Mulder, 1997), case inflection (Münte, Heinze, Matzke, Wieringa, & Johannes, 1998), wrong pronoun inflection (Coulson et al., 1998) and phrase structure violations (Neville et al., 1991; Friederici et al., 1993; Hahne & Friederici, 1999). However, not only syntactic *violations* evoke such a positivity, as it has also been found in response to ambiguities (Frisch, Schlesewsky, Saddy, & Alpermann, 2002; Osterhout & Holcomb, 1992, 1993; Osterhout, Holcomb, & Swinney, 1994; Osterhout & Mobley, 1995; Mecklinger, Schriefers, Steinhauer, & Friederici, 1995), garden-path-sentences, and sentences with increased syntactic complexity (Kaan, Harris, Gibson, & Holcomb, 2000). Friederici et al. (2002) further distinguishes between a 'violation'- P600, which is centroparietally distributed and a 'complexity'-P600, that is mostly pronounced at frontal electrode sites. Thus, van Herten, Kolk, and Chwilla (2005) summarize the reported syntactic functions of the P600 as follows: "The P600 has been claimed accordingly to reflect various kinds of syntactic processing difficulties, such as the inability of the parser to assign the preferred structure to incoming words, syntactic reanalysis or syntactic integration difficulty."

However, the P600 has been recently found in response to semantic violations as well (Kuperberg, Sitnikova, Caplan, & Holcomb, 2003; Hoeks, Stowe, & Doedens, 2004), e.g. in Dutch sentences like *The cat that fled from the mice...* (Kolk, Chwilla, van Herten, & Oor, 2003; van Herten et al., 2005). Additionally, the authors found no N400, but solely a P600. As van Herten et al. pointed out, this P600 could not be evoked due to a violation of the syntactic expectancy. The reader predicts the verb to be morphologically marked as plural, but it is in fact marked as singular. In a further study the authors conducted the same experiment but marked both subject and object with the plural. This manipulation also resulted in a P600 - and not in an N400-effect. Thus, the authors concluded that the reader used a plausibility strategy. This ended in two different theta-role assignments. Whereas the first assignment is due to the plausibility (cats: agent, mice: patient) the second assignment is due to the syntactic parsing algorithm (mice: agent, cats: patient). Consequently, there is a conflict between these two possibilities and this conflict resulted in a P600, as soon as the reader detects the error and refocusses his/her attention to the unexpected event in order to reanalyze the sentence.

Additionally, a P600 has been found in response to music violations (Patel, Gibson, Ratner, Besson, & Holcomb, 1998; Besson & Faita, 1995). Patel et al. (1998) manipulated a specific target chord. Once the target was within the key of a phrase and once it was out of the key. Targets that were out of key elicited a positivity around 600 ms post-target onset. This result prompted the authors to interpret the P600 as a response to "knowledge-based structural integration".

Besides the domain specific nature of the P600 there has been ample discussion that the P600 is solely a delayed P300. Representatives of this opinion (Coulson et al., 1998; Gunter et al., 1997) argue that the distribution of the P600 is very similar to that of the P3b, as both are mostly pronounced at centroparietal sites. Furthermore, both components are sensitive to the degree of probability a certain target stimulus may occur in and both behave in an additive fashion (Osterhout et al., 1994). The latency differences are thought to result from differences in complexity as linguistic stimuli are much more complex than single tones (i.e. a classical P3-oddball paradigm).

However, Frisch, Kotz, Cramon, and Friederici (2003) provide data that dispute this possibility. In an auditory ERP-experiment, patients with focal lesions of the basal ganglia were tested in a syntactic violation paradigm as well as in a P3-oddball task. While healthy controls showed a P600 in response to the syntactic violations and a P300 in response to the deviant stimuli in the oddball paradigm the patients showed no P600 but a P300. Thus, the authors stated that the basal ganglia play a crucial role in the modulation of the P600, but not in the modulation of the P300 component and concluded that a neural and functional distinction between these two ERP-components speaks for two different components.

2.2 A Neurocognitive Model of Language Processes

In the following section a neurocognitive approach of language processing is described and discussed in the context of syntax and meter processing. This model has been proposed by Friederici (2002) and Friederici and Kotz (2003). It integrates results from methodologically different approaches investigating language processes, such as PET, fMRI, EEG and MEG (please, see Figure 2.3). Furthermore, the model subsumes temporal as well as anatomical aspects of auditory language processing. Thus, it provides information about the time course of encoding the incoming speech stream (i.e. which cues are used first?) and specifies brain regions involved in these processes.

According to this model, auditory language processing proceeds in four phases: phase 0, phase 1, phase 2, and phase 3. In **phase 0** the speech input is analyzed at approximately 100 ms post-stimulus onset (EEG: N1, MEG: M100). The auditory cortices of the left and the right hemisphere are engaged in this phase. Furthermore, the identification of the phonological word form takes place in the left planum temporale, while the upper and posterior part of Brodman area ('BA') 44 is involved in the extraction of phonetic segments and in phonologic sequencing. In **phase 1** word category information is encoded. This starts at 100-300 ms post stimulus onset and involves BA 22. Information will then be passed to anterior regions (BA 44 inferior). The encoding of lexical-semantic, as well as morpho-syntactic information is supposed to take place in **phase 2**. Both processes are within the same timeframe (400 ms and later), but they can correlate with different electrophysiological (N400/LAN) as well as neuroanatomical structures. Whereas left anterior regions (BA 44/45) are engaged in morphosyntactic processing, the middle temporal lobe (MTL) and BA 45/57 are active during the processing of semantic information.

With regard to the current thesis, the fourth and also last phase is of special interest. In **phase 3** the syntactic structure and lexical-semantic information are integrated. If such mapping does not occur, the parser has to reanalyze or repair a sentence, respectively. This process results in a P600-component in the EEG. Neuroanatomically this phase is connected to the posterior region of the superior temporal gyrus (STG), as well as to the basal ganglia. However, neural processes underlying this phase are not yet completely specified.

The described model is used as the underlying framework of this thesis as it has the advan-

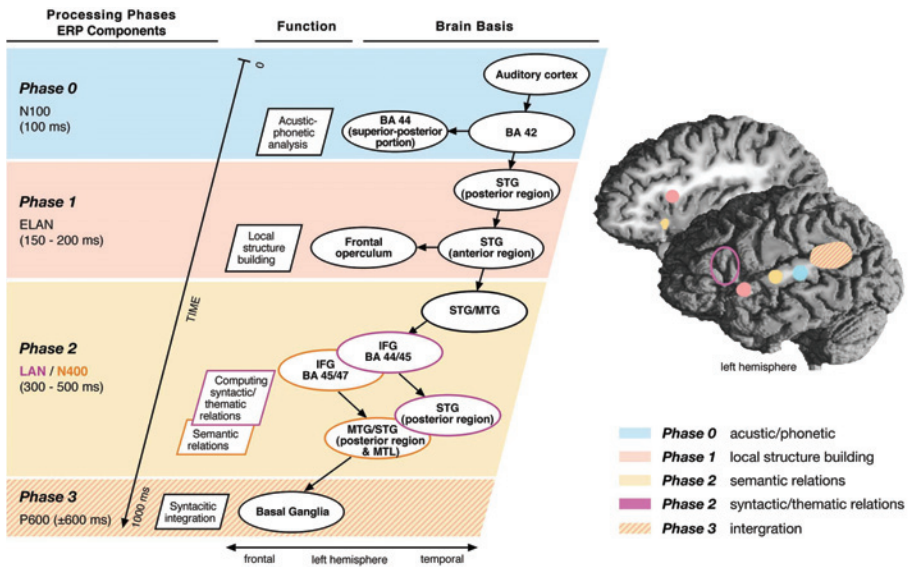

Figure 2.3: Model of language comprehension (Friederici, 2004)

tage to make precise predictions about the temporal availability of certain information. With regard to a detailed investigation of the relation between meter and syntax as well as their processing course, it is possible to make certain predictions within this framework. At this moment the model does not include statements about the temporal availability of metric information as well as involved neuroanatomical correlates. Here - analogous to syntactic processing - two components may be evoked in relation to metric structure, namely an early metric-structural mapping and a late controlled integration of available information. Furthermore, it has to be demonstrated whether reanalysis is elicited by metric violation, and which role the basal ganglia play in this context. Thus, the thesis is motivated to integrate the new data into the model and to extend it with respect to metric processes.

Chapter 3

The Basal Ganglia

Recently conducted studies have indicated that the basal ganglia (in the following BG) play an important role in auditory language and especially syntactic processing (Frisch et al., 2003; Kotz, Frisch, Cramon, & Friederici, 2003; Kotz, Gunter, & Wonneberger, 2005). The authors showed that the P600 - a component connected to syntactic reanalysis or integration, respectively (Friederici, Gunter, Hahne, & Mauth, 2004; Kaan et al., 2000) - is neither elicited in patients with BG lesions nor in patients with neurodegenerative change of the basal ganglia (Parkinson's Disease; PD).
These results encourage to investigate the role of the BG in language perception in more detail. Therefore the following section will provide a brief description of the BG and functionally associated areas, about their role in time perception and the link to language processing.
The BG are a group of connected subcortical nuclei, namely the *striatum* (nucleus caudatus, putamen, nucleus accumbens), the *globus pallidus* (globus pallidus pars interna, globus pallidus pars externa, globus pallidus pars ventralis), the *nucleus subthalamicus* and the *substantia nigra*. Historically the claustrum and the amygdala were also added to the BG. The striatum and the pallidum were described as <u>core structures</u> while the other parts are not always viewed as belonging to the BG and therefore labeled <u>associated structures</u> (Parent, 1986). Together these structures form the BG system (see Figure 3.1).

Striatum The *striatum* is further subdivided into the caudate nucleus and the putamen. The caudate nucleus can be divided into head (caput/body/corpus) and tail (cauda). Between the caudate nucleus and the putamen lies the capsula interna.

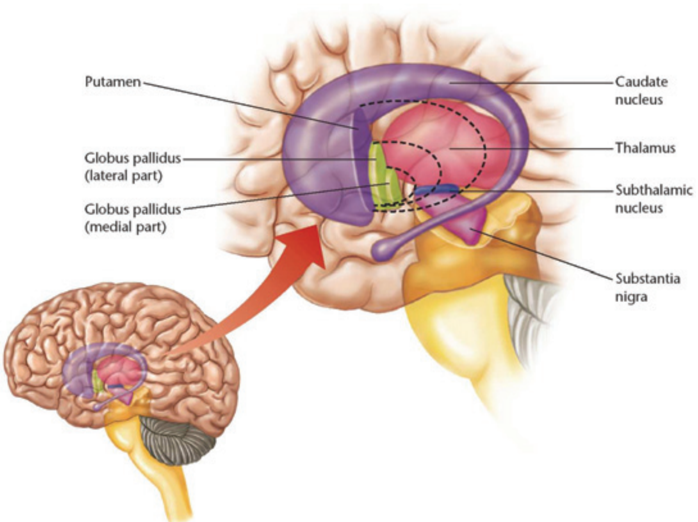

Figure 3.1: The basal ganglia system (http://cti.itc.virginia.edu/∼psyc220/)

The corpus striatum contains spiny (90 %) as well as aspiny neurons. Spiny neurons consist of GABA, taurine and neuropeptides and are efferent neurons. Aspiny neurons can be small or large. The small ones consist of GABA while the large ones contain acetylcholine. The striatum entails two types of patches, namely *striosomes*, which are weakly reactive patches and *matrix*, strongly reactive patches (Graybiel, 1995).
Furthermore, the striatum receives most of the input from the cerebral cortex, especially from the sensory motor and frontal cortex and is the 'doorway' of the BG (Poeck & Hacke, 2001). Caudate and putamen are reciprocally interconnected with the substantia nigra but send most of their output to the globus pallidus.

Pallidum The *pallidum* can be divided into three parts: the globus pallidus externa (GPe), the globus pallidus interna (GPi) and the substantia nigra pars reticulate (SNr). As already mentioned, the GPi and the GPe receive input from the caudate and the putamen and both are in communication with the subthalamic nucleus. In contrast to the striatum as input nucleus, the globus pallidus serves as an output nucleus. The GPi and SNr resemble each other chemically and morphologically. Thus, the main part of their neurons contain GABA. These are multipolar projection neurons (Wise, Murray, & Gerfen, 1996; Haber, 2003). Interneurons are rare in these structures.

Substantia Nigra The *substantia nigra* (SN) consists of two parts, namely the substantia nigra pars compacta (SNc) and the substantia nigra pars reticulate (SNr). The SNc receives input from the caudate and putamen and sends information back to the striatum and the thalamus. Furthermore the SNc produces dopamine which is critical for normal movements. This structure degenerates in Parkinson's Disease. The SNr is functionally and chemically different as its neurons project primarily to the thalamus and the brain stem and contain GABA. The SNr receives striatal input via GABA which is inhibitory.

Subthalamic Nucleus The *subthalamic nucleus* comprises the extrapyramidal system. It is formed as a biconvex lens and lies between the cerebral peduncle and the thalamus. The subthalamic nucleus serves as input nucleus for almost all cortical areas. Several cortical areas as the primary motor cortex, the somatosensory cortex, the premotor cortex, the prefrontal cortex and the cingulum project to the subthalamic nucleus glutamergically and excitatorically.

All these structures together form the BG-system. Within the BG-system two parallel projecting pathways do exist which process signals of the striatum: the direct and the indirect pathway. The *direct pathway* is GABAerg and inhibitory in nature. It projects to the GPi and the SNr. The *indirect pathway* is inhibitory as well as excitatory. The projections from the striatum to the GPe and from the GPe to the subthalamic nucleus are inhibitory, while the projections from the subthalamic nucleus to the GPe and the SNr are excitatory. The activity of both pathways is controlled by an internal loop extending from the corpus striatum to the SNc and back to the striatum (Poeck & Hacke, 2001).

Connections of the Basal Ganglia As already mentioned above, the striatum functions as the major receptive component of the BG. It receives input from the cerebral cortex, the substantia nigra, the lateral amygdala and other regions.
Based on the assumption of two existing loops, namely the motor loop and an association loop, Alexander, DeLong, and Strick (1986) proposed at least five existing circuits. These are labeled motor circuit, occulomotor circuit, limbic circuit, lateral orbitofrontal circuit and anterior cingulate circuit. Each circuit receives several corticostriatal inputs that are integrated on their way through the basal ganglia. It has been proposed that each of these loops funnels multiple cortical inputs which are projected back to a single cortical structure. This organizational pattern should be applied to the SNr as well (Middleton & Strick, 1996).
With respect to the prefrontal cortex it seems that several parts of this area which are involved in higher order cognitive functions are target output structures of the BG. Furthermore, it has been stated that those output channels of the BG which are related to motoric areas of the cortex are different from those output channels related to areas of the prefrontal

cortex associated with cognitive functions. However, it is important to mention that studies with primates revealed that probably motor cognitive and motivational systems interact within the striatum (Kimura & Matsumoto, 1997). In sum, the BG modulate activity of many parts of the cortex and brain stem (Alm, 2004).

3.1 Functions of the Basal Ganglia

The main function of the BG is the regulation and timing of cortically planned movements. This contains several aspects, namely:

1. Saving of a started movement with respect to concurring movements.
2. Retrieving already learned programs.
3. Coordination of all muscles involved in the certain sequence of movements.

A dysfunction of the BG therefore often results in two famous diseases, namely hypokinesia, known as Parkinson's Disease (PD) and hyperkinesia, known as Chorea Huntington (CH). PD has three main symptoms: Akinesia, resting tremors and rigidity. In contrast CH patients suffer from reduced tonus, as they have suddenly starting movements of their extremities and 'motionrestless'.

Thus, the prominent role of the BG in motor behavior is undisputed. However, according to Marsden and Obeso (1994) the widespread motor system does not rely on the BG for execution of experienced and automatic movements. Damage to the BG - system causes inflexibility regarding motor and mental responses, i.e. patients have difficulties with novel circumstances. Therefore it is postulated by Marsden and Obeso that the BG accomplish two functions:

1. Under normal circumstances, the striato-pallidal system continuously requests information of the cortical motor state and returns information to the SMA supporting cortically generated movements. Such support comprises facilitation of the execution of movements as well as inhibition of unwanted motor activity.
2. Novel external as well as internal events capture attention and accentuate the necessity within striatal regions to change a motion sequence. Such striatal signals modify the motor pallido-nigral output to interrupt the flow of motor sequencing and allow a new adequate action, i.e. striatal signals allow a change of the automatic course of motor sequencing.

Furthermore, the BG are thought to be part of a widely distributed network in which sequences "of activation and inhibition are coded in both time and space with exquisite precision. This network endows the brain with a high level of neural plasticity necessary to modulate motor behavior in a subtle manner and to overcome motor deficits through ingenious strategies" (Parent & Cicchetti, 1998). Thus, the BG are important for coding the temporally patterned stimulus-stimulus and stimulus-response relationships that underlie implicit cognitive and motor skills. These implicit skills are important to automate those sequences of thought and action that lead to the attainment of goals and receipt of rewards of various kinds (Ochsner & Barrett, 2001).

Consequently, the BG are important for motor learning, sequencing, movements, attentional allocation and filtering, working memory, implicit learning and memory, and they engaged in reward processes. With respect to the current thesis, the aspect of *sequencing* is of major interest. The execution of a complex motor sequence requires a spatial pattern of muscle activation and exact timing of each submovement (Alm, 2004). This exact timing is relevant in speech processing as well, as the processing of speech requires a high amount of timing precision.

As Cunnington, Bradshaw, and Iansek (1996) proposed, the SMA seems to play a role in internally cued movements while the lateral premotor cortex seems to play a key role in externally cued movements. It is of further interest that these two motor areas of the cortex receive input from different subcortical sources: the SMA from the BG and the premotor cortex from the cerebellum. Thus, Cunnington et al. suggested the SMA to be important in self-initiated, well-learned, complex and sequential movements. Furthermore, the authors proposed the SMA to be related to the timing of movements, a function which is necessary in speech. Thus, the BG provide internal timing cues via the SMA in healthy participants, to facilitate the initiation of the submovements in well learned motor sequences. As Alm (2004) concluded, external timing cues can compensate deficient internal timing cues from the BG to the SMA, resulting in the rhythm effect in stutterers with BG-lesions [1]. Alexander et al. (1986) proposed that the BG do not only project to the primary motor cortex but also to specific areas of the premotor and the prefrontal cortex: Thus, the BG should influence motor control as well as cognitive and limbic function.

In sum the role of the BG is very complex in nature. Without doubt the most important function of these subcortical nuclei is the control of motoric activation. However, the BG are also engaged in many more functions. As Saint-Cyr (2003) pointed out, they play a significant role in attentional and preparatory function, implicit learning, forming of response

[1] Stutterers with lesions in the BG profit from external timing cues (metronome) that is, speech production can become fluent again

habits, procedural learning, skill learning, rule learning, associative learning, as well as some kinds of cognitive skill acquisition. In the following, I want to give a brief review about these non-language functions of the BG which are of further interest in the current context, as well as the proposed language functions of the BG.

Non-language functions A first main function of the BG is the regulation of *sequential sequencing* (Brown & Marsden, 1998). According to Marsden and Obeso (1994) "the sequencing of motor activation and the sequencing of thought could be a uniform function carried out by the basal ganglia". Graybiel (1997) proposed that the BG are "cognitive pattern generators". This regulation mentioned by Brown and Marsden should take place via a direct and indirect pathway, which controls initiation, switching, modulation, and termination of serial processes (Kotz, 2006). This idea was supported by several studies investigating sequencing (Martin, Phillips, Iansek, & Bradshaw, 1994; Harrington, Haaland, & Hermanowicz, 1998; Malapani, Dubois, Rancurel, & Gibbon, 1998; Sagar, Sullivan, Gabrieli, Corkin, & Growdon, 1988; Janata & Grafton, 2003). Furthermore, experiments conducted by Graybiel (1998), Dominey, Arbib, and Joseph (1995), Dominey, Ventre-Dominey, Broussolle, and Jeannerod (1995), Dominey and Jeannerod (1997), and Beiser and Houk (1998) indicate that the BG are involved in chunking[2] of action sequences, learning of sequences and sequential information processing as well. As Matsumoto, Kasri, and Kooken (1999) proposed the cortical-striatal circuitry must be involved in the encoding of sequential sequences.

A second interesting function of the BG is the neural *timing* (Meck, 2005; Gibbon, Malapani, Dale, & Gallistel, 1997). Thus, many studies could support the role of the BG in timing per se as well as in timing in speech with respect to a general timing mechanism. Here, two mechanisms were differentiated: First, intervals in a millisecond range should be processed by an automatic circuitry without any attentional processes, while longer intervals in a second range are processed by controlled processes and are discretely perceived (Lewis & Miall, 2002).
Several studies report that in the case of short intervals the *left* BG are only activated if those intervals are presented continuously or if they are defined by movements (Larsson, Gulyas, & Roland, 1996; Schubotz & Cramon, 2001), while the *right* BG are activated during long time intervals, which are presented noncontinuously and when no movement takes place (Meck & Benson, 2002). Furthermore, Meck and Benson reported that PD patients take longer intervals between sequential self-paced movements than controls. It seems that PD

[2]Chunking refers to the segmentation of a sequence into smaller subsequences (Palmer, 1997), in order to facilitate the processing and execution of events.

patients do have an increased temporal discrimination threshold (Artieda, Pastor, LaCruz, & Obeso, 1992).

With respect to timing in speech, several studies with patients suffering from lesions in the BG or PD were conducted. Thus, Breitenstein, Lancker, Daum, and Waters (2001) provided evidence that PD-patients are not able to detect temporal cues in speech. They also have problems in speech production as soon as the acceleration is too fast or too slow (Canter, 1963; Gräber, Hertrich, Daum, Spieker, & Ackermann, 2002) and they cannot use pauses in speech stream (Canter & Lancker, 1985; Fraïle & Cohen, 1999). The important role of the BG in timing could further be supported by studies showing that external cues facilitate speech perception as well as production in patients with BG lesions. Alm (2004) reports that stutterers with lesions in the BG could profit from external timing cues (metronome) that is, speech production became fluent again. Therefore patients seem to profit from external cues facilitating timing of syllables. Kotz, Gunter, and Wonneberger (2005) provide evidence that the processing of syntactic violations could be facilitated by external rhythmic cues (march rhythm) in PD patients as well as patients with focal lesions of the BG.

In conclusion, one can say that the BG seem to play an important role in timing as deficits across domains such as motor, sequencing, or interval timing - all lack precise timing.

Language functions While the role of cortical structures are mainly of interest in the field of language research, the language function of subcortical structures has been less explored as these structures are in general more related to motoric deficits than to language deficits.

However, several studies provide evidence that the BG are involved in speech production, especially in prosody and grammar (Swennilson, Torvika, Lowe, & Leksell, 1960; Murray, 2000; Longworth, Keenan, Barker, Marslen-Wilson, & Tyler, 2005; Abdullaev & Melnichuk, 1997; Demonet, Price, Wise, & Frackowiak, 1994; Friston, Frith, Liddle, & Frackowiak, 1993). As the focus of this thesis lies on language perception, especially on syntax and meter processing, a brief review is given about the role of the BG in language perception.

Firstly, the BG seem to be involved in *lexical-semantic processing*. A lot of studies report an activation increase in the BG during semantic categorization (Abdullaev, Bechtereva, & Melnichuk, 1998; Binder et al., 1997; Mummery, Patterson, Hodges, & Price, 1998; Pilgrim, Fadili, Fletcher, & Tyler, 2002; Price, Moore, Humphreys, & Wise, 1997), semantic anomaly judgement (Kuperberg et al., 2000; Ni et al., 2000), semantic working memory (Crosson et al., 1999), lexical decision (Abdullaev et al., 1998; Fiebach, Friederici, Müller, & Cramon, 2002) and semantic priming (Kotz, Cappa, Cramon, & Friederici, 2002; Rossell, Bullmore, Williams, & David, 2001).

A further function of the BG with respect to language function lies in the processing of prosody. In this case it is important to differentiate between prosodic deficits relying on motoric deficits, and prosodic deficits which go back to acoustic features such as pitch, duration and intensity. A couple of studies provide evidence for a subcortical structure being involved in the processing of emotional tone (Adolphs, Damasio, & Tranel, 2002; Baum & Pell, 1999; Buchanan et al., 2000; George et al., 1996; Kotz, Meyer, et al., 2003; Morris, Scott, & Dolan, 1999; Wildgruber et al., 2004; Wildgruber, Pihan, Ackermann, Erb, & Grodd, 2002) as well as deficits in patients with BG lesions in processing emotional prosody (Brådvik et al., 1991; Breitenstein, Daum, & Ackermann, 1998; Breitenstein et al., 2001; Cancelliere & Kertesz, 1990; Pell & Leonard, 2003; Starkstein, Federoff, Price, Leiguarda, & Robinson, 1994; Wedell, 1994; Pell & Leonard, 2005; Paulmann, 2006). Nevertheless, it has to be noted that some studies do not report BG involvement in decoding prosodic cues (Buchanan et al., 2000; George et al., 1996).
As recently conducted imaging studies showed the BG get engaged in *syntactic processing* (Friederici, Rueschemeyer, et al., 2003; Moro et al., 2001). In both studies the left striatum was activated during syntactic processing. It was postulated that grammatical processing deficits in PD patients are resulting from an underlying attentional deficit (Grossman et al., 1993), but this was refuted by an ERP-study conducted by Frisch et al. (2003) which provides evidence that BG patients do not suffer from an attentional deficit, as patients showed a comparable P300 to controls, but failed to show a P600 in response to syntactic violations. Additionally, PD and Huntingtons patients seem to be affected in rule governed language processing, that is essential to process grammar (Longworth et al., 2005).
It seems obvious that the BG are engaged in syntax perception, but it is less clear whether this is a real syntactic deficit or an epiphenomenon of an underlying, more basic, deficit such as a meter perception. This is one of the core questions to be dealt with in the current thesis.
Thus, in conclusion the BG are engaged during the processing of various linguistic functions, but it still remains open whether these involvements are domain specific in nature or whether they underlie a general function, for example the temporal decoding of perceivable events.

3.2 Meter, Syntax, and the Basal Ganglia

As already mentioned in the introduction the aim of the current thesis is to address the question whether syntactic processing relies on metric processing and to investigate the role of the BG in this context.

But why should syntax processing rely on metric cues and what is the relative role of the BG here?
First of all, it is important to note that both meter and syntax are structural and hierarchical principles, i.e. both processes have underlying rules and regularities and are therefore predictable for the competent percipient. For example, German native speakers will predict a following NP/DP while listening to a preposition. In the context of meter, everyone can clap their hands to the meter of a rhyme without any problems and may predict the next accent. Thus, both meter and syntax are underlying language principles facilitating segmentation and in consequence, the understanding of the incoming speech stream by structurally organizing it. Furthermore, both domains are building up hierarchical relationsships, as the specificator-head-relationship or filler-gap-dependency in syntax or the sublevels [3] in meter. The importance of meter in sentence production is supported by data from Vogel (2004) (pers. com.) who conducted a production study with metrically regular sentences, that were either syntactically or metrically or doubly violated. The error rate for the production of syntactically violated sentences does not vary significantly from the error rate for the production of metrically violated sentences. Thus, both syntax and meter seem to play an important role in sentence production as well as perception. Nevertheless, meter is without doubt the more 'basic' principle of the two, as it is relevant for other domains as well, such as music perception and production, motoric sequencing, learning of new sequences etc.
Meter, however, has much to do with *timing*. A look into music perception may clarify this statement: Underlying meter in music appears in regular intervals. The computation of those intervals is the pre-requisite to detect the rhythmic deviations in a music piece, e.g. a syncope. This is why meter perception has much to do with timing. Meck (2005) states, that "subjective timing estimation requires the participant to use an internal clock in order to measure objective time without the benefit from external clocks". The BG should function as such an internal clock because - as described in the previous paragraphs - they are mainly involved in such timing mechanisms and consequently should also be engaged in the processing of meter. On the other hand, ERP-studies conducted by Kotz, Frisch, et al. (2003) and Frisch et al. (2003) could show that patients with BG-lesions do have problems with syntactic reanalysis. What remains to be addressed is whether this deficit is really syntactic in nature or whether it is an epiphenomenon of a metric and therefore a timing deficit. If syntactic and metric processes interact during auditory language processing in healthy subjects so that an intact metric 'taktgeber' is necessary to process syntax, then it should be a logical deduction that syntactic reanalysis is disturbed in patients with BG-lesions.

[3]For example, regarding a 3/4 meter one can clap to every single beat but also the first beat in a group of three. Thus several sublevels are possible in a metric structure.

3.3 Conclusion

According to Marsden and Obeso (1994) damage to the BG - system causes inflexibility regarding motor and mental responses and consequently patients have difficulties with novel (motoric) circumstances. In analogy, the BG may get engaged in the re-sequencing of syntactic information when one encounters violations of the syntactic structure as well as deviations from the preferred structure (as for example in garden-path-sentences or in the case of ambiguities) during language perception. The situation is novel (that is, the syntactic information as such is incorrect) and demands re-sequencing of information. As evidence from visual (Kotz et al. in prep.) and auditory (Kotz, Gunter, & Wonneberger, 2005) presentation points out, the BG seem to be triggered in an isochronous way. In the visual domain, an isochronous presentation allows a reanalysis, while in the auditory domain an isochronous auditory prime such as a march results in the same effect.
In a study conducted by Mayville, Jantzen, Fuchs, Steinberg, and Kelso (2002) syncopated coordination gives rise to increased activation distributed throughout the putamen, the caudate nucleus, the right ventral anterior nucleus, the thalamus and the cerebellum. Furthermore, the authors showed that the basal ganglia do not play a major role in the initiation of movements but in the case of complex sequential movement. This supports the hypothesis that the BG function as an inner clock and are involved in such movements which require detailed timing information. The observation that the BG were always involved when there is need of detailed temporal information is consistent with Marsden & Obesos' (1994) claim and can be transferred into the language domain even in the case of metrically non-regular speech.
Combining the knowledge about the functions of the BG with the introduced Dynamic Attending Theory (Large & Jones, 1999; Large, 2000) one can speculate that the BGs in healthy participants do provide the cognitive dynamic oscillations, which make subjects capable to self-evidently deal with new motoric or mental responses. If the BG-system is damaged this may result in an inflexibility of those cognitive oscillations, thus in a metric deficit.
The observation that an isochronous rhythm allows re-sequencing gives rise to investigate the relation between (regular) meter and syntax processing in detail. This is a crucial test of testing the P600 in relation to a syntactic deficit. A missing P600 could be an epiphenomenon of a rhythmic or rather metric perception deficit. If this is the case one would assume that in healthy participants this information is automatically going hand in hand with the syntactic parser as it was shown in the introduction. This is supported by data from Lehiste (1977) in English. Here sentences were disambiguated by interpreting pause lengthening, thus a divergence from isochronous meter in line with a syntactic anomaly.

As has been derived by the explanations in this chapter it is important to investigate the interaction of syntax and meter, and the role of the BG in this potential network in order to enlighten this issue.

Part III

Experiments

Chapter 4

Experiment 1a

ERP-data from patients with BG lesions demonstrated that regular time intervals during syntactic processing are important. As already mentioned in the theoretical part of this thesis, Friederici, Kotz, Werheid, Hein, and Cramon (2003) and Kotz, Frisch, et al. (2003) showed that BG-Patients do not display a P600-component when presentation rate is random (Kotz, Cramon, & Friederici, 2005). This applies to several syntactic violations which evoke a P600 in healthy populations.
Very recent evidence has shown that external rhythmic stimulation re-elicits the P600 in PD and BG patients during *auditory* presentation of syntactically erroneous sentences (Kotz, Gunter, & Wonneberger, 2005). Therefore random (normal) speech was presented preceded by a 3-minute prime of rhythmic stimulation (march-tactus). In another *visually* conducted experiment (Kotz et al. in prep.) words of a sentence were presented isochronously. In both cases the P600 was re-elicited in a PD and BG patient group. Based on these observations it is assumed that perceived metrical regularities can influence speech perception and, in turn, syntactic processing. This has raised the question whether timing guides auditory syntactic processing as a crucial 'taktgeber'. The aim of the experimental series 1a and 1b was to investigate the impact of external timing cues on auditory speech processing in healthy participants. Therefore no real external pacemaker was provided, but words were presented acoustically in a predictable manner. Sentences contained phrase-structure violations as well as semantic violations. Three ERP-components were expected, namely the ELAN (as an early correlate of phrase structure violations), the P600 (as a correlate of syntactic reanalysis) and the N400 (correlating with semantic violations).
In Experiment 1a the isochronous condition was realized by a constant interval of silence following each *word* while in the chunked condition each *chunk* (linguistic phrases) was followed by a constant interval of silence. Temporal predictability was thus induced by

keeping pauses between successive words and chunks, respectively, constant. Based on the observation in patient studies it was assumed that an external rhythm will facilitate the re-sequencing of syntactic information. That is to say, the **P600** which has been linked to the amount of syntactic reanalysis/repair (Friederici & Kotz, 2003) or syntactic integration (Kaan et al., 2000) should be smaller in the isochronous condition than in the random condition, as the predictable onset of the phrases facilitates sequencing and thus less resources are required. However, it could be that the amplitude of the P600 is unaffected by the timing manipulation in healthy participants, as an intact 'internal pacemaker' will not profit from further temporal information. Thirdly, the existing internal metric template may interfere with the externally given meter and this in turn would require more ressources, resulting in an increased P600.

The *chunk condition* was of special interest. As will be explained in more detail in the material-section, it is possible to detect the syntactic violation as soon as one hears the preposition followed by a pause. This is because the critical chunk (prepositional phrase) in the ungrammatical sentences contains only the preposition, as the nominal phrase is cut off due to the phrase structure violation, while in the correct condition the critical chunk is complete. It was of particular interest to see whether participants would detect the violation immediately or whether they would synchronize with the underlying meter, so that the rhythm controls the processing speed, i.e. they process the information not until the given interval (between two following chunks) is finished. If the first hypothesis would turn out to be true, a positivity after the onset of the preposition is expected. A positivity elicited after the onset of the participle would confirm the second hypothesis.

With regard to the **ELAN** it was predicted that this component would not be elicited in the chunked and the isochronous conditions, as it was demonstrated previously that this component is sensitive to long interstimulus-intervals (Kotz, Cramon, & Friederici, 2005; Neville et al., 1991).

With respect to the **N400** no clear hypotheses were formulated, however, it is predicted that the N400 should be unaffected by timing manipulations. Semantics in contrast to syntax does not provide an organizational principle. This feature is specific to syntax and to timing. Thus, it is expected that syntax processing is dependent on timing cues while semantic processing is not.

4.1 Materials and Methods

Participants Thirty-six right-handed participants with normal hearing (18 female) aged 20-29 years (mean: 24,5) took part in the study. All were native speakers of German and had not taken part in a similar study. Participants were paid a small fee for their participation. They all had normal or corrected-to-normal vision and were high-spans according to the Reading Span Test (equal or higher than 3,5). None of the participants had any known neurological impairment. To investigate potential differences in auditory language processing between musically trained and musically untrained participants, participants were divided into subgroups (on the basis of a pre-experimental questionnaire), namely their learning type as some of them were learning with, others without music.

Materials The aim of Experiment 1a was to investigate the influence of temporal patterning on auditory syntactic and semantic processing. Thereby sentences with phrase structure violations and semantic violations (see examples in Table 4.1) were constructed and presented in a random (speech appropriate), isochronous and chunked temporal condition (will be further explained in more detail). All sentences were spoken by a female native speaker of German at a normal speech rate, recorded onto digital audiotape and digitized at a sampling rate of 44.1 kHz.

a) short correct condition	Die Natur wurde gefilmt.
b) semantically incorrect condition	Der Hauch wurde gefilmt.
c) syntactically incorrect condition	Das Pferd wurde im gefilmt.
d) long correct condition	Der Tiger wurde im Zoo gefilmt.

Table 4.1: Experimental conditions in Experiment 1a

The short correct sentences served as contrast for the semantic violations, the correct sentences with a prepositional phrase (PP) served as contrast for the syntactic violations. Semantically incorrect sentences were only presented to avoid a high percentage of critical (syntactically wrong) sentences. Furthermore, even though the N400 is not in the focus of the current thesis, it was interesting to investigate whether this component would be affected by the timing manipulations.
Ungrammatical sentences (*Das Pferd wurde im gefilmt*) were constructed by inserting a nonword between preposition and participle. The onset and offset of this nonword consisted of the same phonemes as the preposition and the participle, e.g. *Das Pferd wurde im Gelimm gefilmt (The horse has been filmed in the "gelimm".)* This is to avoid coarticulatory deviations. The nonword was cut out of the sentence afterwards (see Figure 4.1).

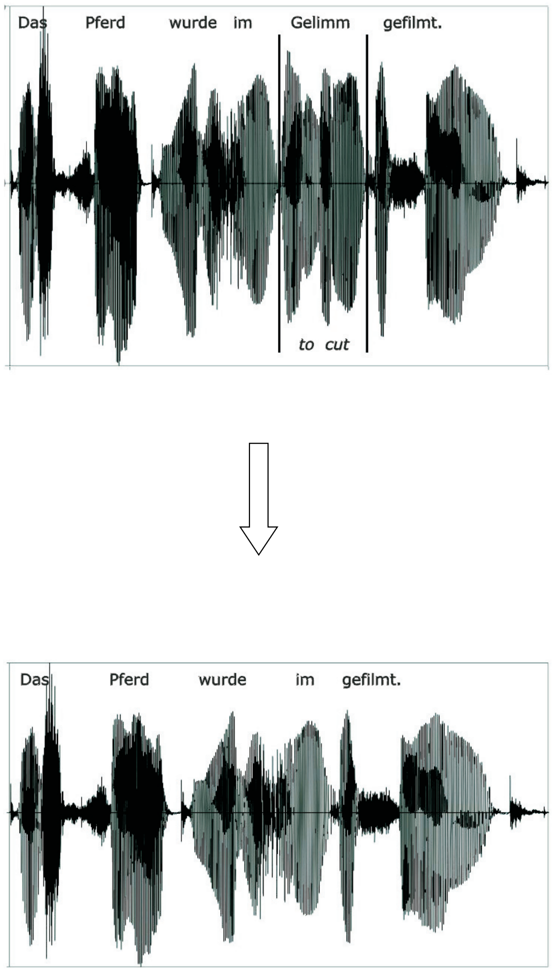

Figure 4.1: Splicing procedure

In the random condition sentences remained as they were spoken by the professional speaker. 50 ms of silence were added at the onset and offset of each sentence. In the *isochronous* condition 400 ms of silence were inserted between consecutive words whereas in the chunked condition 400 ms of silence were inserted after each chunk[1]. This resulted in a

[1]Chunking is what most people call grouping. This refers to the segmentation of a sequence into smaller subsequences (Palmer, 1997), i.e. into meaningfull structural units (Large, 2001; Lehrdahl & Jackendoff, 1983). This segmentation is done to facilitate the processing of events. For example, telephone numbers are much easier to handle if they were splitted in groups of two or three digits. In speech, such chunks should be linguistic phrases as they build up a hierarchical unit, that means a VP, NP or PP serves as chunk. In this experiment pauses were inserted after each linguistic phrase, in order to build chunks and therefore facilitate the processing of syntactic and semantic errors.

isochron	Der - *sil* - Tiger - *sil* - wurde - *sil* - im - *sil* - Zoo - *sil* - gefilmt.
chunk	Der Tiger - *sil* - wurde - *sil* - im Zoo - *sil* - gefilmt.
random	Der Tiger wurde im Zoo gefilmt.

Table 4.2: Timing manipulations in Experiment 1a; sil = 400 ms silence.

constant inter-stimulus-interval of 400 ms (see Table 4.2). The 400 ms interval of silence was inserted by carefully controlling formant transitions.

In order to ensure a precise time locking of the ERP in each individual sentence, the onset of the critical word (participle) was marked by way of careful inspection of the auditory and visual (spectrogram) signal. All manipulations in Experiment 1a were realized using the speech editor PRAAT (PRAAT version 4.3.07, ©Paul Boersma & David Weenink).

Procedure Data were collected in one session. Stimulus material was divided into three lists with each list being presented in a different timing condition. The order of lists was counterbalanced across participants. Thus, all participants heard sentences in a random, chunk and isochronous condition, each in a different list x timing version. To fully counterbalance lists 36 participants were measured (3*2*2-design, within-participants). All 384 sentences were presented auditory via loud speakers in a randomized order. The experimental trials were presented in six blocks (2 per timing condition) of approximately 12 minutes each. Before running the two blocks in the particular timing condition, participants had a training session to get familiar with the respective timing condition. Each sentence was introduced by a visual cue on the center of a computer screen. 2000 ms after the offset of the sentence, participants were asked to perform an correctness judgement. The next trial started 2000 ms after participant's button press (please, see Figure 4.2).

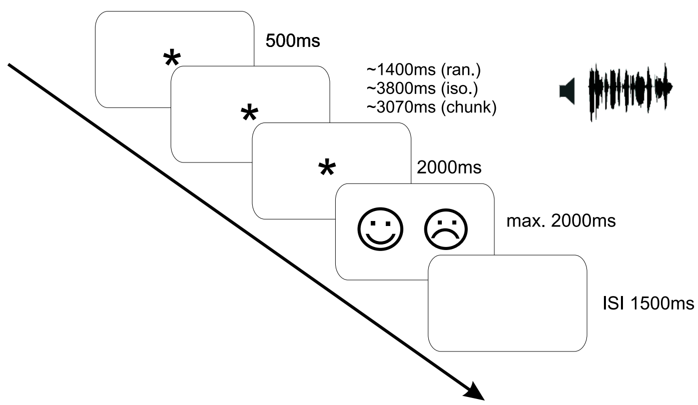

Figure 4.2: Procedure - Experiment 1

Participants were tested in a dimly illuminated sound-attenuating booth. They were seated in a comfortable reclining chair and were instructed to move as little as possible.
The EEG was recorded from 59 scalp sites by means of Ag/AgCl electrodes (see Figure 4.3) mounted in an elastic cap (Electro-Cap Inc., n.d.).

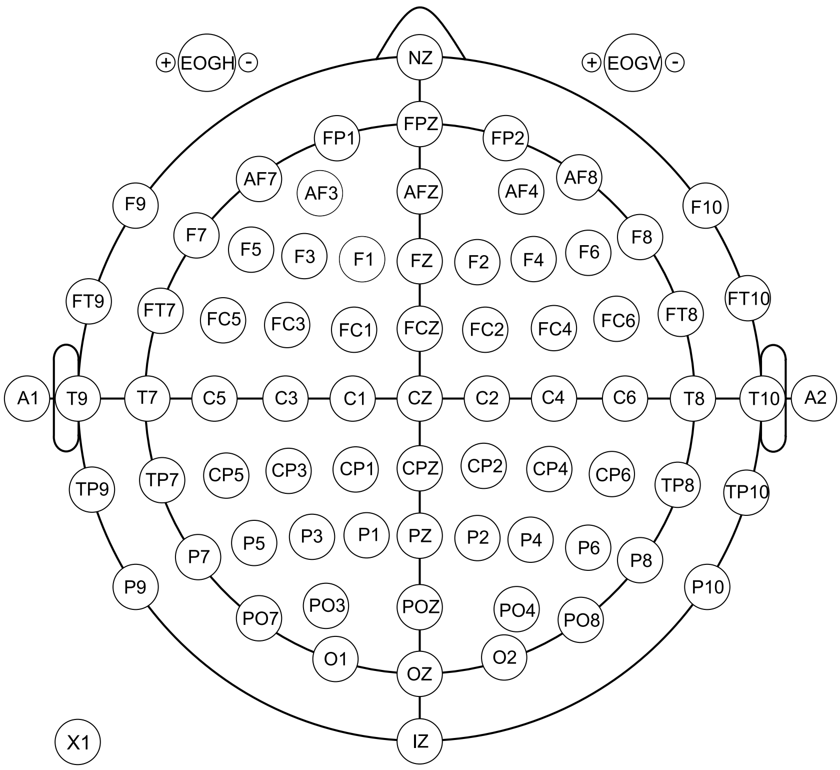

Figure 4.3: Electrode Configuration

Sternum served as ground and the left mastoid as on-line reference (recordings were re-referenced to linked mastoids off-line). Electrode impedances were kept below 3 kΩ. In order to control for eye movement artifacts, a horizontal and a vertical EOG were recorded. The EEG and EOG signals were digitized on-line with a sample frequency of 500 Hz. Individual EEG recordings were scanned for artifacts such as electrode drifting, amplifier blocking, muscle artifacts, eye movements or blinks by means of a rejection algorithm as well as on basis of visual inspection. This was done 100 ms before onset of the critical item (the participle) up to 2500 after the critical item. All contaminated trials as well as wrongly answered trials were rejected, thus approximately 23 % of the trials were excluded. Per participants and per condition average waveforms were computed across all remaining trials (25 trials per condition and timing manipulation) taking a baseline from -100 to 100 ms. This partly post-stimulus baseline was chosen in order to avoid the baseline noise comparing correct and incorrect sentences that were not completely phonetically identical up to the critical item (see Table 4.1). For graphical display only, data were filtered offline with a 7 Hz low pass filter. All statistical evaluations were carried out with unfiltered ERP data.

4.2 Results Experiment 1a

4.2.1 Behavioral Data

Reaction times were not analyzed because participants were instructed to indicate their answer via button press 2 seconds post-stimulus. Thus, only differences in error rates were interpreted. Correctly answered sentences were above 96 %. An ANOVA with the within-subject-factors *condition* (correct short, correct long, semantic, syntactic) and *presentation* (isochronous, chunk, random) revealed a significant main effect of *condition* ($F(3,105) = 5.63$, $p < 0.01$). Planned comparisons between the several levels of the factor *condition* revealed a significant difference between the syntactic and the correct condition, as well as between the correct sentences with PP and without PP, whereas the error rate of the syntactic condition was significantly lower (98.43 % correct) than the error rate of the correct condition (96.38 % correct; ($F(1,35) = 14.04$, $p < 0.001$). Subjects performed better in sentences without a PP (97.74 % correct) than with PP (96.38 % correct; $F(1,35) = 10.05$, $p < 0.01$). The Bonferroni-corrected α-level was 0.025 (using the modified Bonferroni-correction described in Keppel (1991) for multiple comparisons).

4.2.2 ERPs

As hypothesized three different components were elicited in Experiment 1a. The syntactic violation evoked a biphasic pattern consisting of an early negativity (ELAN) and a late positivity (P600). As a correlate of the semantic violation an N400 emerged. The averaging time window started 100 ms prior to the onset of the critical item which was the 'ge'-participle in the experiment.

On the basis of visual inspection, four time windows were statistically analyzed. These included for the syntactic violation 120-250 ms (ELAN) and 500-900 ms (P600) after the onset of the critical item, for the semantic violation 300-600 after the onset of the critical item (N400). In the following analyses different subsets of electrodes were taken together in regions of interest (ROI) and labeled as follows: Anterior-left (FP1, AF7, AF3, F9, F7, F5, F3, FT9, FT7, FC5, FC3), Anterior-right (FP2, AF8, AF4, F10, F8, F6, F4, FT10, FT8, FC6, FC4), Posterior-right (CP4, CP6, TP8, TP10, P4, P6, P8, P10, PO4, PO8, O2), and Posterior-left (TP9, TP7, CP5, CP3, P9, P7, P5, P3, PO7, PO3, O1).

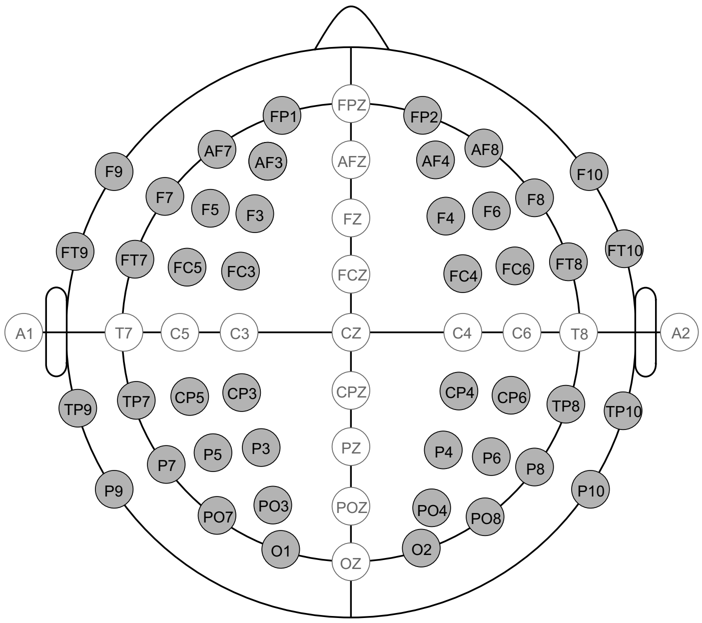

Figure 4.4: Statistically analyzed electrodes (marked in grey) in Experiment 1a.

The three ERP effects were analyzed in separate repeated measured ANOVAs. The Geisser-Greenhouse-Correction was applied when evaluating effects with more than one degree of freedom. Only those significant results that correlate with a critical factor are reported in the following.

ELAN To evaluate the early negativity an ANOVA with four within-subject-factors was conducted, namely *condition* (grammatically correct/incorrect), *presentation* (isochronous/random/chunk), *hemisphere* (left/right) and *region* (anterior/posterior). The omnibus ANOVA revealed a main effect for *condition* ($F(2,70) = 10.23$; $p < 0.01$) and an interaction between *condition* and *presentation* ($F(2,70) = 13.48$, $p < 0.001$). Resolving the interaction reveals a significant effect for *condition* in all of the three timing conditions, but only the random condition resulted in a negativity, whereas chunk and isochronous condition resulted in a statistically significant positivity (chunk: $F(1,35) = 24.56$, $p < 0.001$; isochronous: $F(1,35) = 5.13$, $p < 0.05$; random: $F(1,35) = 4.75$, $p < 0.05$).

ELAN: 120 - 250 ms			
Effect	*df*	*F value*	*p value*
con	1,35	10.26	<0.01
pres	2,70	40.60	<0.001
*con*pres*	2,70	13.48	<0.001
*pres*hem*	2,70	11.96	<0.001
*pres*reg*	2,70	28.57	<0.001
Chunk (Positivity)			
Effect	*df*	*F value*	*p value*
con	1,35	24.56	<0.001
hem	1,35	9.80	<0.01
Isochronous (Positivity)			
Effect	*df*	*F value*	*p value*
con	1,35	5.13	<0.05
*con*hem*reg*	1,35	4.89	<0.05
Random (Negativity)			
Effect	*df*	*F value*	*p value*
con	1,35	4.75	<0.05

Table 4.3: Experiment 1a: Significant results from ANOVAs on mean amplitudes for the time window of 120 to 250 ms (ELAN)

P600 Due to visual inspection of the P600 only posterior electrodes were analyzed, as the positivity was only visible over posterior sites. The omnibus ANOVA includes the within-subject-factors *condition*, *presentation* and *hemisphere* and resulted in a main effect for *condition* ($F(1,35) = 6.87$, $p < 0.05$), an interaction *condition* x *hemisphere* ($F(1,35) = 5.15$, $p < 0.05$), and an interaction *condition* x *presentation* ($F(2,70) = 6.94$, $p < 0.01$). Step-down-analyses revealed significant effects for *condition* in the isochronous ($F(1,35) = 4.40$, $p < 0.05$) and random presentation ($F(1,35) = 13.50$, $p < 0.001$) only. Resolving the interaction *condition* x *hemisphere* by the factor hemisphere reveals a significant effect for *condition* only in the left hemisphere ($F(1,35) = 10.30$, $p < 0.01$).

The null result of a P600-effect in the chunked condition may result from the fact that participants detected grammatical violations as soon as they heard the preposition followed by a pause as mentioned in the introduction of this experiment. For this reason a separate ANOVA for the chunked condition was conducted namely for amplitude means averaged from 800 - 1200 ms (on the basis of visual inspection - see Figure 4.8) after the onset of the *preposition*. In this omnibus ANOVA the condition-effect turns out to be significant ($F(1,35) = 37.43$; $p < 0.001$).

Time Window: 500 - 900 ms			
Effect	*df*	*F value*	*p value*
con	1,35	6.87	<0.05
*con*pres*	2,70	6.94	<0.01
*con*hem*	1,35	5.15	<0.05
Isochronous			
Effect	*df*	*F value*	*p value*
con	1,35	4.40	<0.05
Random			
Effect	*df*	*F value*	*p value*
con	1,35	13.50	<0.001
Left Hemisphere			
Effect	*df*	*F value*	*p value*
con	1,35	10.30	<0.01

Table 4.4: Experiment 1a: Significant results from ANOVAs on mean amplitudes for the time window of 500 to 900 ms (P600).

Time Window: 800 - 1200 ms			
Effect	*df*	*F value*	*p value*
cond	1,35	37.43	<0.001
hem	1,35	7.85	<0.01

Table 4.5: Experiment 1a: Significant results from ANOVAs on mean amplitudes for the time window of 800 to 1200 after onset of the preposition in the chunked condition

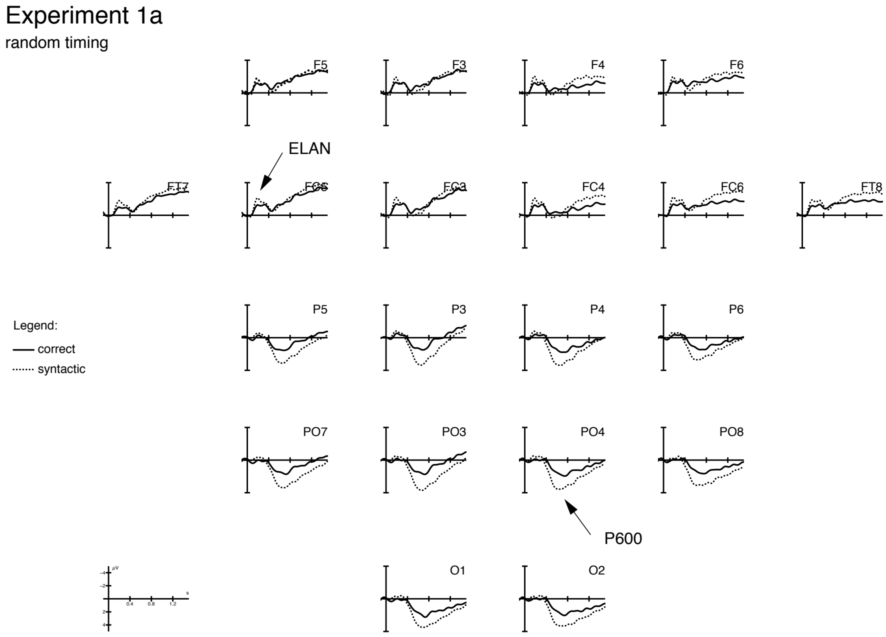

Figure 4.5: Experiment 1a: ERPs elicited by the syntactic violation in the ***random*** *timing condition*

N400 The omnibus ANOVA for the N400 time window entailed the four within-subject-factors *condition*, *presentation*, *hemisphere* and *region*. The analysis resulted in a main effect of *condition* (F(1,35) = 111.61, $p < 0.001$) and an interaction between *region* and *condition* (F(1,35) = 7.49, $p < 0.01$). Step-down-analyses showed a significant effect of *condition* for frontal and parietal electrode sites (Frontal: F(1,35) = 36.40, $p < 0.001$, ES [2] = 0.394; Parietal: F(1,35) = 111.47, $p < 0.001$, ES = 0.739) while the effect was larger over parietal sites (see Figures 4.9, 4.10, and 4.11) .

Groups Posthoc-analyses with the between-factor *group* to evaluate processing differences between participants learning with music and participants learning without did not reveal any significant effect.

[2] ES = effect size; the larger this effect the greater is power

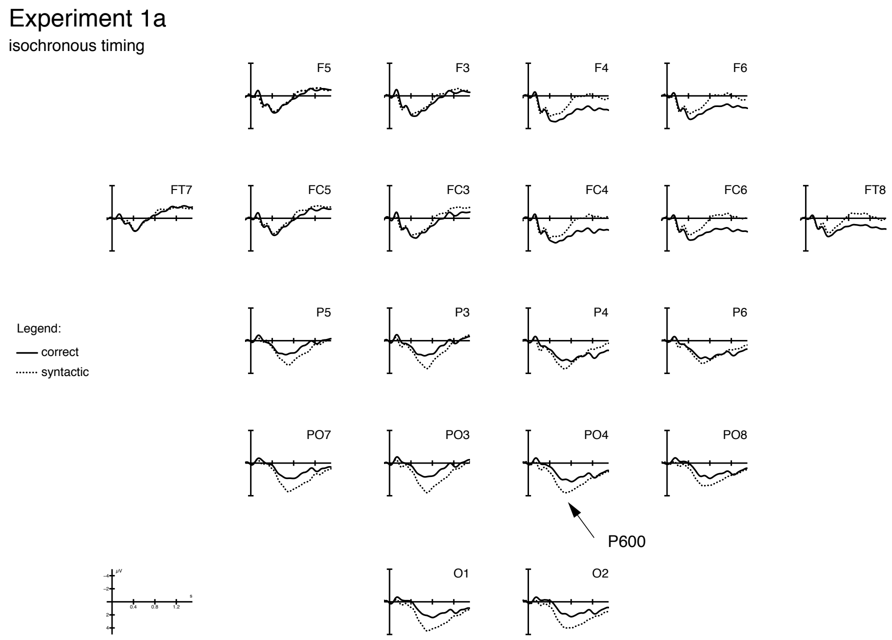

Figure 4.6: Experiment 1a: ERPs elicited by the syntactic violation in the ***isochronous*** *timing condition*

4.3 Discussion Experiment 1a

Experiment 1a investigated the impact of a constant inter-stimulus-interval on auditory sentence processing. Thus, semantically as well as syntactically incorrect and correct sentences were presented in three different timing conditions. Due to previous studies, three components were expected: The ELAN, an early negativity, the P600 as a neurophysiological correlate of syntactical reanalysis and the N400 as a correlate of semantic integration.

ELAN As hypothesized, the ELAN was only visible in the random timing condition and is of different nature in the isochronous as well as in the chunked condition. This is consistent with the results of previous studies, that showed this component that is related to automatic word-category processing to be very time-sensitive, e.g. when the interstimulus-

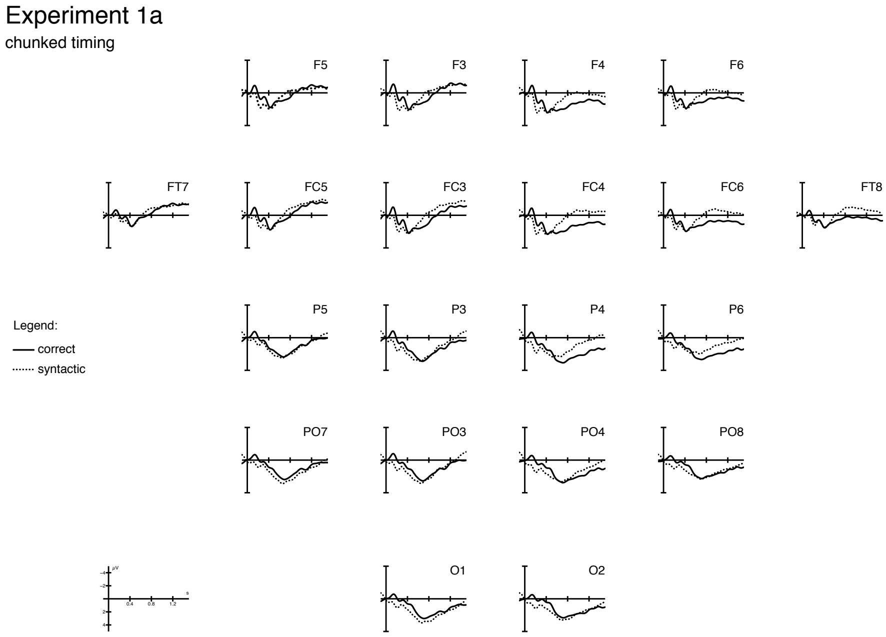

Figure 4.7: Experiment 1a: ERPs elicited by the syntactic violation in the ***chunked*** *timing condition*

interval is too long (Kotz, Cramon, & Friederici, 2005). In previous studies the ELAN has been reported to have its maximum at left anterior electrode sites. As the missing interaction between the factors *condition* and *region* indicates, the early negativity in the current experiment has a whole-head-distribution. In order to evaluate whether the timing manipulation in each block could have influenced the processing of the speech signal in the random condition, an ANOVA was conducted, which contained only those twelve participants that started the experiment with the two speech-appropriate spoken blocks (random timing condition). Thus, these participants could not have been influenced by other timing manipulations. Consequently, if the deviant topography could be traced back to the timing manipulation in the other blocks, the twelve participants should show an anterior distribution of the ELAN. But, as can be seen in Table 4.7 this ANOVA resulted in an interaction *condition* x *presentation* ($F(2,22) = 8.74$, $p < 0.01$) with a significant negativity only in the random presentation ($F(1,11) = 5.89$, $p < 0.05$), but the predicted three-way interaction of

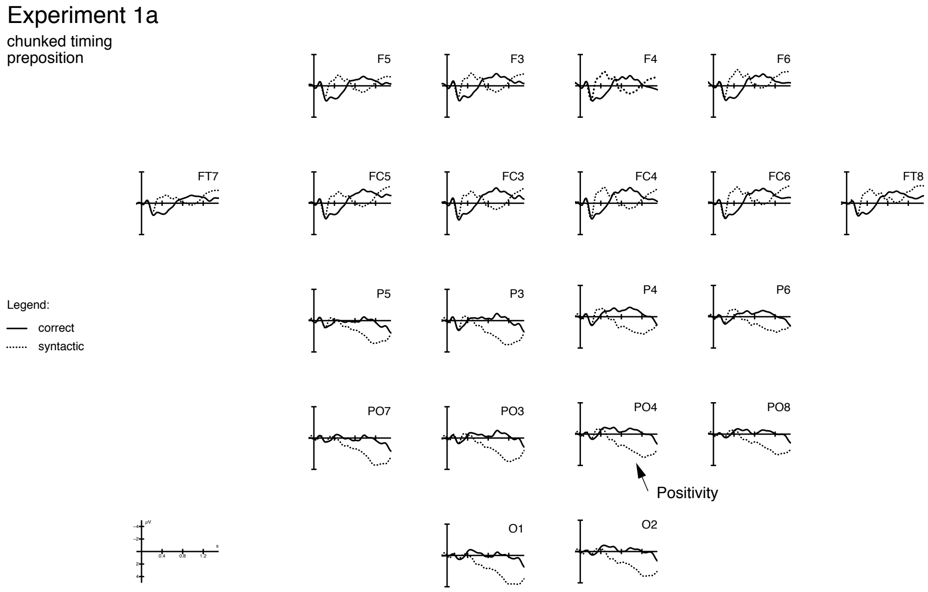

Figure 4.8: Experiment 1a: Positivity-effect of the word category violation in the chunked timing condition after onset of the preposition

condition, *presentation* and *region* was not confirmed. Consequently, the above described whole-head topography of the ELAN was not due to the timing manipulations. Also, results from MEG-studies with similar material indicate that the source generators of the ELAN are not only frontal, as the strongest activation for phrase structure violations was found in temporal cortices (Friederici et al., 2000). With respect to the bilateral distribution of the ELAN, Eckstein and Friederici (2006) proposed that incongruent prosody could drive the appearance of the ELAN at right electode sites as prosody is linked to right hemispheric processing. This seems to be plausible in the context of the present experiment, as the syntactic violation falls together with a prosodic violation (unexpected sentence-ending-prosody). However, it remains open why previous studies, using the same material, reported only a left hemispheric distributed ELAN and why the present ELAN is whole-head-distributed. Thus, future studies have to shed more light on this issue.

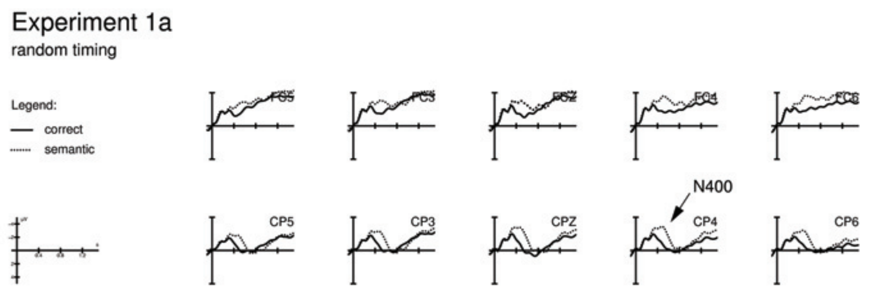

*Figure 4.9: Experiment 1a: ERPs elicited by the semantic violation in the **random** timing condition*

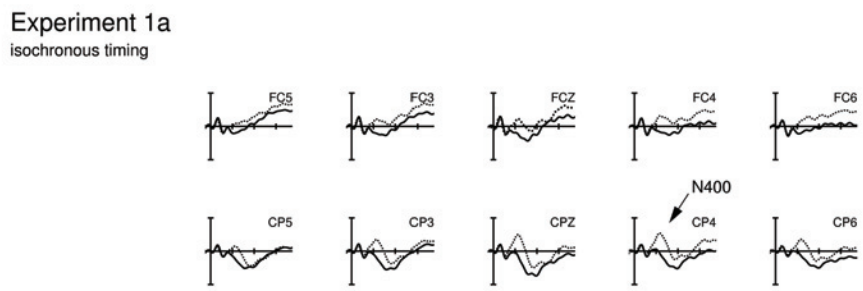

*Figure 4.10: Experiment 1a: ERPs elicited by the semantic violation in the **isochronous** timing condition*

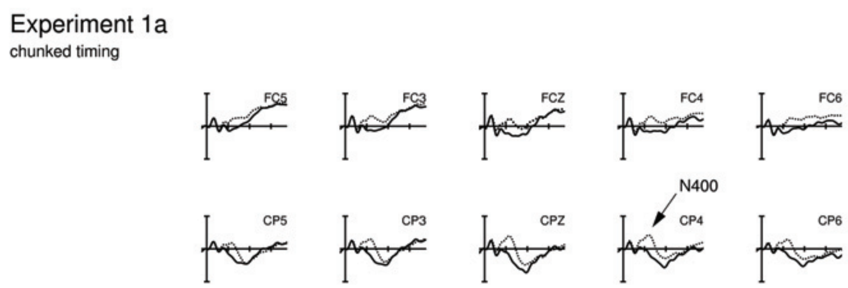

*Figure 4.11: Experiment 1a: ERPs elicited by the semantic violation in the **chunked** timing condition*

Time Window: 300 - 600 ms			
Effect	*df*	*F value*	*p value*
con	1,35	111.61	<0.001
pres	2,70	26.08	<0.001
*con*reg*	1,35	7.49	<0.01
Anterior			
Effect	*df*	*F value*	*p value*
con	1,35	36.40	<0.001
Posterior			
Effect	*df*	*F value*	*p value*
con	1,35	111.47	<0.001
Post-hoc-comparisons			
Condition	*df*	*F value*	*p value*
Pres	2,70	26.08	<0.001
chunk vs. random	1,35	42.37	<0.001
isochronous vs. random	1,35	31.94	<0.001

Table 4.6: Experiment 1a: Significant results from ANOVAs on mean amplitudes for the time window of 300 to 600 ms (N400).

P600 As there are no significant differences in amplitude size of the P600 between the random and the isochronous condition, it can be concluded that the P600 is unaffected by the isochronous timing manipulation. The left hemispheric lateralization of the P600 in the present study seems not to be surprising as several fMRI-studies revealed that syntax is mainly processed in the left hemisphere (e.g. Friederici, 2002).
The apparent omission of the P600 in the chunked condition could be refuted by conducting an analysis at the onset of the preposition that demonstrated a late positivity after the presentation of the preposition. Thus, the omission of the P600 after the critical item is linked to the fact that the participants detected the violation as soon as they heard a preposition followed by silence.

Furthermore, as visible in the data plots late long sustained negativity has been elicited at frontal and central electrodes. This negativity was more pronounced over right than left hemisphere sites. Post-hoc-analyses were conducted in order to evaluate this negativity (for detailled statistical analysis please see Appendix A.1). These analyses revealed a significant negativity only over right anterior electrode sites. A late negativity with a similar distribution was found by Schröger and Wolff (1998) as a correlate of re-orientation from task-irrelevant to task-relevant aspects of a stimulus. In their study participants' attention was distracted by task-irrelevant deviations in the stimuli. These deviations evoked inter alia a frontal and central late negativity. An interpretation of the present negativity as a correlate

Time Window: 120 - 250 ms			
Effect	*df*	*F value*	*p value*
con (positivity)	1,11	5.94	<0.05
pres	2,22	19.36	<0.001
*con*pres*	2,22	8.74	<0.01
Chunk - Positivity			
Effect	*df*	*F value*	*p value*
con	1,11	11.96	<0.01
Isochronous - Positivity			
Effect	*df*	*F value*	*p value*
con	1,11	7.52	<0.05
Random - Negativity			
Effect	*df*	*F value*	*p value*
con	1,11	5.89	<0.05

Table 4.7: Experiment 1a: Significant results from ANOVAs on mean amplitudes for the time window 120 to 250 ms (ELAN) - 12 subjects with random-first version.

of re-orientation to task-relevant aspects of the stimuli is conclusive as in Experiment 1a an existing (task-irrelevant) prosodic violation was adhering the (task-relevant) syntactic violation. This is because participants expected a normally articulated noun phrase but instead they heard a stimulus (participle) with 'sentence ending prosody'. Thus, the wrong prosody may function as a distractor with respect to the task-relevant syntactic violation. This may have caused the long sustained negativity.

N400 The N400 appears to be almost unaffected by the timing manipulation. This component continues more positive in the isochronous presentations independent of the factor condition (mean chunk: 0.007 μV; mean isochronous: 0.056 μV; mean random: -1.463 μV), however, it is constant regarding its latency and amplitude across the presentation types.

The results of Experiment 1a demonstrate that extended timing, i.e. slowing down the natural speech stream does not influence the processing of syntactic violations in a healthy population in contrast to patients with BG lesions (Kotz, Gunter, & Wonneberger, 2005). This is due to a functionally intact internal pacemaker in healthy participants. So, external cues neither facilitate syntactic processing nor do they interfere with an internal metric template. However, it is possible that the chosen time interval - the ISI - is inappropriate to investigate a facilitation in sentence processing. In a previously conducted visual experiment a constant ISI automatically led to a constant SOA as well, i.e. a constant word duration plus a constant ISI resulting in a predictable time-unit from the onset of a word to the onset of the following word. Thus, the participants are synchronized. In the auditory modality, a non-varying ISI does not automatically lead to a constant SOA as each word has variable duration and thus the SOA is unpredictable. To profit from the constant pause between two successive words and chunks, respectively, it is obligatory to have a concept of a 400 ms time interval. In other words, participants have to remember the interval of 400 ms in order to predict the onset of the next acoustic event. This requires a special competence to estimate time intervals that may impose additional working memory demands (Mayville et al., 2002). Therefore a second manipulation in form of a constant time period between the onsets of successive words/chunks was realized and tested in the following experiment (1b).

Chapter 5

Experiment 1b

The results of Experiment 1a have shown that healthy participants neither profit from a constant pause between two successice acoustic events (i.e. words) nor does such external metric cueing interfere with a cognitive metric template with respect to syntactic reanalysis. The following Experiment 1b was conducted in order to clarify whether the SOA is a critical time window to influence syntactic processing in healthy participants, that is if a predictable onset of each word or chunk facilitates the detection and processing of syntactic information. Analogous to the meter perception model proposed by Large and Jones (1999) the system produces self-sustained oscillations and temporal structured patterns under rhythmic stimulation. Such an oscillation is synchronizing with an external rhythmic signal. However, oscillations do not respond to every onset of a beat, but only to an expected beat. As could be shown by the results of Experiment 1a, a constant ISI did not serve as such an external rhythmic signal to synchronize participants' auditory language processing. The following Experiment 1b was conducted to investigate the influence of a constant SOA on the auditory language processing system.
If the SOA serves as an external 'taktgeber' in healthy participants one may expect that participants synchronize with the external cue in the chunked timing condition as well. This may have consequences on the processing speed so that syntactic violations are detected and processed not until the participle is perceived. This should result in a P600 after the onset of the participle rather than after the onset of the preposition (Experiment 1a). However, if the positivity already deflects after the onset of the preposition it can be concluded that healthy participants are unaffected by either a constant ISI or a constant SOA. It is important to note that the stimuli in Experiment 1b were exactly the same as in Experiment 1a thus only the nature of timing predictability was changed. Regarding the isochronous timing condition, the P600 is expected to be unaffected if healthy participants do not profit from the external

'taktgeber'. Otherwise, an amplitude modulation of the P600 in the isochronous and chunk timing condition compared to the random condition speaks for a facilitation in syntactic processing.
With respect to the ELAN and the N400 the same results as in Experiment 1a were expected, namely no ELAN for the chunked and the isochronous condition as this component is sensitive to extended timing and a timing-unaffected N400 in all of the presentation modes.

5.1 Materials and Methods

Participants Thirty-six right-handed volunteers with normal hearing (18 female) aged 18-28 years (mean: 25,1) participated in that study. All were native speakers of German and had not taken part in Experiment 1a. Participants were paid a small fee for their participation. All participants had normal or corrected-to-normal vision and were high-spans according to the Reading Span Test (equal or higher than 3,5). None of the participants had any known neurological impairment.
Furthermore, participants were divided into subgroups (on the basis of a pre-experimental questionnaire), namely their learning type as some of them were learning with, others without music. This was done to keep on observing potential differences in syntactic processing of musically trained compared to musically untrained participants.

Materials The aim of the Experiment 1b was to investigate the influence of temporal patterning in the auditory modality with respect to a constant SOA. The same sentences as in Experiment 1a were used. Thus, random timed sentences in Experiment 1b were identical to those presented in Experiment 1a. The chunked and isochronous sentences were manipulated as follows: Isochronous as well as chunked conditions used constant time intervals between word onsets, i.e. the SOA corresponds to the word duration of the longest word (798 ms) and chunk (859 ms) respectively plus 400 ms of silence. The manipulations in Experiment 1b were likewise realized using the speech editor PRAAT.

isochron	Der - *x ms* - Tiger - *400 ms* - wurde - *x ms* - im - *x ms* - Zoo - *x ms* - gefilmt.
chunk	Der Tiger - *400 ms* - wurde - *x ms* - im Zoo - *x ms* - gefilmt.
random	Der Tiger wurde im Zoo gefilmt.

Table 5.1: Time conditions in Experiment 1b.

To clarify Table 5.1 a brief example is given: Imagine "Tiger" would the longest word of the whole set of materials lasting 798 ms. Thus, 400 ms of silence were added after the offset of "Tiger". If the article "der" only takes 125 ms then the variable x after "der" takes (798-125) + 400 ms, thus 1073 ms of silence were added after "der".

Procedure The procedure of Experiment 1b was the same as in Experiment 1a. As all contaminated and wrongly answered trials were rejected approximately 21 % of the trials were excluded.

5.2 Results Experiment 1b

5.2.1 Behavioral Data

ANOVAs were conducted for percentages correct only (see Experiment 1a).
All accurately answered sentences were above 96 %. The omnibus ANOVA included the within-subject-factors *condition* (correct with PP, syntactic, semantic, correct without PP) and *presentation* (isochronous, chunk, random) and showed a significant main effect of *condition* ($F(3,105) = 12.17$, $p < 0.001$). Planned comparisons between the several levels of the factor *condition* revealed a significant difference between the syntactic and the correct condition (with PP), whereas the error rate of the syntactic condition was significantly lower (99.01 % correct) than the error rate of the correct condition (96.32 % correct; $F(1,35) = 31.76$, $p < 0.001$) as in Experiment 1a. The Bonferroni-corrected α-level is 0.025 (using the modified Bonferroni-correction described in Keppel (1991)).

5.2.2 ERP

In Experiment 1b the ERP-effects had slightly different latencies compared to Experiment 1a. Therefore other time windows were defined for statistical analyses. These were: syntactic violation 150-300 ms (ELAN) and 600-1000 ms (P600) after the onset of the critical item (participle), semantic violation 300-600 ms after onset of the critical item. The same ROIs as in Experiment 1a were used. As in Experiment 1a the ANOVAs were conducted with 4 within-subject factors, namely *condition*, *presentation*, *hemisphere* and *region*.

ELAN Visual inspection displayed that the ELAN in Experiment 1b has a whole-head-distribution (see Experiment 1a). Thus, an ANOVA with four within-subject-factors was

Time Window: 150 - 300 ms			
Effect	*df*	*F value*	*p value*
pres	2,70	92.31	<0.001
*con*pres*	2,70	14.90	<0.001
*con*pres*hem*	2,70	4.10	<0.05
Isochronous - Positivity			
Effect	*df*	*F value*	*p value*
con	1,35	5.42	<0.05
Random - Negativity			
Effect	*df*	*F value*	*p value*
con	1,35	18.74	<0.001
*con*hem*	1,35	3.98	<0.06
Random - Left Hemisphere			
Effect	*df*	*F value*	*p value*
con	1,35	21.20	<0.001
Random - Right Hemisphere			
Effect	*df*	*F value*	*p value*
con	1,35	10.39	<0.01

Table 5.2: Experiment 1b: Significant results from ANOVAs on mean amplitudes for the time window 150 to 300 ms (ELAN).

computed, namely *condition* (correct, syntactic), *presentation* (isochronous, chunk, random), *region* (anterior, posterior) and *hemisphere* (left, right). The omnibus ANOVA revealed a main effect of *presentation* (F(2,70) = 92.31, $p < 0.001$) and an interaction between the factors *presentation* and *condition* (F(2,70) = 14.90, $p < 0.001$), as well as a three-way interaction between the factors *condition*, *presentation*, and *hemisphere*. Resolving both interactions by the factor *presentation* showed a significant condition effect for random (F(1,35) = 18.74, $p < 0.001$) and isochronous presentation rate (F(1,35) = 5.42, $p < 0.05$) as well as a marginal condition effect for the chunked presentation [1] (F(1,35) = 3.58, $p < 0.08$), and a marginal interaction-effect *condition x hemisphere* for the random presentation (F(1,35) = 3.98, $p < 0.06$). Resolving this interaction by the factor *hemisphere* resulted in a significant condition-effect in both hemispheres (left: F(1,35) = 21.20, $p < 0.001$, ES = 0.686; right: F(1,35) = 10.39, $p < 0.01$, ES = 0.487), with the left hemispheric effect larger than the right hemispheric effect. The missing interaction *condition x region* indicates that the whole-head distribution of the early negativity reached significance (see Figure 5.1).

[1] However, only in the random condition a *negativity* revealed significance whereas the isochronous und chunk manipulation resulted in a *positivity*.

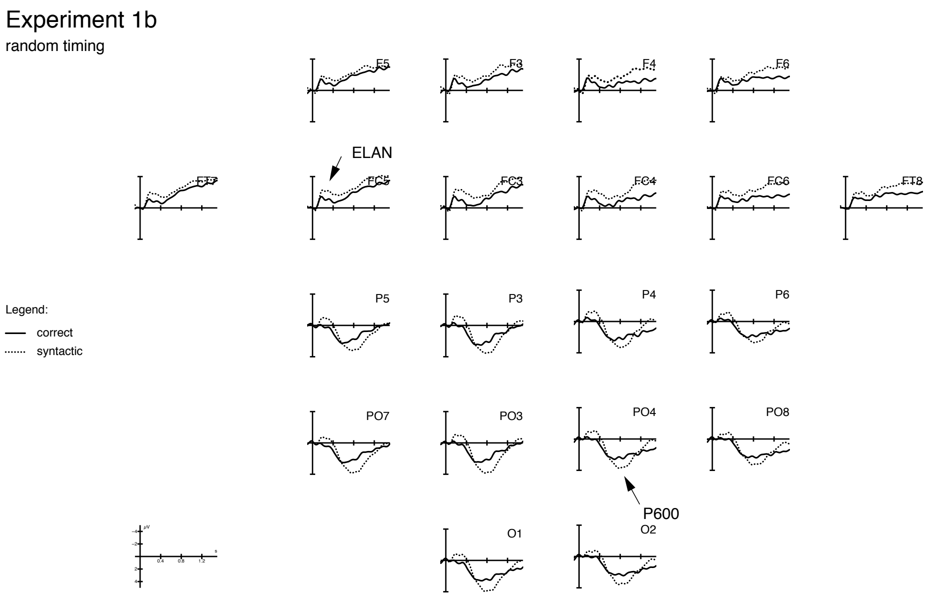

Figure 5.1: Experiment 1b: ERPs elicited by the syntactic violation in the ***random*** *timing condition*

P600 To evaluate the P600 component, an ANOVA over posterior electrodes was conducted. It included the within-subject-factors *condition* (correct/syntactic), *presentation* (isochronous, chunk, random) and *hemisphere* (left, right). In the 600 to 1000 ms latency window the omnibus ANOVA resulted in a main effect of *condition* ($F(1,35) = 6.29$, $p < 0.05$), a main effect of *presentation* ($F(2,70) = 11.56$, $p < 0.001$) and an interaction effect between *condition* and *hemisphere* ($F(1,35) = 7.58$, $p < 0.05$). Step-down-analyses showed a significant effect of condition only for the left hemisphere ($F(1,35) = 9.86$; $p < 0.01$). Planned comparisons of the different presentation rates resulted in significant differences between the isochronous and the chunked presentation rate ($F(1,35) = 11.84$, $p < 0.01$), as well as the random and the isochronous presentation rate ($F(1,35) = 13.72$, $p < 0.001$). These effects are due to the fact that the isochronously presented sentences resulted in a more positive amplitude (mean: 3.72 μV) than the randomly (mean: 2.21 μV) and chunked (mean: 2.57 μV) presented sentences. One can observe that in contrast to Experiment 1a

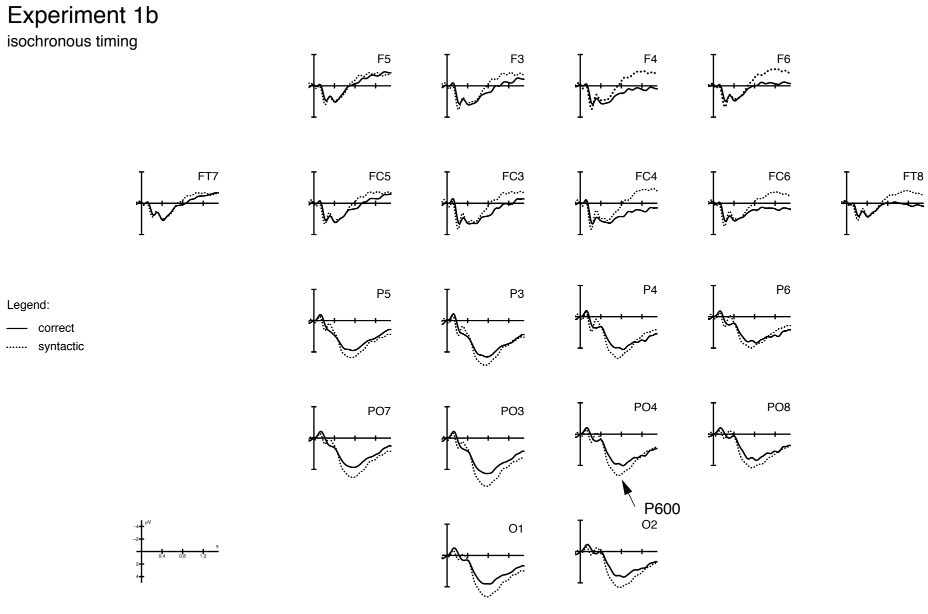

Figure 5.2: Experiment 1b: ERPs elicited by the syntactic violation in the ***isochronous*** *timing condition*

the P600 in Experiment 1b was evoked in all of the three timing conditions after the onset of the participle (see Figures 5.1, 5.2 and 5.3).

Groups Posthoc-analyses with the between-factor *group* and the above mentioned within-subject-factors were conducted to evaluate the P600. The results showed a significant interaction between *condition* and *learning type* ($F(1,34) = 10.90$, $p < 0.01$). Step-down analyses revealed a significant effect of *condition* only for those participants learning while listening to music ($F(1,34) = 12.74$, $p < 0.01$) (see Figures 5.4, 5.5, 5.6, 5.7, 5.8, and 5.9).

N400 Regarding the semantic violation, a 300 to 600 ms time window was chosen to compute data for the omnibus ANOVA with four within-subject-factors, namely *condition* (correct, semantic violation), *presentation* (isochronous, chunk, random), *hemisphere* (left, right) and *region* (anterior, posterior). This ANOVA resulted in a significant main effect

Time Window: 600 - 1000 ms			
Effect	*df*	*F value*	*p value*
con	1,35	6.29	<0.05
pres	2,70	11.56	<0.001
*con*hem*	1,35	5.20	<0.05
Left Hemisphere			
Effect	*df*	*F value*	*p value*
con	1,35	9.86	<0.01
Post-hoc-comparisons			
Effect	*df*	*F value*	*p value*
Pres	2,70	9.08	<0.001
chunk vs. isochronous	1,35	11.84	<0.01
random vs. isochronous	1,35	13.72	<0.01

Table 5.3: Experiment 1b: Significant results from ANOVAs on mean amplitudes for the time window 600 to 1000 ms (P600).

Time Window: 600 - 1000 ms			
Effect	*df*	*F value*	*p value*
*con*LType*	1,34	10.90	<0.01
Learner with Music			
Effect	*df*	*F value*	*p value*
con	1,14	16.52	<0.01

Table 5.4: Experiment 1b: Significant results from ANOVAs on mean amplitudes with between-subject-factor 'learning type' (P600).

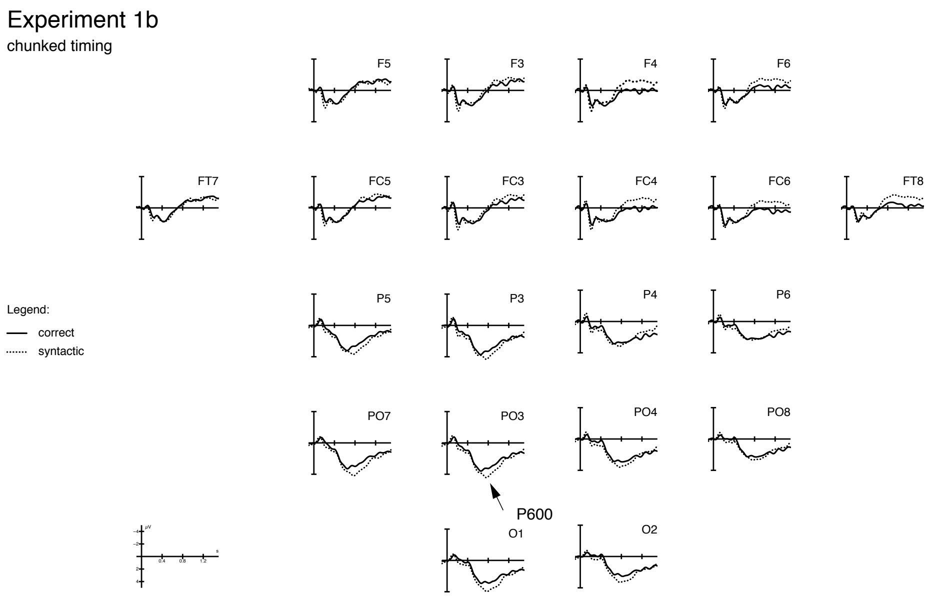

Figure 5.3: Experiment 1b: ERPs elicited by the syntactic violation in the ***chunked*** *timing condition*

for *condition* (F(1,35) = 82.17; $p < 0.001$), a main effect for *presentation* (F(2,70) = 55.38, $p < 0.001$) and a significant interaction between *condition* and *region* (F(1,35) = 5.79; $p < 0.05$), as well as an interaction between the factors *condition* and *hemisphere* (F(1,35) = 4.20; $p < 0.05$). Resolving the interaction between *condition* and *region* by the factor *region* resulted in a significant condition-effect for both regions, while the calculated effect size indicates that the effect was larger in the posterior region (anterior: F(1,35) = 30.90; $p < 0.001$, ES = 0.394; posterior: F(1,35) = 94.32; $p < 0.001$, ES = 0.769). Regarding the interaction between *condition* and *hemisphere* step-down-analyses revealed a significant effect of *condition* in both hemispheres, while the effect was larger over the right hemisphere (left: F(1,35) = 29.20; $p < 0.001$; right: F(1,35) = 55.38; $p < 0.001$). Planned comparisons between the different levels of the factor *presentation* revealed significant differences between the chunk presentation and the random presentation (F(1,35) = 59.84, $p < 0.001$) as well as between the isochronous condition and the random condition (F(1,35) = 91.42, $p < 0.001$).

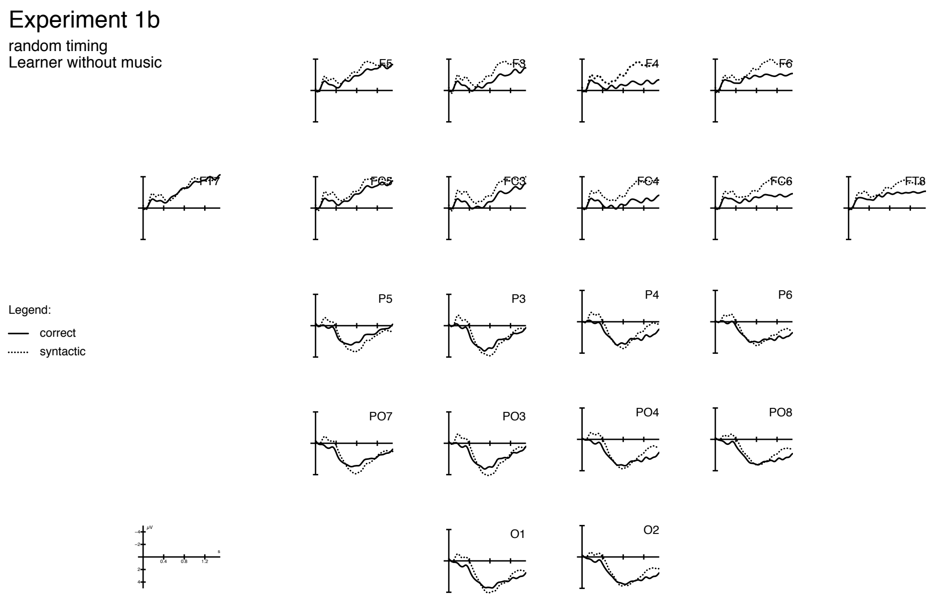

*Figure 5.4: Experiment 1b: **Random** timing - Learningtype without music*

These effects were due to different voltage levels, i.e. the amplitudes of chunked (0.57 μV) and isochronous (0.70 μV) presentations were generally more positive than the amplitude of random (-1.72 μV) presentation.

5.3 Discussion Experiment 1b

ELAN In general, data from the Experiment 1a were replicated in Experiment 1b as the time sensitivity of the ELAN was demonstrated. These results clearly show that the ELAN is omitted in the isochronous and the chunked condition. Furthermore, according to the results in Experiment 1a, the ELAN in Experiment 1b had a whole-head distribution, but in this experiment the effect is stronger at left electrode sites. Thus, the same post-hoc-analysis as in Experiment 1a was conducted to check for possible order-effects. Consequently, the

Time Window: 300 - 600 ms			
Effect	*df*	*F value*	*p value*
con	1,35	82.17	<0.001
pres	2,70	55.38	<0.001
*con*hem*	1,35	4.20	<0.05
*con*reg*	1,35	5.79	<0.05
Anterior			
Effect	*df*	*F value*	*p value*
con	1,35	30.90	<0.001
Posterior			
Effect	*df*	*F value*	*p value*
con	1,35	94.32	<0.001
Left Hemisphere			
Effect	*df*	*F value*	*p value*
con	1,35	29.20	<0.001
Right Hemisphere			
Effect	*df*	*F value*	*p value*
con	1,35	36.98	<0.001
Post-hoc-analyses			
Effect	*df*	*F value*	*p value*
Pres	2,70	55.38	<0.001
chunk vs. random	1,35	59.84	<0.001
isochronous vs. random	1,35	91.42	<0.001

Table 5.5: Experiment 1b: Significant results from ANOVAs on mean amplitudes for the time window 300 to 600 ms (N400).

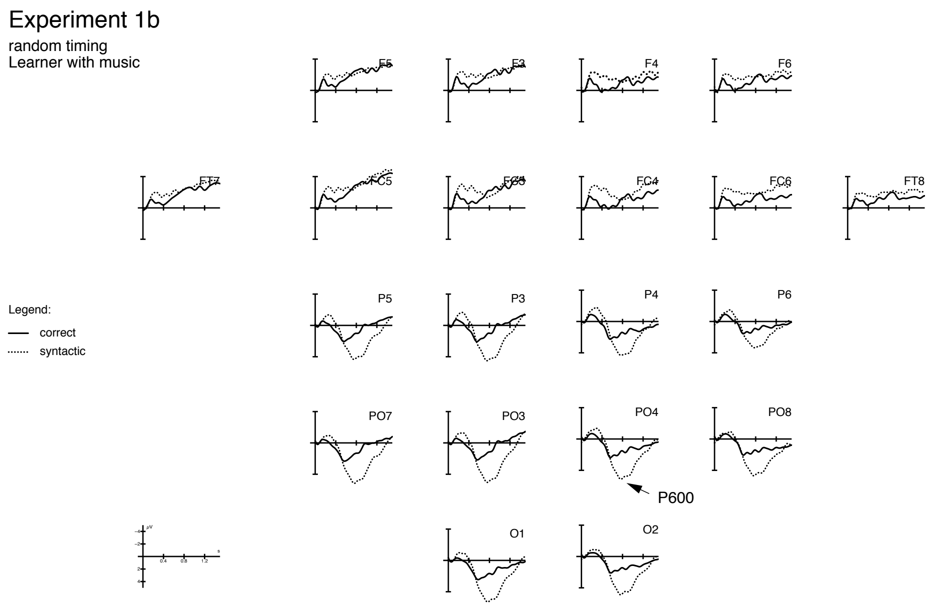

Figure 5.5: Experiment 1b: ***Random*** *timing - Learningtype with music*

post-hoc conducted ANOVA included only those twelve participants who heard the randomly presented sentences first. These participants could not have been influenced by the timing manipulation as they did not hear any other presentation rates before. In this case the ELAN was also significant at posterior sites (*condition* x *presentation*: F(2,22) = 4.35; $p < 0.05$); random condition: F(1,11) = 11.19, p = < 0.01).

This post-hoc conducted ANOVA (see Table 5.6) demonstrates that the whole-head distribution is not an artifact of the timing manipulation in the other blocks. However, the explanation of Eckstein and Friederici (2006) does not suffice with regard to the present data. As already mentioned, the material in Experiment 1b is the same as in Experiment 1a. Thus, if the lateralization of the ELAN has to do with prosodic incongruence, the distribution has to be the same in both experiments, but this is not the case. An explanation has to remain speculative. It could be that this is a general distributional variance as other studies as well reported bilateral distribution (see for example Müller, 2005).

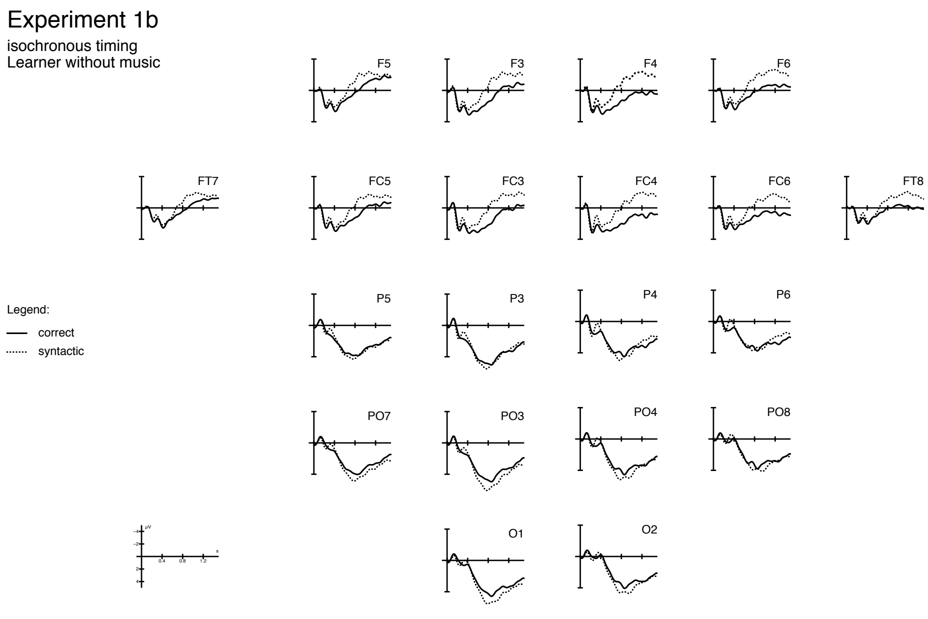

Figure 5.6: Experiment 1b: ***Isochronous*** *timing - Learningtype without music*

P600 The most remarkable result of Experiment 1b is the distribution of the P600. Firstly, there are no significant differences in amplitude size between the timing manipulations. This confirms the assumption that the internal pacemaker functions smoothly in healthy participants and that they do not benefit from an external pacemaker. Thus, there is no saving of ressources due to the external pacemaker. However, the present sort of timing seems to have a high impact on auditory sentence processing. In contrast to Experiment 1a the P600 emerged in all of the three timing manipulations about 600 ms after the onset of the participle, although participants could already detect the violation at the offset of the preposition in the chunk condition. Due to the constant SOA in Experiment 1b the onset of every phrase is maximally predictable and is maximally anticipated at a certain time point. Data from a production study conducted by Cummins and Port (1998) indicate that the human processing system is relatively inflexible in synchronizing with an external 'taktgeber'. The authors demonstrated that the production of mini-phrases such as "big for a duck" to the tactus of an external 'taktgeber' was only possible in certain ratios. This evidence supports the

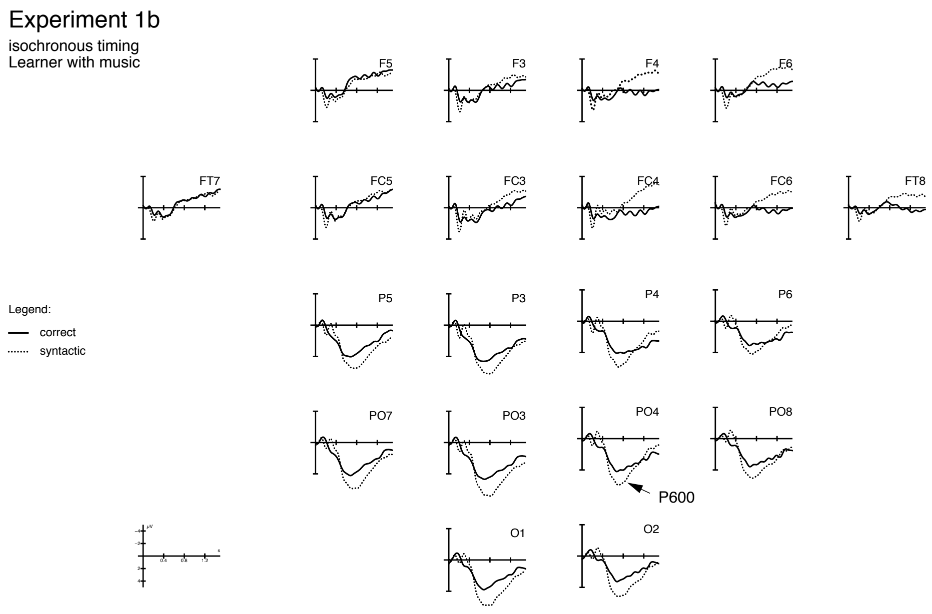

Figure 5.7: Experiment 1b: ***Isochronous*** *timing - Learningtype with music*

fact that synchronization with an external event is relatively stable. This is in line with the Dynamic Attending Theory (Large & Jones, 1999). This theory defines meter perception as follows: "When the individual attends to an environmental (external) rhythm, the phase and the period of the internal attending rhythm's oscillations become coupled, via entrainment, to those of the external rhythm, creating stable attractor states. The period of the oscillation reflects the rhythmic rate or overall tempo, while the phase relationship between the coupled external and internal attending rhythms expresses the listener's expectation about when an (external) onset or beat should happen." (Hawkins & Smith, 2001). According to this theory the constant SOA serves as such an external rhythm, that entrains[2] internal oscillations and

[2]According to Port et al. (1999) self-entrainment is when the timing of repetive motions by one oscillator influences the motions of the other oscillator resulting in a temporal relationship with each other. The oscillators thus tend to perform their motions in the same amount of time, or some integer ratios. For example during steady-state jogging, one's breathing tends to lock into a fixed relationship with the step cycle. The entrainment-mechanism has mainly been formulated in motoric contexts, such as rhythmic facilitation of gait training in hemiparetic stroke rehabilitation (Thaut, McIntosh, & Rice, 1997). That this theory turns out to be true in speech

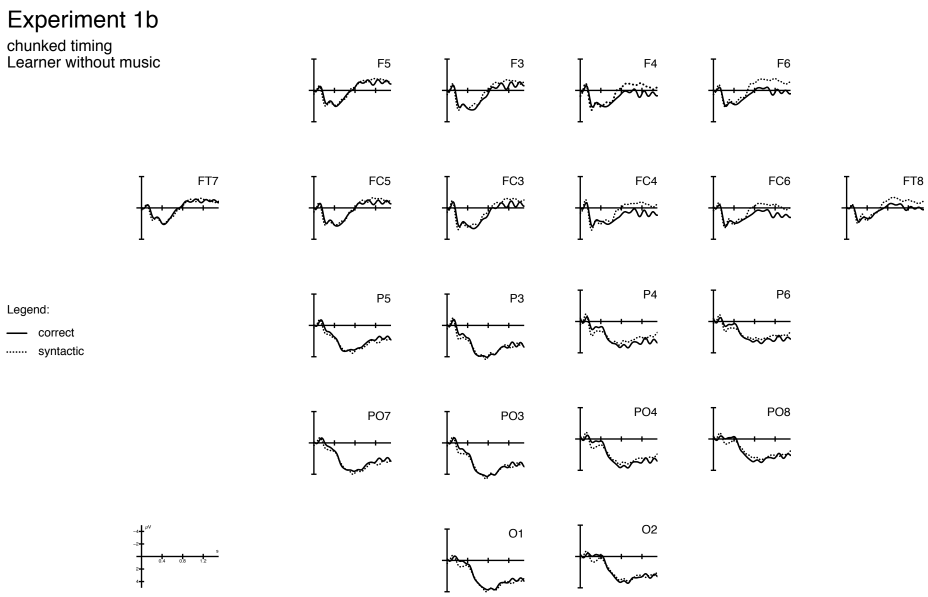

Figure 5.8: Experiment 1b: ***Chunked*** *timing - Learningtype without music*

thus creates stable attractors at certain sentence positions. Therefore, the processing speed will be adapted to an expectancy when a next item will be presented. This in turn shows that in healthy populations syntactic processing and sequencing, respectively, can be influenced by a given external 'taktgeber' as the 'chunk P600' in Experiment 1b was evoked after the onset of the participle although the syntactic violation could already be recognized at the onset of the pause.

Furthermore, post-hoc-analyses with the factor *group* revealed that learners with music background show a larger P600 than participants learning without music. This results seem to be interesting with respect to the discussion of possible interactions between music and syntax processing. Several studies have investigated the connection between music and language processing (Koelsch, Gunter, Wittfoth, & Sammler, 2005; Patel, 2003) as music, like language, is a human universal involving perceptually discrete elements organized into

production has been shown in the mentioned experiment conducted by Cummins and Port (1998), whereas the present experiment is evidence for its validity in speech *perception* too.

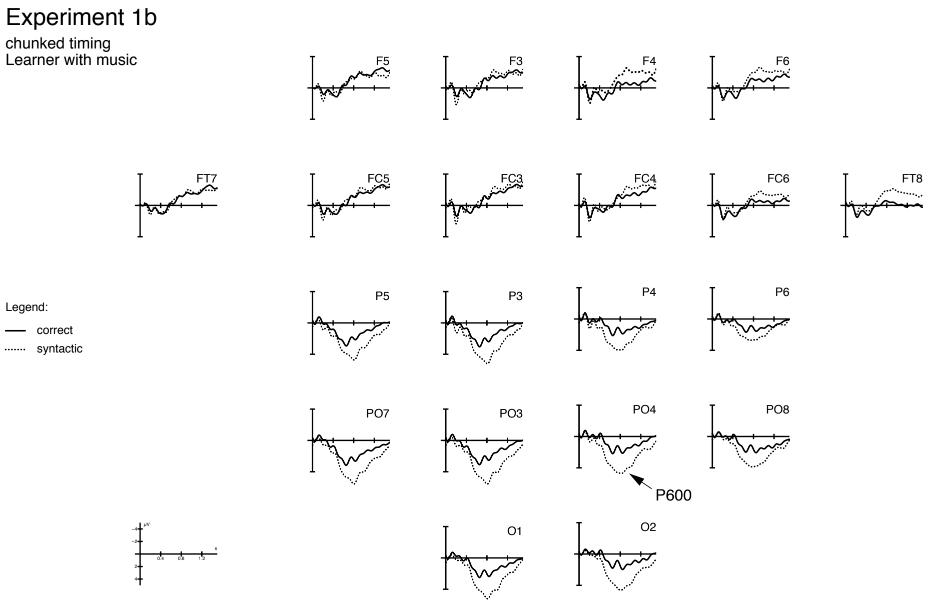

Figure 5.9: Experiment 1b: ***Chunked*** *timing - Learningtype with music*

hierarchically structured sequences (Patel et al., 1998; Sloboda, 1985). This let Patel (2003) to argue that syntactic comprehension problems in Broca's aphasia are not selective to language but influence music perception as well. In his "shared syntactic integration resource hypothesis" Patel (2003) proposed a neural overlap between syntactic processing in music and language, as in both domains syntactic processing can be described as the mental connection of "each incoming element X to another element Y in the evolving structure". This close relationship between music and language is in line with the assumption of an evolutionary motivated 'musilanguage' being the ancestor of both music and language according to Brown (1999). Thus, it seems to be plausible that those people who are familiar with the linking of music and language processing have advantages in processing of syntactic structures. Without doubt the results of the present study are not sufficient to formulate any theories in this direction, but they give further reason to investigate the connection between the ability to process music and the ability to process language in more detail in future research.

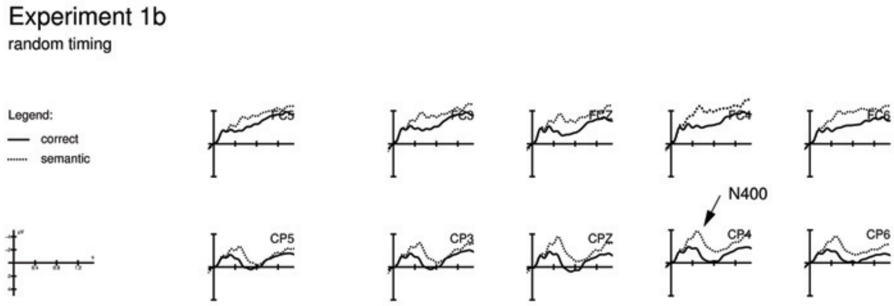

*Figure 5.10: Experiment 1b: ERPs elicited by the semantic violation in the **random** timing condition*

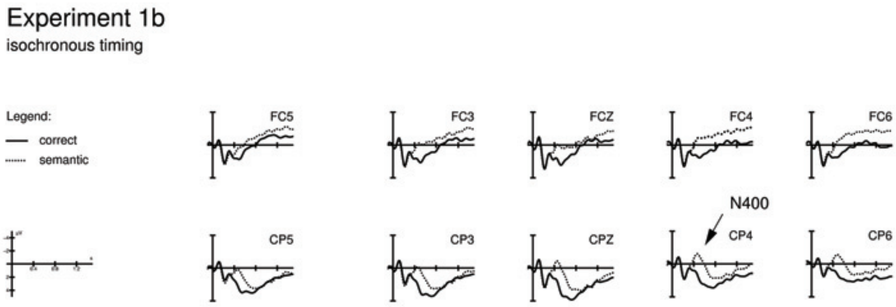

*Figure 5.11: Experiment 1b: ERPs elicited by the semantic violation in the **isochronous** timing condition*

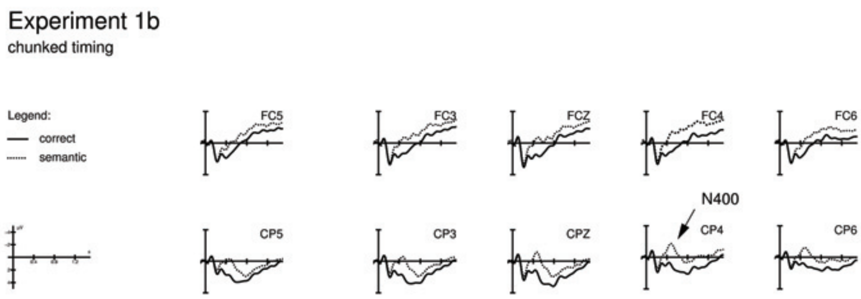

*Figure 5.12: Experiment 1b: ERPs elicited by the semantic violation in the **chunked** timing condition*

Time Window: 150 - 300 ms			
Effect	*df*	*F value*	*p value*
pres	2,22	24.83	<0.001
*con*pres*	2,22	4.35	<0.05
Random			
Effect	*df*	*F value*	*p value*
con	1,11	11.19	<0.01

Table 5.6: Experiment 1b: Significant results from ANOVAs on mean amplitudes for the time window 150 to 300 ms (ELAN) - 12 subjects with random-first version.

Next to the three described and expected ERP-components, a late anterior negativity was again evoked in Experiment 1b. As in Experiment 1a post-hoc analyses over anterior electrodes in a time window from 600 to 1000 ms after onset of the critical item were computed (for statistical details, please, see Appendix A.2). This ANOVA revealed a significant right lateralized anterior negativity. Analogous to Experiment 1a this negativity is interpreted as a reorienting negativity (Schröger & Wolff, 1998), as the described phonological deviation has been distracted the task relevant response to syntactic violations. Visual inspection of data from other studies seems to confirm this hypothesis. Eckstein and Friederici (2006) in a recently conducted experiment investigated syntactic and prosodic violations separately. As their data show there is a right lateralized long sustained negativity in the prosodic violation condition whereas this effect is omitted in the prosodic congruent condition. As participants were always asked to perform a grammaticality judgement, the prosodic incongruence also serves as a distractor in terms of Schröger and Wolff (1998), resulting in a re-orientating negativity.

N400 With regard to the N400, results from Experiment 1a were replicated. Obviously, semantic processing does not interact with time predictable processing in healthy participants as there is no omission nor temporal shift of this component. Furthermore, latencies and amplitude sizes of the N400 in the three different timing conditions remained comparable.

Conclusion The experimental series 1a and 1b demonstrated the impact of a constant SOA on the processing of syntactic violations in healthy participants. These findings support a theory that external cues may influence sequencing of information in form of self-entrainment of internal oscillations. The data further indicate that even the 'healthy' system is sensitive to an external taktgeber. Nevertheless, this sort of timing is somehow unnatural as the syntactic parser is not confronted with such isochronous speech in daily life. Without doubt external timing seems to have a great influence on the language and speech ontogenesis as children are sensitive to strongly metrical sequences such as nursery rhymes, counting-out rhymes or jump-rope-rhymes to which they clap their hands or bounce. Thus, the impact of an external 'taktgeber' on language development seems to be omnipresent. To investigate a possible 'taktgeber' inherent to speech the following experiments 2a and 2b focussed on two questions:

- Are there rhythmic cues inherent to speech of a given language that help the listener in sequencing syntactic information?
- If so, which electrophysiological correlate is attributed to these cues?

Chapter 6

Experiment 2a

As already mentioned in the introduction section the languages of the world are associated with different speech inherent rhythms. For example, German traditionally belongs to stress-timed languages. Even though the original idea by Abercrombie (1967) has been rejected, it is indisputable that different languages have different underlying speech rhythms (Nazzi & Ramus, 2003). In this context German offers an alternation of stressed and unstressed syllables that is very prominent. This has also been stated by Lee and Todd (2004) who noticed that syllables of stress-timed languages show a greater variability in auditory prominence than syllables in syllable-timed languages (like French). Applying this statement to Large's (1999) *Dynamic Attending Theory* of meter perception, in stress-timed languages stressed syllables may build up attractor states.
The trochee as a pattern of stressed and unstressed syllables is considered to be the default meter in German (Eisenberg, 1991; Féry, 1997). It seems to be that basic rhythmic structures of a language play an important role in language acquisition and therefore in sequencing. This is supported by the fact that nine months old English children - as English is a stress-timed language it likewise prefers the trochee - recognize their mother tongue solely by speech rhythm. The linguistic meter helps to structure the linguistic input (Cutler, 1994). This structural moment is reflected in syntax as well (Patel et al., 1998). For this reason the interaction of meter and syntax should be further investigated in the following studies.

On a critical note, previous studies using syntactical violations often coincided with metrical or phonological violations. In German sentences containing phrase structure violations such as "Das Pferd wurde im gefilmt" ($*$*The horse was filmed in*) the metrical expectancy is violated as a preposition is always followed by a stressed element, but in this case the preposition is followed by an unstressed element ('ge'). The same applies to sentences with morphosyntactic violations (e.g. Frisch et al. (2003)) like "Im Institut wurde viel lachen und..." (∗ In the institut was *laugh* a lot and...). Because of the passivized structure in this sentence the listener expects a ge-participle (ge'lacht) and consequently an unstressed syllable, but instead the listener hears a stressed syllable ('lachen) due to the infinitive. As meter functions as a complex form of temporal expectancy as events are more expected at strong beats and less expected at weak beats, it becomes apparent that temporal expectancy-violations coincide with syntactic violations in such stimuli.

The aim of the current experiment was to study metrical and syntactical violations in parallel. For this purpose metrically regular sentences were constructed that were either metrically, morphosyntactically or doubly violated. The regular beats of the stressed syllables should couple with cognitive oscillations and therefore build stable attractor states for sentence processing. This is also in line with the "attentional bounce hypothesis" (Pitt & Samuel, 1990) in which attention is thought of as moving from one stressed syllable to the next. If meter works as a rhythmic 'taktgeber' during auditory syntactic processing - because it is proposed to be an organizational principle having its roots in the coordination of complex action (Cummins & Port, 1998) and perception - the P600 should be elicited by metric violations as well. The metric sensitivity of the P600 is also supported by a study conducted by Besson and Faita (1995), who found a late positivity in response to rhythmic violations in musical phrases.

As several studies observed the P600 as depending on probability, salience, and task relevance (Coulson et al., 1998) both experiments (2a and 2b) were conducted with two different tasks, namely a metric task and a syntactic task in two sessions. Therefore, 50 % of the trials in each session contained a violation. Consequently, it is possible to test whether violations vary as a function of explicit and implicit processing. It is predicted that purely automatic potentials are completely unaffected by task demands while attentionally controlled components are affected as soon as the focus is not directed to the processed violation (Tokowicz & MacWhinney, in press). The following electrophysiological components were predicted to be elicited in Experiment 2a:

Negativity As previous studies could show, morphosyntactic violations evoked a LAN (for detailled description see Chapter 2) approximately 450 to 800 ms after the onset of a critical stimulus. In many cases this negativity is more pronounced over left than over right frontal electrode sites. Here, a LAN was predicted as well. With respect to metric violations previous studies observed a negativity as an electrophysiological correlate to metric violations at the sentence level (Magne et al., 2004) as well as in word sequences (Böcker, Bastiaansen, Vroomen, Brunia, & Gelder, 1999) with a latency of 300 to 400 ms and a frontocentral to left lateralized distribution. This latency is first evidence, that meter processing may be processed earlier than morphosyntactic processing. Therefore it is of special interest whether in the present study, a potential metric negativity starts earlier, later or in the same time frame as the LAN. In a recent study conducted by Eckstein and Friederici (2006) the authors argued that at an early processing state prosody (and meter is surely a part of speech prosody) interacts with syntax. Thus, it is predicted that a metrically induced negativity will deflect earlier than the syntactic negativity. Furthermore, potential task specific latency differences are of interest to define whether this component is automatic or rather controlled in nature.

Late Positivity If the P600 detected in numerous studies investigating syntactic processes is not only elicited by syntactic violation but also by metric expectancy violations, the purely metric violation in the following experiment should evoke a late positivity as well. According to the *Dynamic Attending Theory* internal oscillations should be coupled to external regular meter (trochee) but they have to be re-adjusted as soon as this trochee changes into a iambic pattern (metric violation condition). This re-adjustment is hypothesized to evoke a late positivity. With respect to the distribution and latency, respectively, the metric effect should be elicited earlier than the syntactic effect if meter pushes syntactic processing. A focus of this study was to clarify whether the P600 is a purely syntactic component or whether this ERP component rather reflects a general integration mechanism where all available information run together. Similar latencies and distributions of the metric and the syntactic effect would underline the argument that the P600 is not purely syntactic in nature but a function of a general integration mechanism.

Furthermore, if syntax and meter processing interact during language processing, then - in accordance to the Helmholtz law - a double violation should not reveal an amplitude increase of the P600 compared to each single violation condition. Otherwise, meter and syntax processing would be related to distinct electrophysiological processes.

In order to investigate the influence of task, each violation was tested explicitly and implicitly. A delayed onset and a smaller amplitude is predicted in the implicit task, as the task does not focus on the process underlying the P600. This means in accordance with Coulson et al. (1998) the P600 is supposed to be attention dependent and therefore a "controlled" component.

6.1 Materials and Methods

Participants Twenty-four right-handed students aged 21-29 years (mean: 25,12) were tested. All of them had previously participated either in Experiment 1a or 1b.

Materials As already mentioned in the introduction of this experiment, the aim of this study was to investigate whether speech internal metrical cues facilitate syntactic processing. In German, a stress-timed language, the perception of stressed syllables is predicted to be very important for syntactic sequencing. Thus, sentences were constructed which were highly regular in a metrical sense as they were completely trochaic. These sentences were manipulated as follows:

1. A metrically wellformed sentence with a syntactic violation.
2. A syntactically wellformed sentence with metric violation.
3. Metric violation appending the syntactic violation.

To avoid sentence final wrap-up-effects (Frisch, 2000) the penultimate word in a sentence served as the critical item. All critical verbs as well as the preceding adverbs were matched fro word frequency.

All sentences were spoken by a professional female native speaker of German. They were

sentence type	**example**
correct	’Vera ’hätte ’Christoph ’gestern ’morgen **’duzen** ’können.
literal translation	"*Vera could have addressed Christoph informally yesterday morning.*"
syntactically violated	’Wilma ’hätte ’David ’gestern ’morgen **’duzte** ’können.
literal translation	"*Wilma could have **address** David informally yesterday morning.*"
metrically violated	’Detlef ’hätte ’Franzi ’gestern ’morgen **du’ZEN** ’können.
double violation	’Hermann ’hätte ’Anke ’gestern ’morgen **duz’TE** ’können.

Table 6.1: Experimental conditions of Experiment 2a

spoken at a normal speech rate and digitally recorded with a 16 bit resolution and a sampling rate of 44.1 kHz. To familiarize the speaker with the incorrect stress pattern in the metrically and the doubly violated sentences, sequences of three words were constructed, with the first word adhering to a iambic pattern to facilitate the speaker’s access to an unexpected metric item (see Table 6.2). The last two words remained the same as in the original sentence. Afterwards, the two verbs were cut out of the sequence and were inserted into the original sentence. To avoid coarticulatory deviations the iambic word ended with the same consonant-vowel-combination as the adverb located before the critical item in the original sentence.

Original sentence	’Peter ’hätte ’Werner ’gestern ’besser ’loben ’sollen.
Word sequence	Ge’fahr *lo’BEN ’sollen*
Spliced sentence	’Peter ’hätte ’Werner ’gestern ’besser *lo’BEN ’sollen.*

Table 6.2: Splicing procedure of Experiment 2a

The same procedure was performed for the correctly pronounced sentences where the first word of the word sequence was trochaic. This was to ensure that no effects were evoked due to the splicing procedure for any sentence type.
This extensive splicing procedure was conducted in order to avoid coarticulatory artifacts with respect to the incorrectly stressed item.

In Figure 6.1 exemplary pitch contours of the different experimental conditions are plotted. As one can see, pitch patterns are similar for all conditions up to the critical item. The pitch contour of the critical verb in the metric condition proceeds in the opposite direction of the syntactically violated and correctly inflected verb.

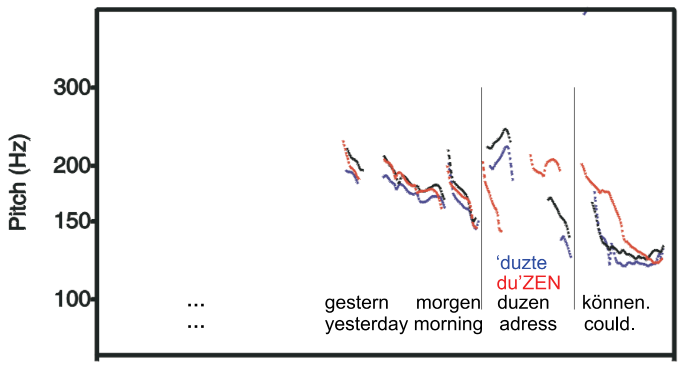

Figure 6.1: Exemplary pitch contours: correct condition (black), syntactic violation (blue), metric violation (red)

Procedure Experiment 2a Data was collected in two sessions. In the first session participants judged metrical correctness (explicit task with respect to meter, implicit task with respect to syntax) and in the second session they judged grammatical correctness. The order of tasks was counterbalanced across participants. All 208 sentences (52 per condition) were presented auditory via loud speakers in a randomized order. The experimental trials were presented in four blocks of approximately 8 minutes each. Each sentence was introduced by a visual cue on the center of a computer screen. 2000 ms after the offset of the sentence, participants were asked to perform the respective judgement. The next trial started 2000 ms after the participant's response (see Figure 6.2).

The EEG-procedure was the same as in the Experiments 1a and 1b, and the identical elec-

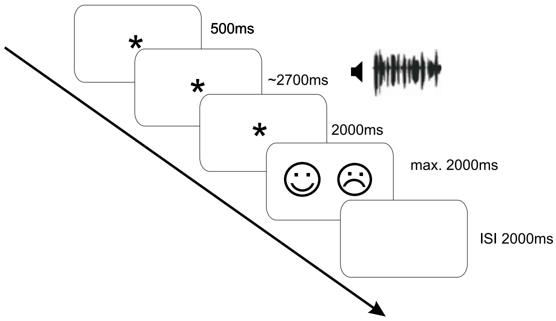

Figure 6.2: Procedure Experiment 2a

trode configuration was used. Approximately 19,6 % of the trials were excluded from the grand average due to artifacts or incorrectly answered trials. The remaining trials (about 42 per condition) were averaged per subject and condition, with a 100 ms prestimulus (critical item) baseline. This baseline was chosen because of the acoustic identity within the speech stream at this time frame (for statistical details see Appendix B.5), that is the pitch contour did not vary significantly between conditions in this time frame. Taking a 200 ms pre-stimulus baseline would have resulted in baseline differences between conditions due to temporal acoustic differences of the proper names.

6.2 Results Experiment 2a

6.2.1 Behavioral Data

Accuracy rates were above 80 % indicating that all participants had understood both tasks. An omnibus ANOVA for the **metric task** revealed a significant main effect of *condition* ($F(3,69) = 19.25$, $p < 0.001$). Planned comparisons between levels of the factor *condition* revealed significant differences between the syntactic (93.02 %) and the correct (99.27 %) condition ($F(1,23) = 13.93$, $p < 0.01$), the correct and the double violation (83.17 %) condition ($F(1,23) = 27.01$, $p < 0.001$), between the syntactic violation and the double violation condition (F(1,23) = 12.30, $p < 0.01$), and between the metric violation (96.07 %) and the double violation condition (F(1,23) = 16.35, $p < 0.001$). The Bonferroni-corrected α-level is 0.025.

Concerning the **syntactic** task all percentages correct are above 99 % (correct: 99.35 %, syntactic: 99.19 %, metric: 99.11 %, double: 99.51 %). Thus, the omnibus ANOVA revealed no significant main effect of *condition*.

6.2.2 ERP

In both tasks two ERP-components were elicited due to the manipulations: A predominately frontally distributed negativity and a late posterior positivity. Due to visual inspections of the ERPs as well as the plotted difference maps (see Appendix A.1) the two tasks were statistically analyzed separately due to the fact that components within each task varied in latency. Greenhouse-Geisser-Correction was applied when evaluating effects with more than one degree of freedom.

In both tasks the following regions of interest were statistically analyzed: anterior left (AF7, AF3, F7, F5, F3, FT7, FC5, FC3) anterior right (AF8, AF4, F8, F6, F4, FT8, FC6, FC4), posterior left (CP3, P3, P5, P7, P9, PO3, PO7, O1), and posterior right (CP4, P4, P6, P8, P10, PO4, PO8, O2).

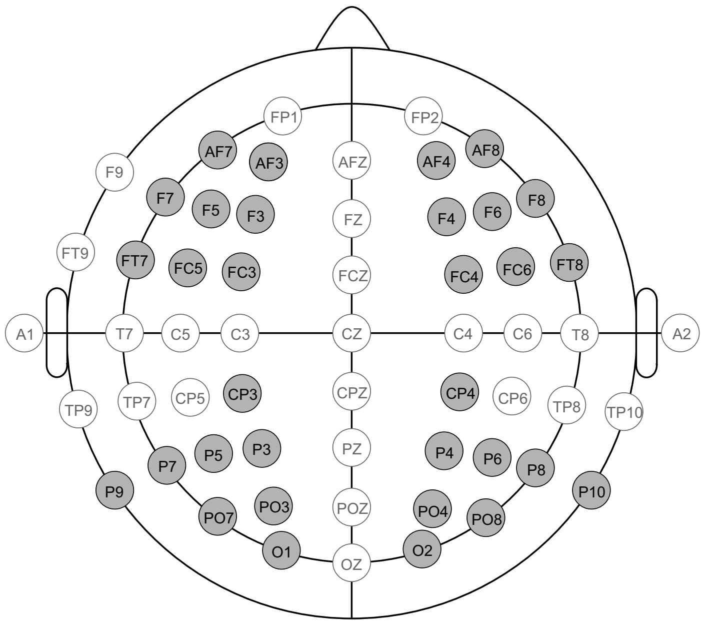

Figure 6.3: Statistically analyzed electrodes (marked in grey) in Experiment 2a.

6.2.2.1 Metric Task

The computed time windows for the metric task were as follows: 250 to 450 ms and 450 to 800 ms after onset of the critical item for the negativity and 550 to 850 ms as well as 850 to 1150 ms after onset of the critical item for the posterior positivity.

Negativity To evaluate the anterior negativity an ANOVA with four within-subject factors was computed: *window* (250-450/450-800), *region* (anterior/posterior), *hemisphere* (right/left) and *condition* (correct/syntactic violation/metric violation/double violation).

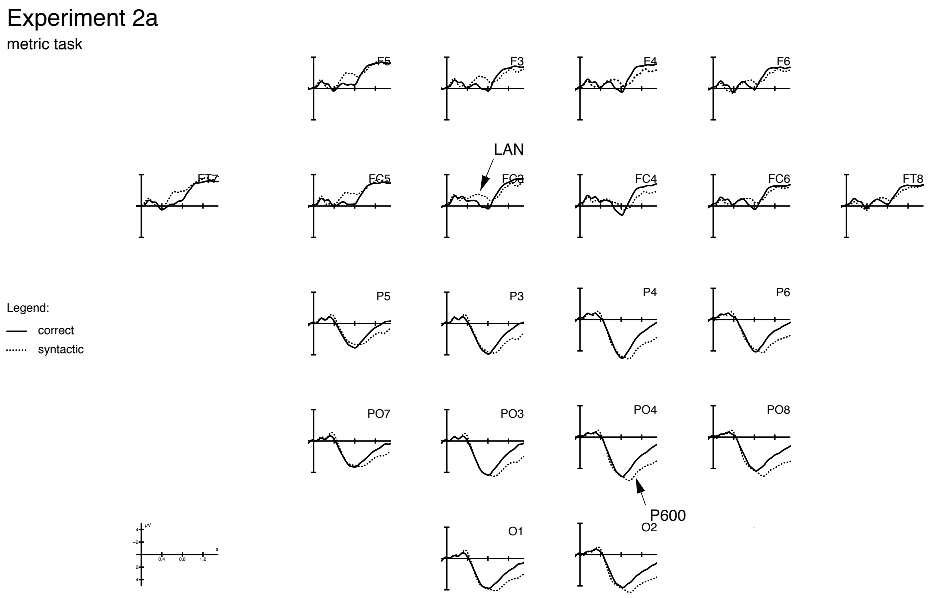

Figure 6.4: Experiment 2a: ERPs of the syntactic violation in the metric task

The Omnibus ANOVA revealed an interaction of the factors *condition* and *window* ($F(3,69) = 17.99$, $p < 0.001$) as well as a three-way interaction between the factors *window*, *condition*, and *region* ($F(3,69) = 9.68$, $p < 0.001$) and between the factors *window*, *condition*, and

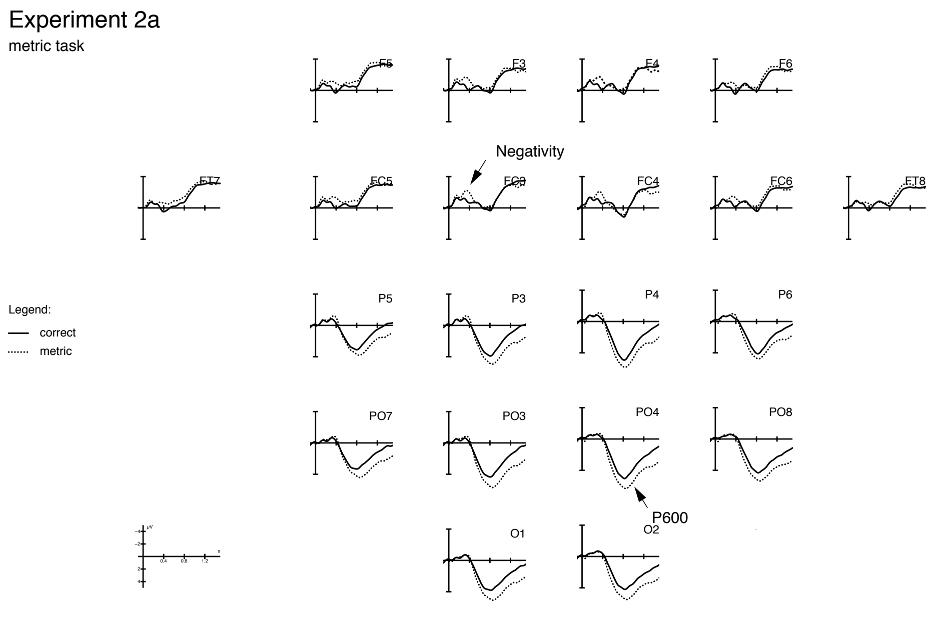

Figure 6.5: Experiment 2a: ERPs of the metric violation in the metric task

hemisphere ($F(3,69) = 3.94$, $p < 0.05$). Resolving all interactions by the factor *window* the **250 to 450 ms** time window revealed a main effect of *condition* ($F(3,69) = 8.39$, $p < 0.001$) and an interaction between the factors *condition* and *region* ($F(3,69) = 8.49$, $p < 0.001$); in the **450 to 800 ms** time window there was a main effect of *condition* ($F(3,69) = 4.31$, $p < 0.01$) as well as an interaction between the factors *condition* and *hemisphere* ($F(3,69) = 6.06$, $p < 0.01$) as well as between the factors *condition* and *region* ($F(3,69) = 6.71$, $p < 0.001$).

With respect **250 to 450 ms** time window resolving the interaction by the factor *region* resulted in a significant effect for *condition* in the anterior region only ($F(3,69) = 14.00$; $p < 0.001$). Break-down-analyses revealed a significant effect for the comparison between the correct and the metric condition ($F(1,23) = 24.83$, $p < 0.001$), as well as for the comparison between the correct and the double violation condition ($F(1,23) = 5.53$, $p = 0.05$), but no significant difference between the syntactic and the correct condition.

Regarding the **450 to 800 ms** time window, resolving the interaction between *condition* and

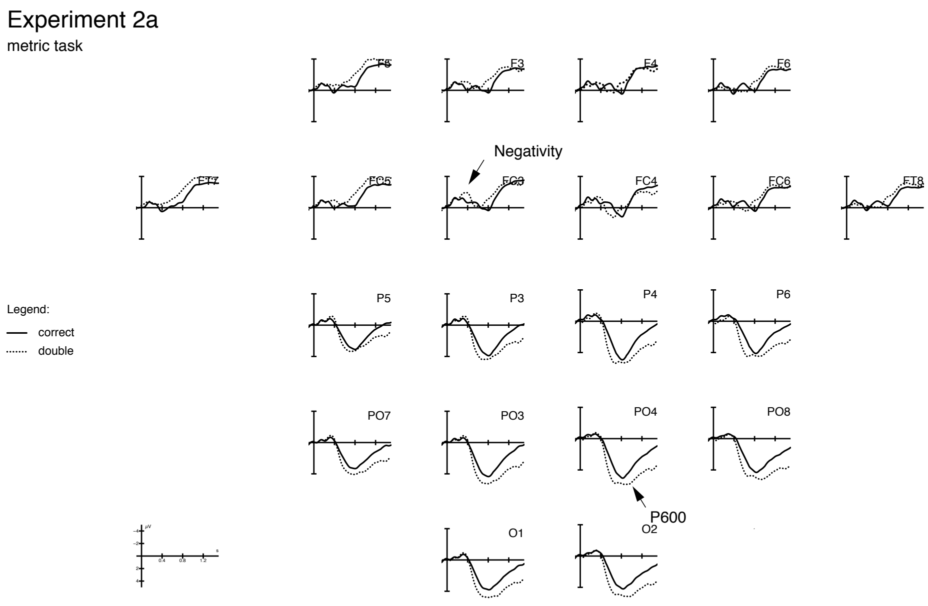

Figure 6.6: Experiment 2a: ERPs of the double violation in the metric task

region resulted in a significant effect for *condition* in both regions (anterior: $F(3,69) = 7.88$, $p < 0.001$; posterior: $F(3,69) = 3.07$, $p < 0.05$). Planned comparisons between the correct condition and the syntactic condition, between the correct condition and the metric condition, and between the correct condition and the double violation condition in both regions resulted in a significant main effect for the comparison between the correct condition and the double violation ($F(1,23) = 10.76$, $p < 0.01$; Diff. = **+1,17**) in the *posterior region* and significant effects for the comparison between the correct condition and the syntactic condition ($F(1,23) = 8.95$, $p < 0.01$), as well as a marginal effect for the comparison between the correct condition and the metric condition ($F(1,23) = 4.16$, $p < 0.06$) in the *anterior region*. Resolving the interaction between *condition* and *hemisphere* by the factor hemisphere resulted in a significant effect for condition in both hemispheres (left: $F(3,69) = 5.64$, $p < 0.01$; right: $F(3,69) = 3.79$, $p < 0.05$).

Break-down analyses revealed a significant effect for the comparison between the correct and the syntactic condition ($F(1,23) = 12.75$, $p < 0.01$) in the left hemisphere and a significant effect for the comparison between the correct condition and the double violation ($F(1,23) = 4.98$, $p = 0.05$) in the right hemisphere.

Positivity Due to visual inspections and results of previous experiments, the ANOVA was computed only over posterior sites. Thus, three within-subject-factors exist: *window* (550-850/850-1150), *hemisphere* (left/right) and *condition* (correct/syntactic violation/metric violation/double violation). The omnibus ANOVA yielded a main effect of *condition* ($F(3,69) = 5.42$, $p < 0.05$), a two-way interaction between the factors *window* and *condition* ($F(3,69) = 3.62$, $p < 0.05$) and a three-way interaction between *window*, *condition*, and *hemisphere* ($F(3,69) = 7.24$, $p = 0.001$). The interactions were resolved by the factor *window*, which revealed a main effect of *condition* in both time windows **(550-850:** $F(3,69) = 6.32$, $p < 0.01$; **850-1150:** $F(3,69) = 4.15$, $p < 0.05$) and an interaction between the factors *hemisphere* and *condition* in the later time window. Planned comparisons between the correct condition and each of the violation conditions for the **550 to 850 ms** time window revealed a significant effect for the comparison between the correct condition and the double violation ($F(1,23) = 8.87$, $p < 0.01$) and a marginally significant effect for the comparison between the correct condition and the metric violation ($F(1,23) = 4.20$, $p = 0.05$). In the **850 to 1150 ms** time window planned comparisons yielded a significant effect for all violation types (syntactically wrong: $F(1,23) = 4.13$, $p = 0.05$; metrically wrong: $F(1,23) = 12.39$, $p < 0.01$; double violation: $F(1,23) = 6.02$, $p < 0.05$). Resolving the mentioned interaction between *hemisphere* and *condition* by the factor *hemisphere* yielded in a significant effect for *condition* in the left hemisphere ($F(3,69) = 5.09$, $p < 0.01$) as well as in the right hemisphere ($F(3,69) = 3.22$, $p < 0.05$). Planned comparisons between the levels of the factor *condition* in the **left hemisphere** revealed a significant condition effect for comparisons between the correct condition and the metric violation ($F(1,23) = 17.17$, $p < 0.001$) and between the correct condition and the double violation ($F(1,23) = 5.18$, $p < 0.05$). In the **right hemisphere** planned comparisons revealed significant effects for the comparisons between the correct condition and the syntactic violation ($F(1,23) = 5.27$, $p < 0.05$), between the correct condition and the metric violation ($F(1,23) = 6.67$, $p < 0.05$) and between the correct condition and the double violation ($F(1,23) = 5.63$, $p < 0.05$).

6.2.2.2 Syntactic Task

For the syntactic task the following time windows were computed on the basis of visual inspection: 250 to 450 ms and 450 to 650 ms for the negativity and 650 to 1000 ms for the late positivity.

Negativity - OMNIBUS			
Effect	*df*	*F value*	*p value*
win	1,23	35.88	<0.001
*win*cond*	3,69	17.99	<0.001
*win*cond*hem*	3,69	3.94	<0.05
*win*cond*reg*	3,69	9.68	<0.001
Time Window: 250-450			
Effect	*df*	*F value*	*p value*
cond	3,69	8.39	<0.001
*cond*reg*	3,69	8.49	<0.001
Time Window: 250-450 *anterior*			
Effect	*df*	*F value*	*p value*
cond	3,69	14.00	<0.001
Correct vs. Metric	1,23	24.83	<0.001
Correct vs. Double	1,23	5.53	<0.05
Time Window: 450-800			
*cond*hem*	3,69	6.06	<0.01
*cond*reg*	3,69	6.71	<0.001
Time Window: 450-800 *posterior*			
cond	3,69	7.88	<0.001
Correct vs. Double	1,23	10.76	<0.01
Time Window: 450-800 *anterior*			
cond	3,69	3.07	<0.05
Correct vs. Syntactic	1,23	8.95	<0.01
Correct vs. Metric	1,23	4.16	=0.05
Time Window: 450-800 *left hemisphere*			
cond	3,69	5.64	<0.01
Correct vs. Syntactic	1,23	12.75	<0.001
Time Window: 450-800 *right hemisphere*			
cond	3,69	3.79	<0.05
Correct vs. Double	1,23	4.98	<0.05

Table 6.3: Experiment 2a: Significant results from ANOVAs on mean amplitudes for the time windows 250 to 450 ms and 450 to 850 ms (Negativities) in the metric task.

P600 - Omnibus			
Effect	*df*	*F value*	*p value*
cond	3,69	5.42	<0.01
*win*cond*	3,69	3.62	<0.05
*win*cond*hem*	3,69	7.24	<0.001
Time Window: 550 to 850 ms			
Effect	*df*	*F value*	*p value*
cond	3,69	6.32	<0.01
Correct vs. Metric	1,23	4.20	=0.05
Correct vs. Double	1,23	8.27	<0.01
Time Window: 850-1150 ms			
Effect	*df*	*F value*	*p value*
cond	3,69	4.15	<0.05
*cond*hem*	3,69	3.09	<0.05
Correct vs. Syntactic	1,23	4.13	=0.05
Correct vs. Metric	1,23	12.39	<0.01
Correct vs. Double	1,23	6.02	<0.05
Time Window: 850-1150 ms *left hemisphere*			
Effect	*df*	*F value*	*p value*
cond	3,69	5.09	<0.01
Correct vs. Metric	1,23	17.17	<0.001
Correct vs. Double	1,23	5.18	<0.05
Time Window: 850-1150 ms *right hemisphere*			
Effect	*df*	*F value*	*p value*
cond	3,69	3.22	<0.05
Correct vs. Syntactic	1,23	5.27	<0.05
Correct vs. Metric	1,23	6.67	<0.05
Correct vs. Double	1,23	5.63	<0.05

Table 6.4: Experiment 2a: Significant results from ANOVAs on mean amplitudes for the time windows 550 to 850 ms and 850 to 1150 ms (P600) in the metric task.

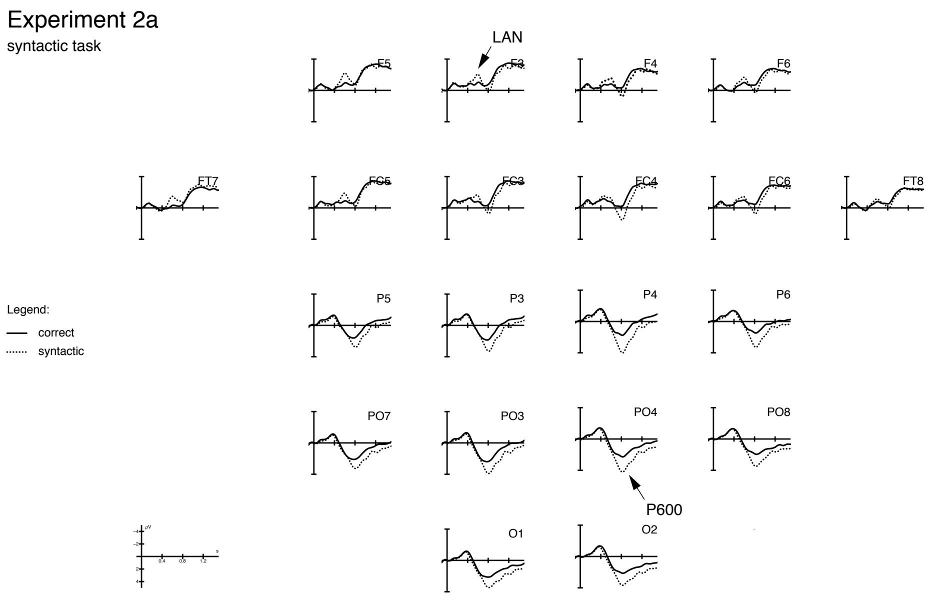

Figure 6.7: Experiment 2a: ERPs of the syntactic violation in the syntactic task

Negativity An Omnibus ANOVA with the three within-subject factors *window* (250-450/450-650), *hemisphere* (left/right) and *condition* (correct/syntactic violation/metric violation/double violation) was conducted. Due to visual inspection the analysis was restricted to anterior electrode sites. It yielded in a significant main effect for *condition* ($F(3,69) = 3.68$, $p < 0.05$) and a significant interaction between *window* and *condition* ($F(3,69) = 11.10$, $p < 0.001$). Follow-up analyses by window were carried out. In the **250 to 450 ms** time window this analysis resulted in a significant effect for *condition* ($F(3,69) = 5.62$, $p < 0.01$). Planned comparisons for *condition* revealed a significant condition effect for the comparison between the correct condition and the metric violation ($F(1,23) = 13.56$, $p < 0.01$) as well as for the comparison between the correct condition and the double violation ($F(1,23) = 12.05$, $p < 0.01$).

For the **450 to 650 ms** time window the *condition*-effect turned out to be significant ($F(3,69) = 3.77$, $p < 0.05$). Planned comparisons yielded in significant effects for the comparison between the correct condition and the syntactic violation ($F(1,23) = 8.82$, $p < 0.01$), for

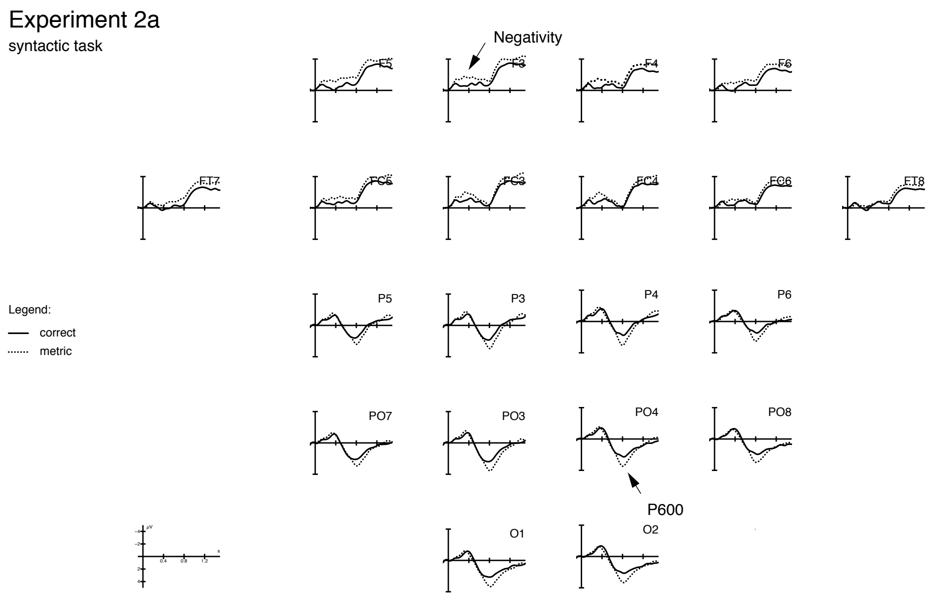

Figure 6.8: Experiment 2a: ERPs of the metric violation in the syntactic task

the comparison between the correct condition and the metric violation ($F(1,23) = 6.71$, $p < 0.05$) as well as for the comparison between the correct condition and the double violation ($F(1,23) = 4.07$, $p = 0.05$).

Positivity On the basis of visual inspection the omnibus ANOVA for the late positivity was restricted to posterior electrodes. Thus, the analysis contains two within-subject factors, namely *hemisphere* (left/right) and *condition* (correct/syntactically wrong/metrically wrong/double violation) in a time frame from 650 to 1000 ms after the onset of the critical item. The global ANOVA resulted only in a main effect for *condition* ($F(3,69) = 4.10$, $p < 0.05$). Planned comparisons revealed a significant condition effect for comparisons between the correct condition and the syntactic violation ($F(1,23) = 14.24$, $p < 0.01$), for comparisons between the correct condition and the metric violation ($F(1,23) = 4.37$, $p < 0.05$) and

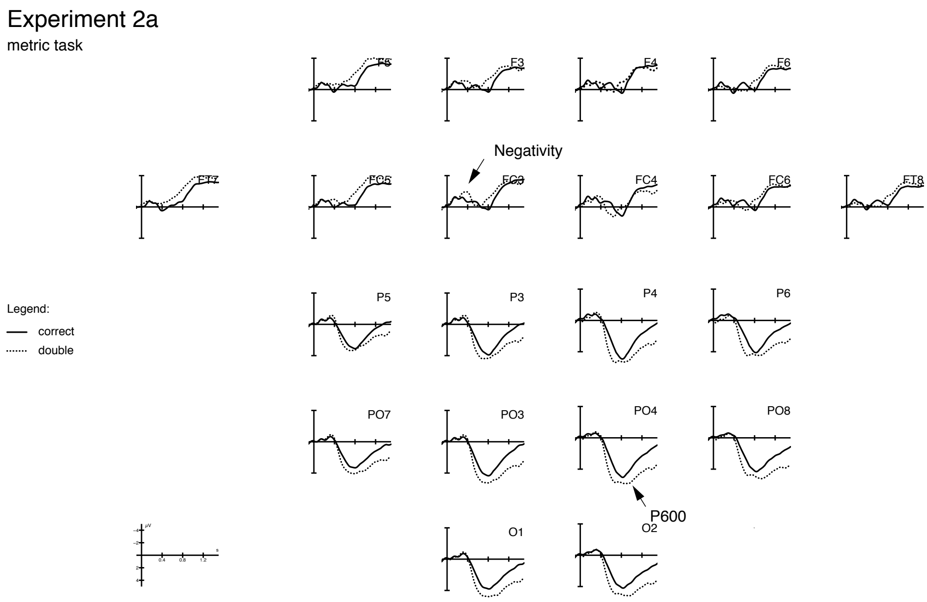

Figure 6.9: Experiment 2a: ERPs of the double violation in the syntactic task

Negativity - OMNIBUS			
Effect	*df*	*F value*	*p value*
win	1,23	7.60	<0.05
cond	3,69	3.68	<0.05
*win*cond*	3,69	11.10	<0.001
Time Window: 250 to 450 ms			
Effect	*df*	*F value*	*p value*
cond	3,69	5.62	<0.01
Correct vs. Metric	1,23	13.56	<0.01
Correct vs. Double	1,23	12.05	<0.01
Time Window: 450 to 650 ms			
Effect	*df*	*F value*	*p value*
cond	3,69	3.77	<0.05
Correct vs. Syntactic	1,23	8.82	<0.01
Correct vs. Metric	1,23	6.71	<0.05
Correct vs. Double	1,23	4.07	=0.05

Table 6.5: Experiment 2a: Significant results from ANOVAs on mean amplitudes for the time windows 250 to 450 ms and 450 to 650 ms (Negativities) in the syntactic task.

P600 - Omnibus			
Effect	*df*	*F value*	*p value*
cond	3,69	4.10	<0.01
Correct vs. Syntactic	1,23	14.24	<0.001
Correct vs. Metric	1,23	4.37	<0.05
Correct vs. Double	1,23	8.29	<0.01

Table 6.6: Experiment 2a: Significant results from ANOVAs on mean amplitudes for the time window 650 to 1000 ms (P600) in the syntactic task.

for comparisons between the correct condition and the double violation ($F(1,23) = 8.29$, $p < 0.01$).

6.3 Discussion Experiment 2a

Both explicit and implicit instruction confirmed participants capacity to understand the manipulations at test. However, the performance between the two tasks differed as only in the metric task differences in error rates turned out to be significant. Thus, the detection of double violations in the metric task seem to be more difficult. One reason could be that metric violations are harder to detect while syntactic violations are more salient. As soon as the participant's attention is focused on metric violations, the double violation has to be identified as "false" but the participant may be unsure whether the violation was a pure syntactic violation or whether there was a metric violation as well. They may have used this strategy to label syntactic violation as "correct" because the sentences are metrically correct and they are in conflict as soon as they were confronted with the double violation condition. In the following the two evoked ERP-components will be discussed in turn.

Negativity The first effect after the onset of the critical item was an anterior negativity whose latency varies as a function of violation type. As statistical analyses showed in both tasks, the negativity evoked by metric and double violations emerged about 200 ms earlier than the negativity evoked by syntactic violations. This means that even at an earlier stage of auditory language processing metric deviations are processed before syntactic violations are recognized, even if attention is not directed to meter processing. This observation is in line with the hypothesis that metric competences are necessary for successful syntactic processing. Furthermore, both negativities seem to be task-dependent in the sense that latencies were more extended when attention was directed on syntactic processing. The LAN, as a correlate of morphosyntactic violations, has been assigned to phase 2 according to the language processing model of Friederici (2002). The results of the current study provide further evidence that this component can not be labeled 'automatic' as there are time course differences of the component relative to the particular task. If the LAN would be automatic there should be no differences with respect to explicit or implicit processing. The same is true for the meter related negativity. Although the latency of the meter related negativity remains the same in both tasks the time course is lengthened when attention is not directed to the metric violation. A similar negativity was found by Böcker et al. (1999) and Magne et al. (2004). While Böcker et al. interpreted this negativity as correlate of metrical stress violations, Magne et al. argue that this component could be an N400 and reflects difficult lexical access as words are pronounced wrongly. Friedrich (2003) on the other hand argued against Böcker et al.'s explanation as she was able to show that this component reflected differences in syllable length of the first syllable of a critical item. As acoustical analyses of the current material could show the duration of the first syllable does not vary statistically significant across the different conditions ($F(3,165) = 2.47$, $p = 0.0828$).
Thus, in the present study this type of negativity could not be an artifact of syllable lengths as Friedrich argued. Thus the negativity could be a correlate of metric stress violation or of more difficult lexical access. Data from the present experiment support both explanations. In the following Experiment 2b this negativity will be investigated and discussed further.

Condition	Mean	Standard Deviation
correct	0.188 s	0.051
syntactic	0.194 s	0.056
metric	0.186 s	0.054
double	0.193 s	0.054

Table 6.7: Experiment 2a: Mean values for first syllables length and standard deviation for each condition.

Positivity The main finding with regard to the P600 is that this component emerges in *all* of the three violation conditions, during implicit as well as explicit processing of violations. These results fit well into the metric model discussed in theoretical part of this thesis. If the constant trochee realized in the current material functions as external rhythm which synchronizes with the cognitive oscillations, stable attractor states are build up. As soon as the trochee changes into a iambic pattern in the metric violation condition, the period of the external oscillation changes as well, and consequently a desynchronisation arises. Thus, the period of the cognitive oscillations has to be re-adjusted. This re-adjustment is a form of integration of new input and should be reflected in the P600 evoked in the metric violation condition.

The presented results are in line with data reported by Magne et al. (2004) who found an early negativity and a late positivity in response to rhythmic violations when meter was processed explicitly. However, in contrast to the present data, no positivity was evoked by metric violations when the focus of attention was on semantics. This may be the case for the following reasons: Firstly, as metric processing does not influence semantic processing (as results of Experiment 1a and 1b showed) meter may be phased out when attention is focused on semantic. In the case of syntactic processing, meter processing is a pre-condition for syntactic processing as both interact. A second reason may be differences in the material. In contrast to the sentences used in the present study the sentences used in the experiment of Magne et al. did not involve an underlying constant meter. Consequently, the violation is not as salient and thus integration only takes place when meter is processed explicitly. However, the appearance of an early negativity is independent of task, according to the results of the present study. Thus, in the study of Magne et al. first error detection takes place even if attention is not focused on the metric process. In the present study the attentional focus only influences the latency of the negativity as can be seen in the extended latency in the implicit task.

Even if the late positivity was evoked in both tasks and in all violation conditions the component - as expected - is clearly task sensitive. Firstly, all positivities elicited in the syntactic task were less extended than the positivities elicited in the metric task. Secondly, positivities deflected earlier in all violation conditions when attention was directed to the particular condition, i.e. the 'syntactic P600' deflected at 650 ms when attention was directed to syntax, but it deflected at 850 ms when attention was directed to meter. Thirdly, the amplitude decreased when the processing of the violation was implicit.

The latency delay during implicit processing could be interpreted in terms of an attentional shift to the process running explicitly. However, as the deflection of the metric violation in the syntactic task occurs at the same time as the deflection for the syntactic violation in the syntactic task indicates that processing of meter is relevant to process syntax (but not vice versa). As already mentioned in the context of the early negativity this is further evidence for the immense importance of an intact and competent meter processing system, as in both predicted effects (early negativity/late positivity) meter seems to push syntactic processing, as the respective latencies were shorter, independent of task (see Table 6.8).

Task	**Effect**	**Violation**	**Latency**	**Conclusion**
metric	Negativity	metric	250-450,450-800	
metric	Negativity	double	250-450,450-800	meter first
metric	Negativity	syntactic	450-800	
syntactic	Negativity	metric	250-450,450-650	
syntactic	Negativity	double	250-450,450-650	meter first
syntactic	Negativity	syntactic	450-650	
metric	Positivity	metric	550-850,850-1150	
metric	Positivity	double	550-850,850-1150	meter first
metric	Positivity	syntactic	850-1150	
syntactic	Positivity	metric	650-1000	
syntactic	Positivity	double	650-1000	time coherent
syntactic	Positivity	syntactic	650-1000	

Table 6.8: Experiment 2a: Overview ERP-effects

Data of the present study suggest that the P600 is a correlate of general integration. This implies that all factors that hamper sequencing or are relevant for sequencing, respectively, can modulate this component. With respect to reanalysis the factors which initiate a reanalysis evoke the greatest amplitude of the P600. The present data evidence that meter and syntax interact during sequencing of auditory language. Due to the Helmholtz Principle of Superposition the amplitude of the double violation has to be increased compared to the single violations if meter and syntax processing could be traced back to separate processes. Thus, independent neural generators have additive effects on the amplitude of the ERP. However, as was demonstrated (statistically) the amplitude of the double violation does not differ significantly from the amplitude of the single violation that is in the attentional focus. Thus, meter and syntax interact during auditory language processing.

The results of Experiment 2a underline the high impact of meter on syntactic processing. However, the metric violations in this experiment were relatively unnatural, as normally one is not confronted with such metric violation in daily communication, except for speakers with a foreign accent. What remains open is whether 'normal' frequently occurring metric deviations in a stable metric pattern will also be recognized, or are refuted due to economic reasons. The following Experiment 2b is conducted to answer this open question. Furthermore, the nature of the discussed metric negativity is further investigated.

Chapter 7

Experiment 2b

As Experiment 2a showed the role of meter in syntactic processing seems to be very important as meter and syntax interact during auditory language processing. The manipulation chosen in Experiment 2a was based on results and materials used in previous studies but was unnatural except in a situation when listening to a speaker with a foreign accent. Experiment 2b was therefore conducted to test whether a subtle metric deviation which is possible in a particular language but unexpected elicits a similar brain response. Therefore, in the metrical violation condition tested here the critical item was a real German verb with stress on the second instead of the first syllable. Unfortunately, German is a language with the predominant stress on the penultimate syllable. Thus, German does not provide any bisyllabic infinitives with second syllable stress. This would be a iambic stress pattern, typical in French. Consequently, the manipulation was realized with tri-syllabic verbs stressed on the second syllable. If there is a brain correlate for this type of deviation, the deviance should be detected on the first syllable of the critical item, as the first syllable is expected to be stressed, but instead is unstressed. If the system is sensitive to react to subtle speech immanent changes this should be reflected in a late positivity as well, as such changes are comparable to minimal phase perturbations as indicated in the *Dynamic Attending Theory* (Large & Jones, 1999). It is not the overall period which has to be adjusted as in Experiment 2a (when a trochee comes up with a iambic pattern) but only the phase relationsship is desynchronized by a metric deviation.

Two different tasks were used in Experiment 2b. It was predicted that the P600 should differ in latency and amplitude size dependent on the task. As the deviant stress pattern is plausible its saliency may not be strong enough to be detected. If, however, a late positivity is evoked then syntactic information processing is highly sensitive with respect to metric regularities.

Concerning the frontal negativities observed in Experiment 2a, it was predicted that a LAN should be evoked by syntactic violations. With regard to the metric deviations the predictions were less clear. If the negativity elicited in Experiment 2a reflects effortful lexical access (due to the wrong pronunciation), the negativity should not be present in the current experiment, as the critical items do have a lexical entry and occur in a coherent semantic context. If this component is an early detection of metrical mismatch or an artifact of different syllable length as proposed by Friedrich (2003), this negativity should be evoked in the following experiment as well as the first syllable of the metrically wellformed sentences and the first syllable of the metrically illformed sentences vary in duration as acoustic analyses could show ($F(3,156) = 214.28$; $p < 0.001$).

Condition	Mean	Standard Deviation
correct	0.275 s	0.062
syntactic	0.378 s	0.067
metric	0.167 s	0.039
double	0.173 s	0.045

Table 7.1: Experiment 2b: Mean values for first syllables length and standard deviation for each condition.

7.1 Materials and Methods

Participants 24 participants (12 female) between 19-29 years (mean: 25,08) were tested. All of them were highspans, right-handed and had normal or corrected to normal vision. None of them had any known neurological impairment.

Materials In Experiment 2b sentences contain either syntactic violations, or metric deviations, or both. Thus, the metrically predictable sentences were manipulated as follows:

1. A metrically wellformed sentence with a syntactic violation.
2. A syntactically wellformed sentence with metric deviation.
3. Metric deviation and syntactic violation.

The metric deviation was realized by a trisyllabic verb stressed on the second syllable even though participants expected stress on the first syllable due to the regular meter in the rest of the sentence (trochee).

sentence type	example
correct *literal translation*	’Vera ’hätte ’Christoph ’gestern ’morgen **’duzen** ’können. "*Vera could have addressed Christoph informally yesterday morning.*"
syntactic violation *literal translation*	’Wilma ’hätte ’David ’gestern ’morgen **’duzte** ’können. "*Wilma could have **address** David informally yesterday morning.*"
metric deviation	’Detlef ’hätte ’Franzi ’gestern ’morgen **ver’höhnen** ’können.
literal translation	"*Detlef could have mocked Franzi yesterday morning.*"
double violation	’Hermann ’hätte ’Anke ’gestern ’morgen **ver’höhnte** ’können.
literal translation	"*Hermann could have **mock** Anke yesterday morning.*"

Table 7.2: Conditions of Experiment 2b: The critical item is printed bold. Quotation marks are placed to indicate stressed syllables.

Sentences were spoken by a professional female native speaker of German at a normal speech rate and digitally recorded with a 16 bit resolution and a sampling rate of 44.1 kHz.

Procedure Analogous to Experiment 2a data was collected in two sessions. In the first session participants judged metrical correctness and in the second session they judged grammatical correctness. The order of tasks was counterbalanced across participants. All 192 sentences (48 per condition) were presented auditory via loud speakers in a randomized order. The experimental trials were presented in four blocks of approximately 8 minutes each. Each sentence was introduced by a visual cue on the center of a computer screen. 2000 ms after the offset of the sentence, participants were asked to perform the respective judgement task. The next trial started 2000 ms after the participants button press (for an overview see Figure 6.2 in Chapter 6).
The EEG-procedure was the same as in the previous experiments. In Experiment 2b about 12.7 % of the trials had to be excluded from statistical analyses due to artifacts or incorrect answers. The remaining trials (about 42) were averaged per participants and condition, with a 100 ms prestimulus baseline (see also Experiment 2a and Appendix B.6 for statistical analyses).

7.2 Results Experiment 2b

7.2.1 Behavioral Data

As in the previous experiments only percentages correct were analyzed, as reaction times were not interpretable due to a temporally delayed response. All sentences were answered correctly above 99 %. The omnibus ANOVAs for each task revealed no significant differences between conditions, neither in the syntactic task (correct: 99.65 %, syntactic violation: 99.39 %, metric deviation: 99.47 %, double violation: 99.73 %), nor in the metric task (correct: 99.65 %, syntactic violation: 99.73 %, metric deviation: 99.47 %, double violation: 99.39 %).

7.2.2 ERP

In both tasks a late posterior positivity was elicited and comparable to Experiment 2a. The tasks were separately statistically analyzed due to latency differences of the components. The following regions of interest were statistically analyzed: anterior left (FP1, AF7, AF3, F9, F7, F5, F3, FT9, FT7, FC5, FC3), anterior right (FP2, AF8, AF4, F10, F8, F6, F4, FT10, FT8, FC6, FC4), posterior right (CP4, CP6, TP8, TP10, P4, P6, P8, P10, PO4, PO8, O2), and posterior left (TP9, TP7, CP5, CP3, P9, P7, P5, P3, PO7, PO3, O1). In both analyses only posterior electrodes sites were computed. The ANOVAs were conducted with 2 within-subject factors, namely condition and hemisphere.

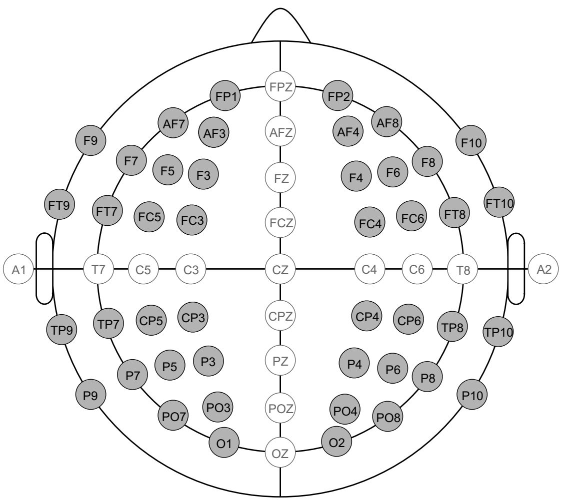

Figure 7.1: Statistically relevant electrodes (marked in grey) in Experiment 2b

7.2.2.1 Metric Task

For the metric task the computed time window was 600 to 1200 ms after the onset of the critical verb. Omnibus ANOVA revealed a main effect of *condition* ($F(3,69) = 8.02$, $p <$

0.001), but no interaction between the factors *hemisphere* and *condition*. Planned comparisons revealed significant differences between the correct condition and the syntactic violation ($F(1,23) = 16.54$, $p < 0.001$), the correct condition and the metric deviation ($F(1,23) = 12.30$, $p < 0.01$) and the correct condition and the double violation ($F(1,23) = 22.21$, $p < 0.001$), but no significant differences between the three violation types.

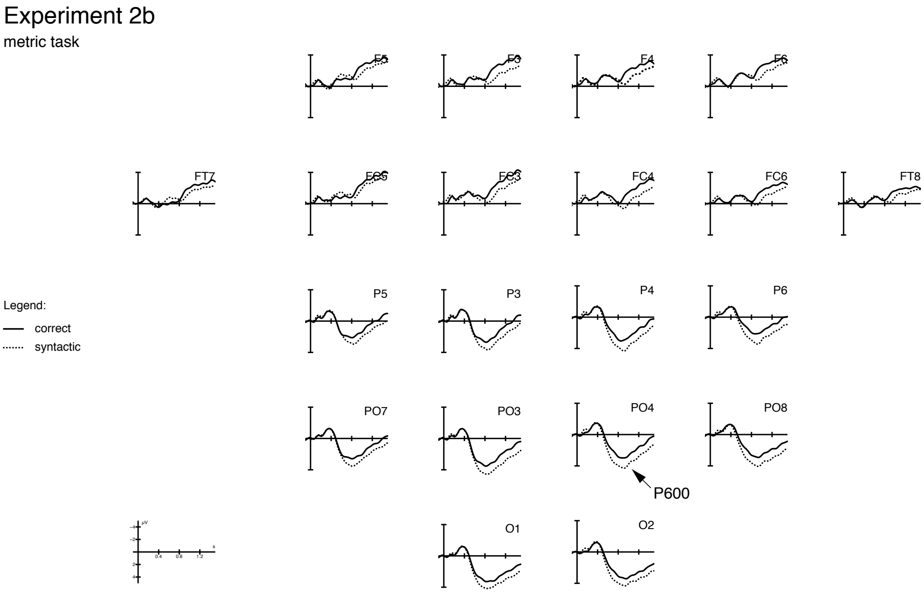

Figure 7.2: Experiment 2b: ERPs of the syntactic violation in the metric task

7.2.2.2 Syntactic Task

Visual inspection of the data indicated that ERP-effects in the syntactic violation and the double violation varied significantly in latency. Thus, two time windows were analysed: 600 to 1200 ms and 900 to 1200 after onset of the critical verb. The omnibus ANOVA for the **early time window** revealed a main effect of *condition* ($F(3,69) = 16.52$, $p < 0.001$) as well as an interaction between the factors *hemisphere* and *condition* ($F(3,69) = 4.80$, $p < 0.01$). Resolving this interaction by the factor hemisphere showed a significant effect for

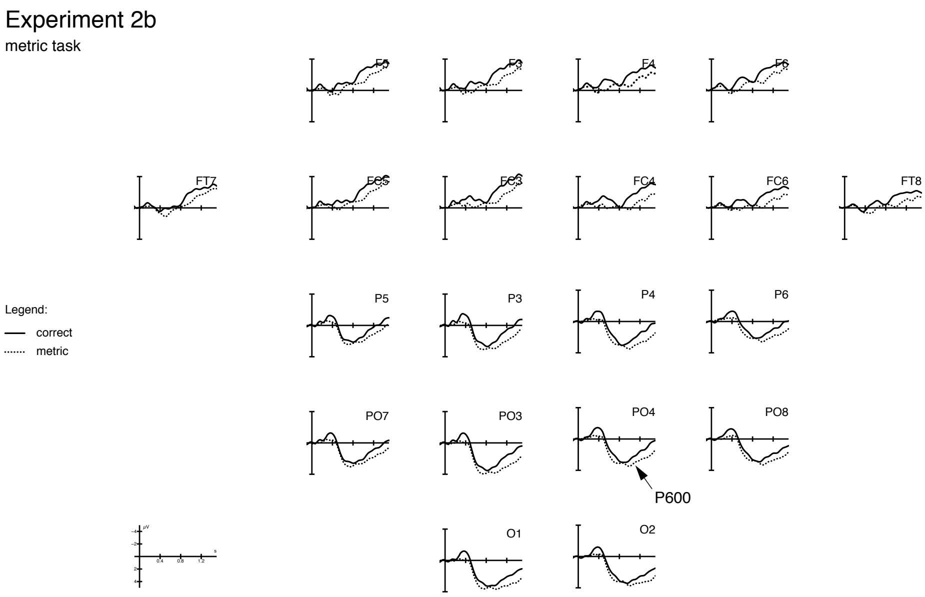

Figure 7.3: Experiment 2b: ERPs of the metric deviation in the metric task

condition in both hemispheres (left: $F(3,69) = 8.90$, $p < 0.001$; right: $F(3,69) = 19.01$, $p < 0.001$), with stronger F-values over the right hemisphere. Planned comparisons in each hemisphere revealed only a significant difference between the syntactic violation and the correct condition (left: $F(1,23) = 18.97$, $p < 0.001$; right: $F(1,23) = 39.13$, $p < 0.001$).
The analysis of the **late time window** revealed a main effect for *condition* ($F(3,69) = 13.54$, $p < 0.001$) and an interaction of the factors *hemisphere* and *condition* as well ($F(3,69) = 3.23$, $p < 0.05$). Resolving the interaction by the factor hemisphere led to a significant effect for *condition* in both hemispheres (left: $F(3,69) = 9.67$, $p < 0.001$; right: $F(3,69) = 14.19$, $p < 0.001$), the effect again appearing larger over right hemisphere sites. Planned comparisons in each hemisphere showed significant differences between the correct condition and the syntactic violation (left: $F(1,23) = 15.27$, $p < 0.001$; right: $F(1,23) = 23.85$, $p < 0.001$) and the correct condition and the double violation (left: $F(1,23) = 21.99$, $p < 0.001$; right: $F(1,23) = 35.65$, $p < 0.001$) in either hemisphere.

Positivity: 600 to 1200 ms			
Effect	*df*	*F value*	*p value*
cond	3,69	8.02	<0.001
Correct vs. Syntactic	1,23	16.54	<0.001
Correct vs. Metric	1,23	12.30	<0.01
Correct vs. Double	1,23	22.21	<0.001

Table 7.3: Experiment 2b: Significant results from ANOVAs on mean amplitudes for the time window 600 to 1200 ms (P600) in the metric task.

Positivity: 600 to 1200 ms			
Effect	*df*	*F value*	*p value*
cond	3,69	16.52	<0.001
*cond*hem*	3,69	4.80	<0.01
Correct vs. Syntactic	1,23	34.21	<0.001
Left Hemisphere			
Effect	*df*	*F value*	*p value*
cond	3,69	8.90	<0.001
Correct vs. Syntactic	1,23	18.97	<0.001
Right Hemisphere			
Effect	*df*	*F value*	*p value*
cond	3,69	19.01	<0.001
Correct vs. Syntactic	1,23	39.13	<0.001

Table 7.4: Experiment 2b: Significant results from ANOVAs on mean amplitudes for the time window 600 to 1200 ms (P600) in the syntactic task.

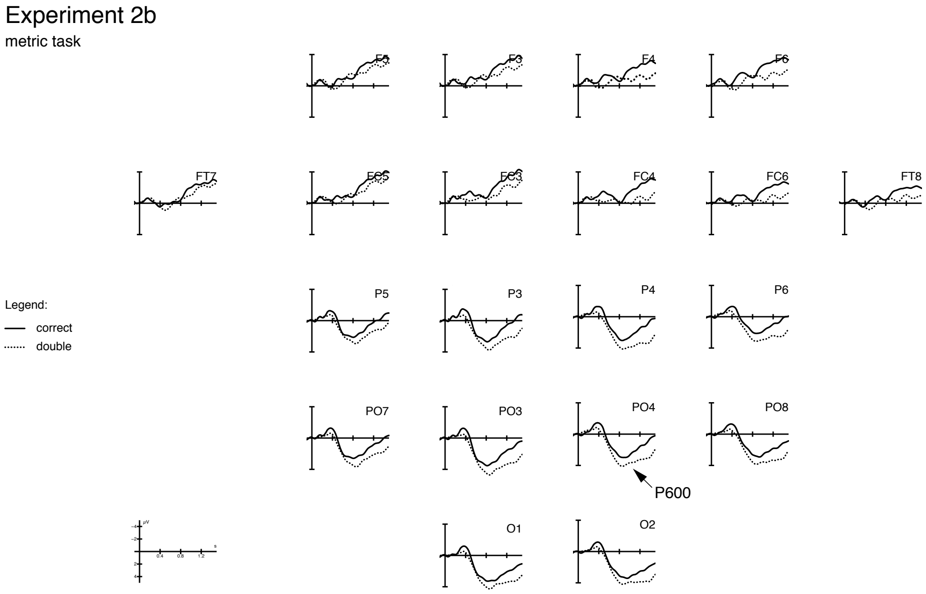

Figure 7.4: Experiment 2b: ERPs of the double violation in the metric task

7.3 Discussion Experiment 2b

Negativity As could be seen no negativity was evoked by the current manipulation. This observation supports the notion that the negativity reported in Experiment 2a is an electrophysiological correlate of effortful access to the mental lexicon. This interpretation is in accord with Magne et al. (2004), who stated that the "lengthening of the penultimate syllable disturbs access to word meaning and consequently increases difficulties in the integration of the word meaning within the sentence context". However, the negativity evoked in Magnes' experiment had a slightly different latency as well as distribution. This could be due to the choice of manipulation: sentences used in the study of Magne et al. did not contain a predictable meter which was broken by the critical item. Instead the authors used "normal" French sentences and manipulated the penultimate word. Example: "Le concours regroupait mille can'DIdats."[1]

[1] Literal translation: The contest regroups thousands of candidates.

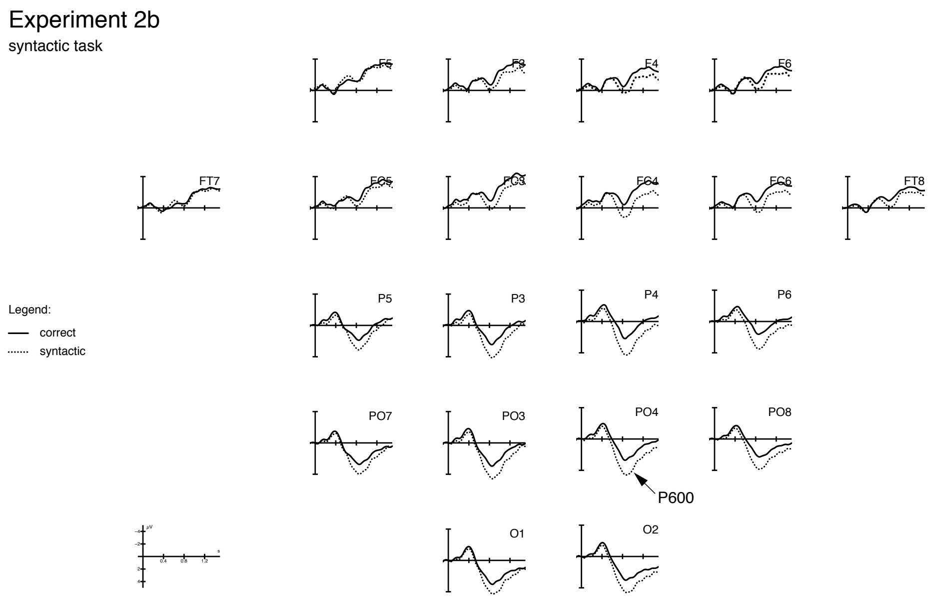

Figure 7.5: Experiment 2b: ERPs of the syntactic violation in the syntactic task

Thus, the manipulation may have been less salient as the one in Experiment 2a of this thesis. This may have led to a shorter latency and a different distribution in Experiment 2a. To further investigate this negativity it should be useful to conduct another study with the material of Friedrich (2003) in which items were spoken as a word list, e.g. three trochaic words followed by a iambic word. This material would be comparable to Böcker (1999), but has the advantage of a controlled syllable length. Thus, no negativity should emerge if this negativity is related to more effortful lexical access as all items are existing German words. This issue will be further elaborated in the general discussion.

What remains open is why no LAN was evoked by syntactic violations in both tasks. Note, that the same sentences had been used as in Experiment 2a with the restriction that all sentences in Experiment 2a were crossspliced while sentences in Experiment 2b were naturally spoken. Indeed, it is implausible that the LAN should be a correlate of an early detection

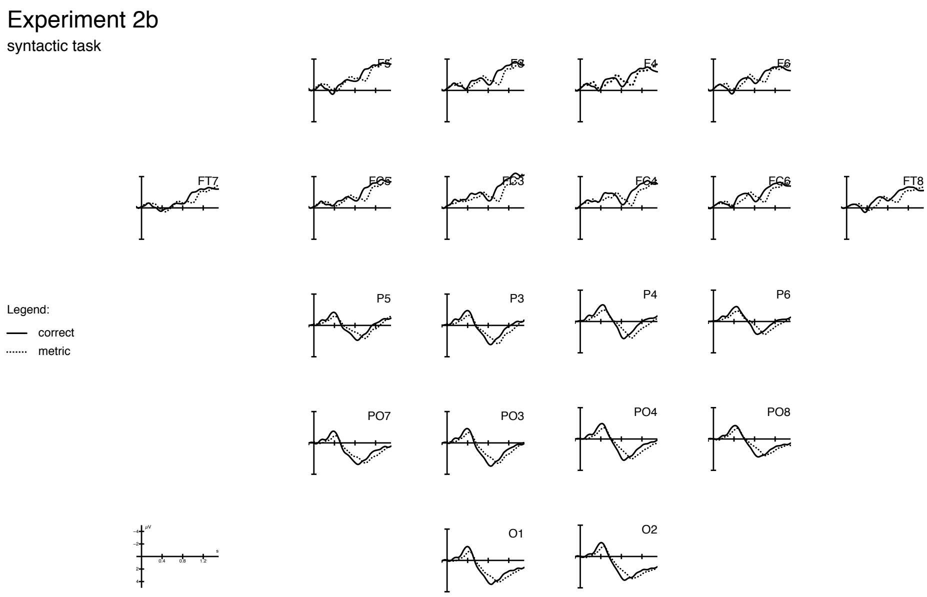

Figure 7.6: Experiment 2b: ERPs of the metric deviation in the syntactic task

of this splicing procedure in Experiment 2a, as all sentences (correct and incorrect) were spliced. Furthermore, the LAN appears to be a 'controlled' component, as it has been manipulated by task differences in Experiment 2a. As such the LAN should not be sensitive to acoustic differences. Therefore each participant was individually inspected posthoc. It appears, that nine of the participants showed a clear statistically significant LAN [2] in reaction to syntactic violations in the metric task.

Searching for external criteria, as age, gender, musical experience, drugs, or language skills to explain this variance was not successful.

Positivity Statistical analyses confirmed a late positivity in Experiment 2b that was similarly task-dependent to the one found in Experiment 2a.
Concerning the **metric task**, all of the violations evoked a bilateral posterior positivity in a

[2]For statistical analysis see Appendix A.3

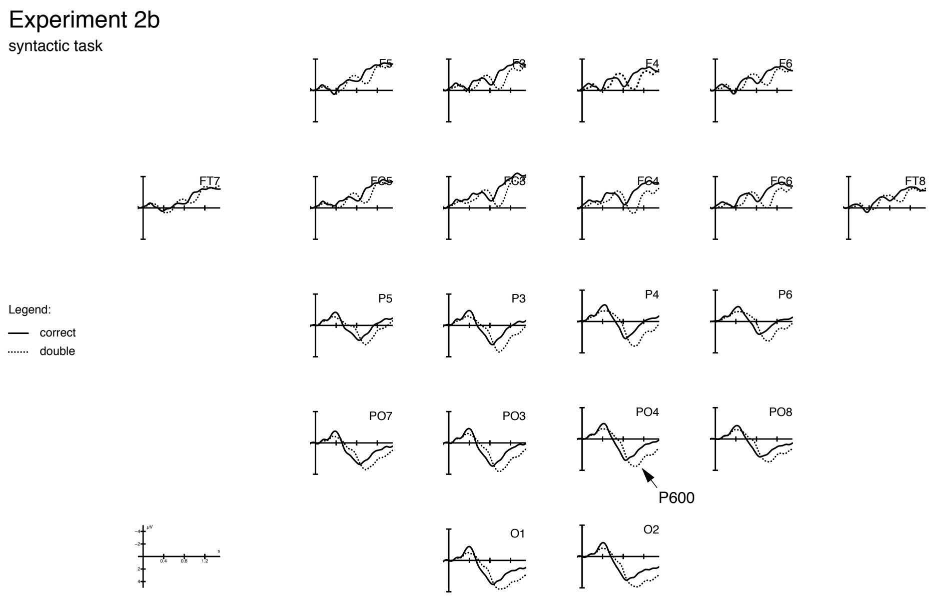

Figure 7.7: Experiment 2b: ERPs of the double violation in the syntactic task

time window from 600 to 1200 ms. With regard to the formulated hypotheses such metrical deviations obviously lead to reanalysis, especially when attention is directed to these deviations. In the framework of the *Dynamic Attending Theory* a phase-adjustment thus also results in a P600 when it is in the attentional focus.

Concerning the **syntactic task** one can observe a late positivity for syntactic and double violations only. How can one interpret these task- and condition-dependent latencies and distributions? As we are confronted with such metric deviations in every day communication, it is highly plausible that the brain can re-adjust such deviations effortlessly. The attentional focus on this phase-adjustment seems to be the reason why reanalysis of the metric structure takes place in the metric task in form of a P600. Consequently, in the syntactic task, the P600 in the double violation is pushed by the syntactic violation. The latency delay of this ERP-effect could be traced back to the fact that the violation appears later (third syllable syntactically violated) in the critical item than in the syntactic violation (second syllable syntactically violated).

Positivity: 900 to 1200 ms			
Effect	*df*	*F value*	*p value*
cond	3,69	13.54	<0.001
*cond*hem*	3,69	3.26	<0.05
Correct vs. Syntactic	1,23	22.14	<0.001
Correct vs. Double	1,23	32.55	<0.001
Left Hemisphere			
Effect	*df*	*F value*	*p value*
cond	3,69	9.67	<0.001
Correct vs. Syntactic	1,23	15.27	<0.001
Correct vs. Double	1,23	21.99	<0.001
Right Hemisphere			
Effect	*df*	*F value*	*p value*
cond	3,69	14.19	<0.001
Correct vs. Syntactic	1,23	23.85	<0.001
Correct vs. Double	1,23	35.65	<0.001

Table 7.5: Experiment 2b: Significant results from ANOVAs on mean amplitudes for the time window 900 to 1200 ms in the syntactic task.

Thus, one can say that in accordance to Large and Jones (1999) period adjustment (Experiment 2a) requires a complete reanalysis which takes place even if the attentional focus is not directed to the metric violation. Phase adjustment on the other hand is so subtle and frequent that there is no need for metrical reanalysis when the attentional focus is directed to other - more salient - events.

Conclusion Experiment 2a and 2b showed that metric and syntactic information processing is going hand in hand in healthy participants. Furthermore, it has been demonstrated that both processes interact and that meter is processed first. This observation underlines the importance of meter in auditory language processing. Consequently, in healthy populations cognitive oscillations do function when attending to rhythms and respond to perturbations of metrical expectancy. However, as already mentioned in the theoretical part of this thesis, patients with neurological impairment, especially with lesions of the BG cannot confidently and self-evidently handle such perturbations. Thus, it is the aim of the final experiment to investigate which language deficit BG patients do indeed have: A syntactic, a metric, or a combined one?

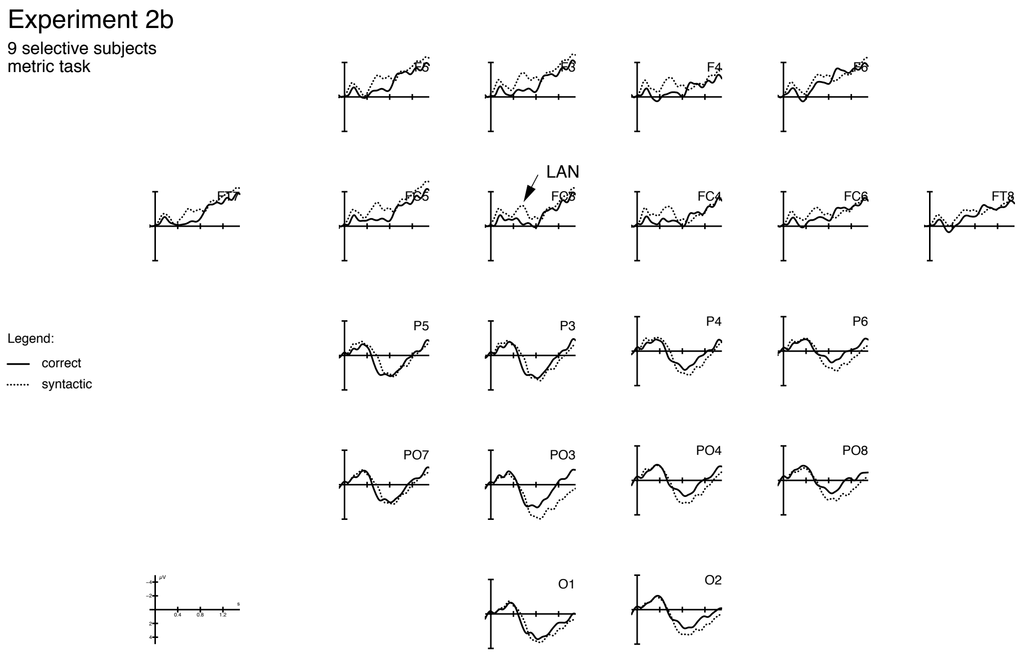

Figure 7.8: Experiment 2b: LAN - 9 selective participants in the metric task

Chapter 8

Experiment 3

Auditory ERP language data from patients with lesions (BG) or neurodegenerative change (PD) of the basal ganglia reveal that timing is crucial for syntax processing. As Friederici and Kotz (2003), Frisch et al. (2003), and Kotz, Frisch, et al. (2003) showed, patients do not display a P600 component when presentation rate is random during syntactic processing. This applies to several syntactic violation types which evoke a P600 in healthy participants. Recent evidence has demonstrated that external predictable rhythmic stimulation re-elicits the P600 in BG patients during auditory presentation of syntactically erroneous sentences (Kotz, Gunter, & Wonneberger, 2005). Based on these observations it is assumed that perceived metrical regularities of a given language should influence language processing and in particular syntactic processing. As the data from Experiments 2a and 2b showed, healthy participants are sensitive to metrical deviations and manipulations during syntactic processing. Given this fact and the evidence that BG patients respond to an external 'taktgeber', the previously reported 'syntactic processing deficit' in BG patients may be an epiphenomenon. Rather, patients may be suffering from a temporal deficit that influences syntactic information processing. Some supporting evidence comes from the observation that BG patients also have motoric rhythmic deficits (Strüder, Kinscherf, Diserens, & Weicker, 2001). Moro et al. (2001) reported inter alia activation of the basal ganglia in response to syntactic violations (using pseudosentences like $*$*'Gulco il giani'geva le 'brale* instead of *Il 'gulco giani'geva le 'brale*) but no BG-activation in response to morphosyntactic violations as $*$*Il 'gulco ha gianigi'ata 'questo 'bralo*. They concluded that the basal ganglia therefore play an important role in syntactic computation but not in morphosyntactic processing. But, as indicated by the stress marks the syntactic violation entails a metric violation as well while the morphosyntactic violation does not. Hence it could be that the BG-activation rather reflects a neural correlate of metric violation than one of syntactic violation.

As data from the above mentioned studies showed an external pacemaker can obviously compensate metric deficit in patients with BG-lesions and therefore allows to re-initiate syntactic reanalysis. Consequently, it seems that BG-patients are not able to synchronize dynamically with external rhythms (as Large and Jones (1999) has proposed for healthy subjects) if the speech input is random, but with an external taktgeber they can synchronize. Thus, synchronization is necessary for sequencing and in turn for syntactic integration. The aim of the following Experiment (3) was to investigate whether patients with focal basal ganglia lesions benefit from speech internal metric cues as designed in the experimental series 2. If so, a P600 should emerge in the syntactic condition. Furthermore, if in fact the lack of a P600 in initial experiments (Frisch et al., 2003) was due to a metric deficit (because previous syntactic violations were a conglomerate of a syntactic and a metric violation) the prediction would be that a purely metric P600 should be absent. With respect to the double violation condition one would predict that no P600 is evoked, as the metric violation interferes with the syntactic violation. However, it is also plausible that a P600 is elicited in the double violations condition for the following reasons: Results of previously conducted experiments with BG-patients showed that an external taktgeber is sufficient to sequence the acoustic input and to allow syntactic reanalysis even though the speech input remained completely metrically random and metric and syntactic violation were collapsed. As the present stimulus material has a predictable regular meter this should compensate the metric deficit of the patients by creating stable attractor states. Therefore, sequencing and in turn syntactic reanalysis should be possible comparable to earlier studies. A regular metric pattern up to the critical item may therefore be sufficient to electrophysiologically detect the syntactic violation in the double violation condition resulting in a P600.
To be sure that potential deficits of the patients were not due to a general attention deficit a classical auditory P3-oddball paradigm was conducted prior to running the critical P600 experiment.

8.1 Materials and Methods

Participants 19 patients with focal lesions in the basal ganglia (3 female, one left-handed, four of them with right sided insult) aged between 27 to 74 (mean: 48.8) years participated in the study. Lesions resulted from ischemic stroke (n = 3), embolic stroke (n = 2), hemorrhage (n = 2), intracerebral bleeding (n = 7), or middle cerebral artery stroke (n = 5). The average time since lesion was 5.7 years (range: 0.8 - 8.11 years). For patient details see Table 8.1.

Lesions sites were determined by anatomical (T1- and T2-weighted) MRI datasets from a 3.0 T system (Bruker 30/100 Medspec) and evaluated by an experienced neuroanatomist (see Figure 8.1). Furthermore 19 healthy controls were tested that were matched in age, handedness, and educational level. All were native speakers of German and had not taken part in a similar study. Participants were paid for their participation.

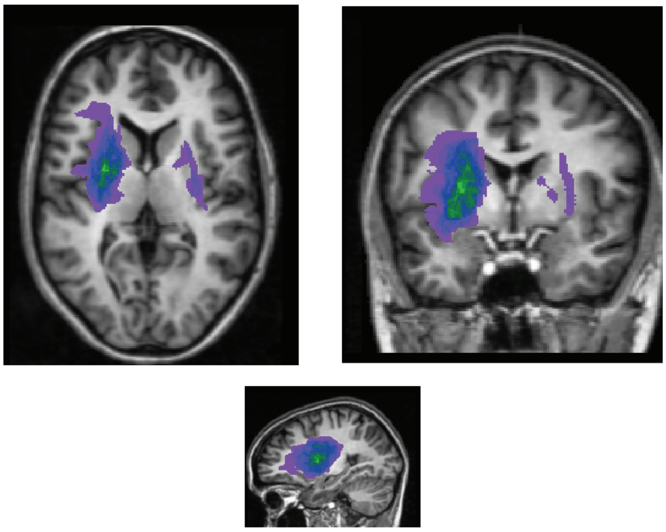

Figure 8.1: Overlay of lesions sites from 19 BG patients. Talairach coordinates: x = -24, y = -2, z = 10 (Talairach & Tournoux, 1988). Green and yellowish shades reveal maximum overlap of lesion sites; purple shades reveal minimum lesion site overlap.

Patient History

Patient	Age at test (years)	Time of lesion	Sex	Etiology	Lesion description
1	48	October 1997	male	MCA	Caudate Nucleus (right), Putamen
2	42	May 1999	male	MCA	Putamen (left), Caudate Nucleus (body and cauda)
3	32	July 1999	male	ischemic infarct	Putamen (posterior part), Caudate Nucleus (body), middle insular, parietal operculum
4	51	May 2005	male	ICB	Putamen, Claustrum
5	69	August 2000	male	ischemic infarct	Caudate Nucleus (anterior body), anterior Putamen, GPe, external capsule, anterior internal capsule, anterior insula, preinsular white matter
6	39	September 2001	female	MCA	Caudate Nucleus (body), Putamen, GPe, anterior internal capsule, external capsule, parietal operculum, posterior insula
7	29	April 2003	male	ICB	left dorsal Putamen, Caudate Nucleus (cauda)
8	46	January 2003	female	MCA	right anterior Putamen, Caudate Nucleus (cauda), Pallidum, internal capsule, Thalamus
9	49	February 1999	male	ICB	left Putamen, Pallidum
10	74	January 2000	male	embolic infarct	left Putamen, Pallidum, Caudate Nucleus (cauda and body), Corona radiata, internal capsule
11	60	August 2000	male	ischemic infarct	left complete BG-system, Corona radiata, Thalamus
12	44	April 2003	male	ICB	right lateral Putamen, Caudate Nucleus (body)
13	66	January 1997	male	hemorrhage	Caudate Nucleus, Putamen
14	54	February 1998	male	ICB	Thalamus, Corona radiata, Pallidum, left Putamen, internal capsule
15	45	August 2005	male	ICB	left and right Putamen

Continuation Patient History					
16	67	August 2003	male	embolic infarct	left Putamen, Caudate Nucleus (cauda), anterior internal capsule
17	52	April 2001	female	MCA	left Putamen, Caudate Nucleus (cauda), parts of the insula
18	27	July 2001	male	ICB	left Putamen, Pallidum, Thalamus, Caudate Nucleus, parts of the insula, left crus cerebri, Wallersche degeneration
19	34	December 1998	male	embolic infarct	left complete BG-system

Table 8.1: Experiment 3: Patient History of 19 tested BG-Patients. *ICB* = Intra Cerebral Bleeding, *MCA* = Infarct of the Middle Cerebral Artery

Materials For the experiment the same material as in Experiment 2a was used. With regard to P3-oddball paradigm, participants listened to standard tones with a frequency of 600 Hz and a probability of 0.8 as well as deviant tones with a frequency of 660 Hz and a probability of 0.2. A total of 550 tones was presented. All stimuli had a duration of 200 ms and were presented with a constant inter-stimulus-interval of 600 ms.

Procedure Data was collected in one session of approximately forty minutes. Patients did an explicit task with respect to syntax, i.e. a grammaticality-judgement. All 208 sentences were presented auditory via loud speakers in a randomized order. The experimental trials were presented in four blocks. Each sentence was introduced by a visual cue on the center of a computer screen. 2000 ms after the offset of the sentence, participants were asked to perform the grammaticality judgement task. Participants had to answer within a time frame of 2000 ms. The next trial started 2000 ms after the button press (see Experiment 2a for a exemplary trial scheme). Participants were tested individually in a dimly illuminated sound-attenuating booth. They are seated in a comfortable reclining chair and were instructed to move and blink as little as possible. Half of the participants had the correct-button on the right side and the incorrect-button on the left side, while the other half has it vice versa.
The EEG was recorded with a sampling rate of 250 Hz from 32 scalp sites by means of Ag/AgCl electrodes mounted in an elastic cap (Electro-Cap Internation, n.d.) from FP1, FP2, F7, F3, FZ, F4, F8, FT7, FC3, FC4, FT8, T7, C3, CZ, C4, T8, TP7, CP5, CP6, TP8, P7, P3, PZ, P4, P8, O1, O2, A1 and A2, referred to A1. Furthermore, horizontal and vertical EOGs were recorded to control eye movement artifacts. In order to increase the number of trials per condition eye artifact control measures were applied to the raw data (Pfeifer, Novagk, & Maess, 1995). Afterwards the EEG recordings were scanned for artifacts on the basis of visual inspection. Thus, approximately 10.7 % of the trials in the control group and 20.4 % of the trials in the patient group had to be excluded from further analysis due to artifacts and incorrect trials. Consequently, about 47 trials per subject per condition in the control group and 41 trials per condition in the patient group entered the grand average. For graphical display only, data were filtered offline with a 7 Hz low pass filter.

8.2 Results Experiment 3

8.2.1 Behavioral Data

An ANOVA applied to the accuracy data with the between-factor group (BG/ Controls) and the within-factor condition (correct, syntactically incorrect, metrically incorrect, double violation) revealed a marginal main effect of *condition* (F(3,54) = 2.87; p = 0.06). Planned comparisons revealed significant effects for the comparison between the correct and the metrically incorrect condition (F(1,18) = 4.87; $p < 0.05$). Overall accuracy rates were above 95 %, indicating that all participants had no difficulties to perform the task (for details, see Appendix A.4).

8.2.2 ERP-Data

The following electrodes were grouped together to regions of interest in order to statistically analyze the ERP-data: anterior left (F7, F3, FT7, FC3) anterior right (F8, F4, FT8, FC4), posterior left (CP5, P3, P7, O1), and posterior right (CP6, P4, P8, O2).

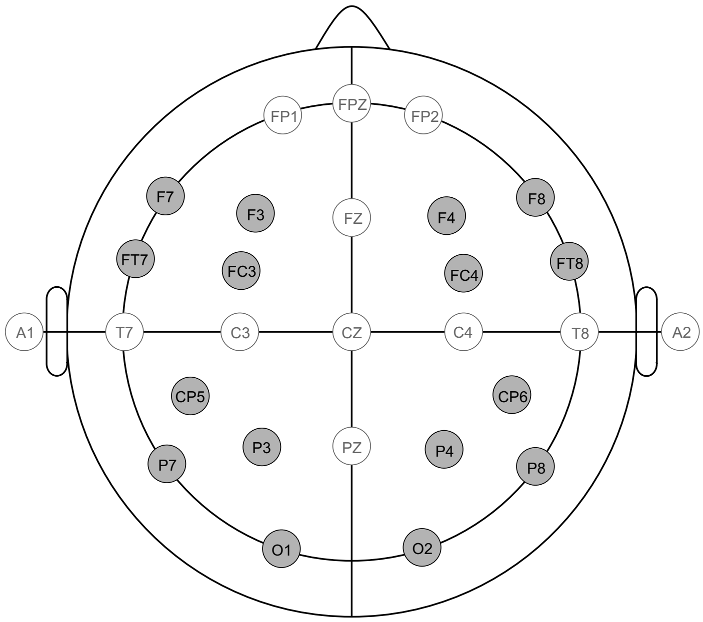

Figure 8.2: Experiment 3: Statistically analyzed electrodes (marked in grey).

P3-Oddball With regard to the P3-Oddball-paradigm an ANOVA with three within-subject-factors was computed: *condition* (standard/deviant), *hemisphere* (left/ right), *region* (anterior/ posterior)) and one between-subject factor (*group* (patients/ controls). A time window from **250 to 500 ms** after the onset of the stimuli was chosen. Only those effects that critically affect the factor condition are reported. The ANOVA revealed a significant interaction between *group* and *condition* (F(1,36) = 6.23, $p < 0.05$). The condition effect

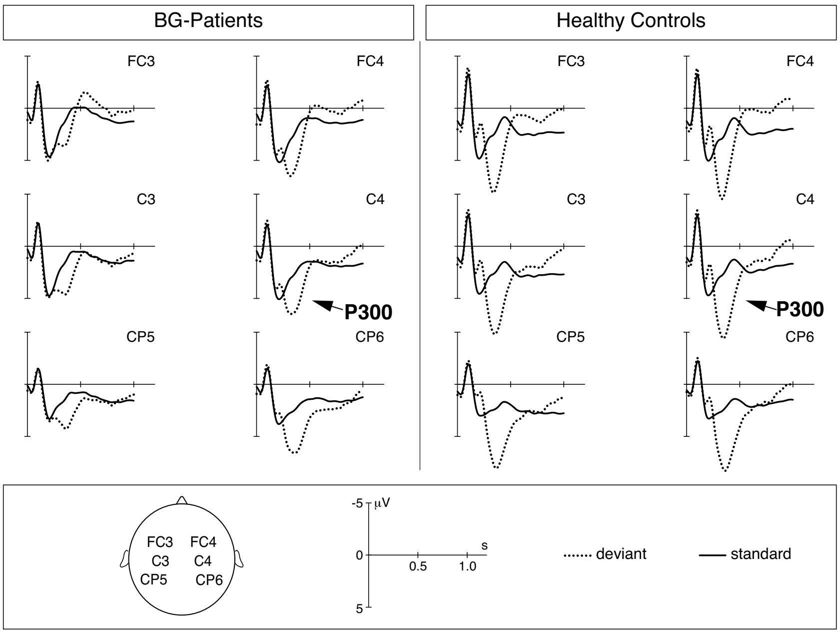

*Figure 8.3: **Experiment 3**: ERPs for P3-oddball paradigm*

in the control group (F(1,18) = 61.88, $p < 0.001$, ES = 1.60) was larger than in the patient group (F(1,18) = 15.10, $p < 0.01$, ES = 0.75). Furthermore, a three-way interaction between *group*, *condition* and *hemisphere* turned out to be significant (F(1,36) = 4.71, $p < 0.05$). Resolving the interaction by the factor group resulted in a significant interaction between *condition* and *hemisphere* only in the patient group (F(1,18) = 6.58, $p < 0.05$). In the patient group break-down analyses revealed significant effects for *condition* in both hemispheres. The effect appeared larger in the right compared to the left hemisphere (left: (F(1,18) = 6.47, $p < 0.05$, ES = 0.604; right: F(1,18) = 20.33, $p < 0.001$, ES = 0.949). Controls showed only a significant main effect of *condition* (F(1,18) = 61.88, $p < 0.05$) but no interaction between condition and hemisphere.

Meter-Experiment Two ERP-components were predicted in the Meter - Syntax - Experiment: An early negativity and a late posterior positivity. Due to visual inspection of the ERP-data as well as difference maps (see Appendix A.2) the conditions were analyzed separately as the particular violations led to different latencies of the components.

Negativity To evaluate the negativities in the Meter - Experiment three time windows were statistically analyzed, namely 250 to 450 ms, 450 to 650 ms and 450 to 800 ms after

P3b: 250 to 500 ms			
Effect	*df*	*F value*	*p value*
Group	1,36	4.64	<0.05
cond	1,36	67.18	<0.001
*cond*hem*Group*	1,36	4.71	<0.05
Patients			
Effect	*df*	*F value*	*p value*
cond	1,18	15.10	<0.01
*cond*hem*	1,18	6.58	<0.05
Patients - Left Hemisphere			
Effect	*df*	*F value*	*p value*
cond	1,18	6.47	<0.05
Patients - Right Hemisphere			
Effect	*df*	*F value*	*p value*
cond	1,18	20.33	<0.001
Controls			
Effect	*df*	*F value*	*p value*
cond	1,18	61.88	<0.001

Table 8.2: Experiment 3: Significant results from ANOVAs on mean amplitudes for the time window 250 to 500 ms.

onset of the critical item. Though visual inspection indicated that controls showed a negativity in the metric violation condition and patients showed a negativity in the double violation condition, none of the conducted ANOVAs revealed a significant effect for condition or an interaction between condition and group in either of the violation conditions (for details see Appendix A.6).

Syntactic violation - P600 In order to evaluate the positivity elicited by the syntactic violation condition an ANOVA with a time window from 600 to 1200 after onset of the critical item was conducted. This ANOVA was restricted to posterior electrode sites and contained the between-subject-factor *group* (patients/ controls) as well as two within-subject-factors, namely *hemisphere* (left/ right) and *condition* (correct/ syntactically incorrect). The analysis resulted in a main effect of *condition* ($F(1,36) = 44.45$; $p < 0.001$) as well as a significant interaction between *hemisphere* and *condition* ($F(1,36) = 6.96$; $p < 0.05$). No interaction with the factor *group* turned out to be significant. Resolving the interaction by the factor *hemisphere* revealed significant effects for *condition* in both hemispheres with the effect being stronger in the right hemisphere (left: $F(1,18) = 26.16$, $p < 0.001$, ES = 0.576; right: $F(1,18) = 46.01$, $p < 0.001$, ES = 0.726).

Time Window: 600 to 1200 ms			
Effect	*df*	*F value*	*p value*
cond	1,36	44.45	<0.001
*cond*hem*	1,36	6.96	<0.05
Left Hemisphere			
Effect	*df*	*F value*	*p value*
cond	1,36	26.16	<0.001
Right Hemisphere			
Effect	*df*	*F value*	*p value*
cond	1,36	46.01	<0.001

Table 8.3: Experiment 3: Significant results from ANOVAs on mean amplitudes in the syntactic violation condition.

Time Window: 750 to 950 ms			
Effect	*df*	*F value*	*p value*
Group	1,36	4.88	<0.05
*cond*Group*	1,36	4.03	=0.06
Controls			
Effect	*df*	*F value*	*p value*
cond	1,18	5.24	<0.05

Table 8.4: Experiment 3: Significant results from ANOVAs on mean amplitudes in the metric violation condition.

Metric violation - P600 Regarding the purely metric violation a time window from **750 to 950 ms** after onset of the critical item was calculated. An ANOVA with the same factors as in the syntactic condition revealed a significant interaction between *group* and *condition* (F(1,36) = 4.03, p = 0.05). Resolving this interaction by the factor group resulted in an significant effect for *condition* only in the control group (F(1,18) = 5.24, $p < 0.05$).

Double violation - P600 To evaluate the effect evoked by the double violation the time window from **600 up to 1200 ms** after onset of the critical item was statistically analyzed. An omnibus ANOVA over posterior electrodes with the between-subject factor *group* and the two within-subject-factors *hemisphere* and *condition* only resulted in a significant main effect of condition (F(1,36) = 33.39, $p < 0.001$).

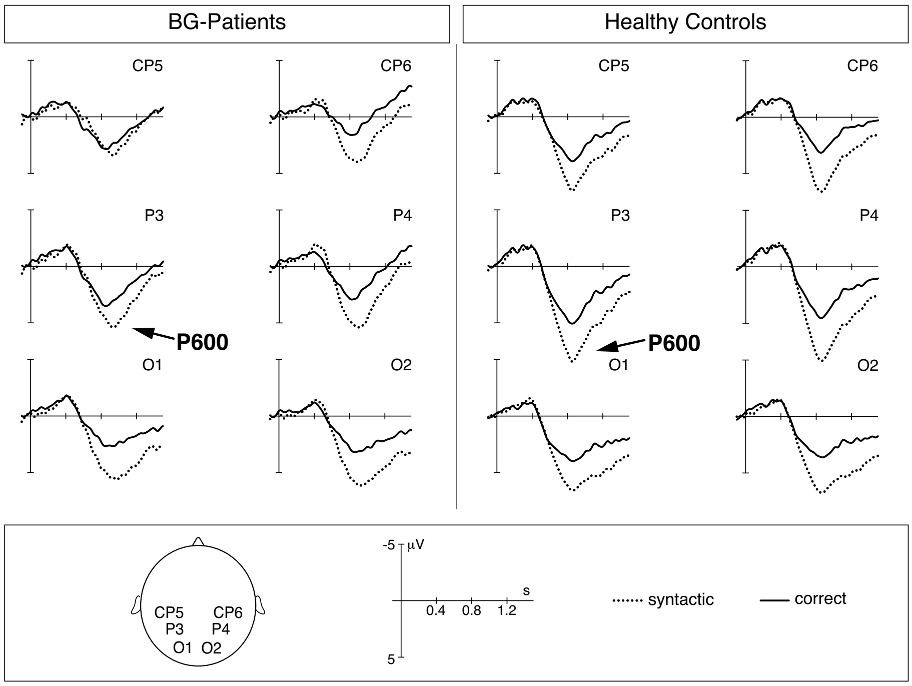

Figure 8.4: ***Experiment 3****: ERPs for the syntactic violation condition - P600*

Time Window: 600-1200 ms			
Effect	*df*	*F value*	*p value*
cond	1,36	33.39	<0.001

Table 8.5: Experiment 3: Significant results from ANOVAs on mean amplitudes in the double violation condition for all participants.

8.3 Discussion Experiment 3

P3b As was demonstrated by the results of the P3-oddball paradigm both groups, patients as well as controls showed a P3b in response to the deviant stimuli a result in line with data reported by Frisch et al. (2003). However, the amplitude of the component was significantly increased in the control group compared to the patient group (difference = 1.6036 μV) indicating that they process the information differently than controls.

Meter-Experiment In contrast to the formulated hypotheses neither a significant LAN nor a metric negativity was elicited in either group. Investigating each participant in detail results in the same pattern as in Experiment 2b: Some of the participants did show the negativities and some of them did not. But in this experiment as well, the distribution is

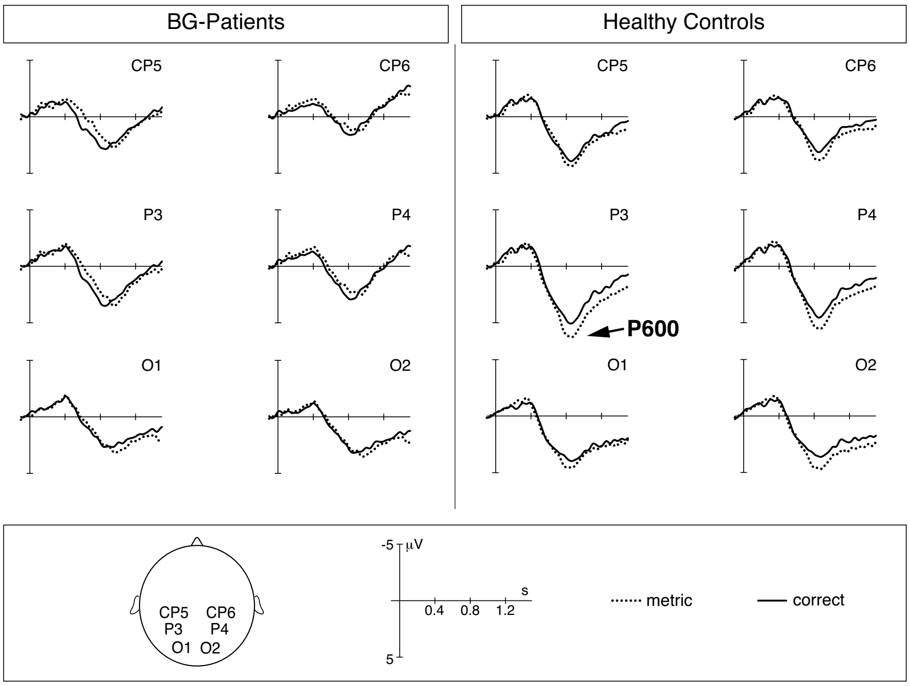

*Figure 8.5: **Experiment 3**: ERPs for the metric violation condition - P600*

completely random and not predictable by external factors (as age, hearing, musical experience, medication, etc).

Without doubt, the most interesting finding of the current experiment is the fact that the patients with lesions of the basal ganglia do show a P600 in response to the syntactic violations although they have not shown this component in previously conducted studies (Frisch et al., 2003; Friederici, Kotz, et al., 2003). This finding indicates that BG patients only have a secondary problem with syntactic reanalysis while the true nature of an underlying deficit is temporal. This underlying deficit seems to be a metric one as results of the current study demonstrate that patients do not reveal a "metric P600" in contrast to the healthy control group. While smaller in comparison to young participants, the "metric P600" was significant in healthy age-matched controls. Furthermore, the amplitude decrease is not surprising as the results of Experiment 2a showed that implicit processing of metric information affects the amplitude size of the P600. In the current experiment the task was not focussed on meter. Furthermore, the mean age is strongly increased in the current sample (48.8 years) compared to the sample in Experiment 2a (25.1 years). This factor has also been stated to influence the latency and to cause an amplitude decrease of late positivities (Fjell & Walhovd, 2003).

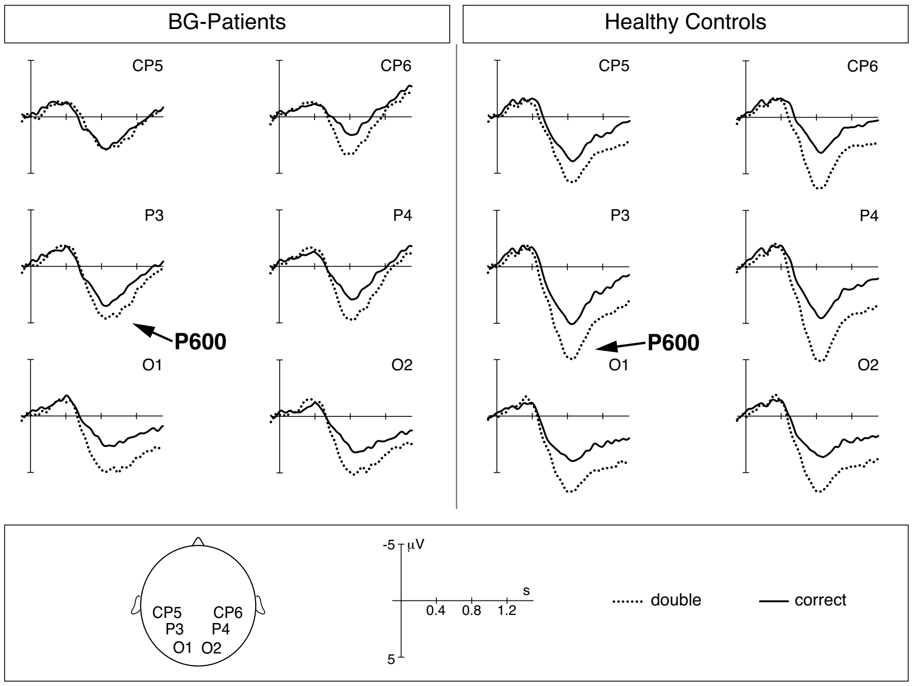

Figure 8.6: ***Experiment 3****: ERPs for the double violation condition - P600*

With regard to the double violation condition the formulated hypothesis also turns out to be true. As in previously conducted studies using an external predictable taktgeber, the patients do profit from the regular trochaic meter up to the critical item and can do syntactic reanalysis in response to the double violation as evidenced in the P600. Thus the results of the patient experiment can be summarized as follows:

- Patients with lesions in the BG do not have a primary syntactic deficit as they do show a P600 in response to syntactic violations when sentences are metrically predictable.
- Instead BG-patients rather seem to have a metric deficit, as the "metric P600" is not elicited in the patient group. This correlates nicely with the fact that the BG have been linked functionally to numerous time sensitive mechanisms and sequencing mechanisms respectively (see Chapter 3).
- Furthermore, it can be noted that speech internal rhythmic cues as a predictable stress pattern may facilitate syntactic information processing as BG-patients obviously profit from a completely trochaic stress pattern. Thus, speech internal metric cues can compensate the disfunctioning internal clock just as well as external rhythmic cues (Kotz, Gunter, & Wonneberger, 2005).

Already in 1775 Joshua Steele noted that rhythmic organization requires a fixed metric pattern as "reference value" that has to be a sequence of isochronous intervals. This reference value may be missing in patients with BG lesions if the BG system regulates such an internal clock (Packard & Knowlton, 2002). Furthermore, the BG-patients fail to show period adjustment according to the *Dynamic Attending Theory*. Thus, they are not able to resynchronize (in the metric violation condition) with a new period as in form of a new iambic stress pattern, resulting in a missing 'metric' P600. One can therefore assume, that the basal ganglia play an important role a) in providing dynamic oscillations that are involved in handling random rhythms, and b) in making modifications of period and phase adjustment. As some neurobiologists (e.g. Gibbon et al., 1997) claim that basal ganglia dysfunctions increase variability in timing and time perception cognitive oscillations of BG-patients are no more dynamic and inflexible to handle metric changes. However, these dysfunctions can be compensated via isochronous input.

In the present experiment meter processing was only implicitly tested. This was done to test metric information processing independent of explicit task demands. In the case of explicit meter processing it is expected that behavioral data would get worse. After conducting the present experiment patients were interviewed as to whether they had perceived anything something strange. While healthy controls recognized the metric deviance, none of the patients did so. Furthermore, under explicit processing demands it is expected that no metric P600 would be evoked even though attention would be directed to the metric violation. As patients cannot integrate new metric cues due to the missing dynamic in cognitive oscillations no period adjustment can take place. Next to the relevance of timing competence in syntactic information processing, the results provide interesting results for a discussion on the generators of the syntactic P600 and to the ongoing debate about the P600 being a late P300 or not. Firstly, it has to be noted that the basal ganglia are not the generator structure for the syntactic P600 but rather are involved in modulating syntactic processing. Furthermore, the BG are involved in a neural network that regulates metric processing that in turn influences syntactic processing. Secondly, Frisch et al. (2003) concluded that the P600 and the P300 must have different neural generators as BG patients did show a P300 but no P600. The current results do not conflict with these data, but they extend them. As both components, the P300 and P600 were elicited in the patients group, it becomes apparent that syntactic processing and syntactic reanalysis/integration is secondary to a metric processing deficit. While the tones in the P3-oddball-paradigm were presented in an isochronous matter with a constant ISI, the syntactically violated sentences always had a random timing pattern. Consequently, it could be that patients solely profit from the predictable timing of the tones as this may function as an external timing cue and thus the two Experiments (P3b and P600) are not really comparable. Future research has to focus on a more differentiated distinction between the P300 and P600. Therefore a more complex P3-paradigm is needed in which stimuli have to be presented in a random (not predictable) mode as well. It may be interesting to see whether BG-patients show a P300 even in the case of randomly presented tones.

Part IV

General Discussion and Outlook

Chapter 9

Summary and Conclusion

The aim of the current thesis was to investigate the impact of metrical structures in form of external as well as speech internal timing cues on auditory sentence processing. More specifically, the influence of these cues on syntactic processing and consequently the effect of timing mechanisms on the amplitude of the P600 were the focus of interest. Exact timing or metric competence, respectively, is very crucial in various aspects of information processing, especially in motoric sequences. Normally, we do not appreciate this capacity as we take it for granted until we encounter a selective loss of it. As has been stated by Gasser et al. (1999) "Meter is a skill, manifested as a particular mechanism, a means by which signals are processed, guided by underlying tendencies toward periodicity and integral relationships between periodicities. This mechanism self-organizes to discover and reproduce the temporal regularities in the input." Consequently, meter as a mechanism is involved in a number of cognitive systems which require a detailed temporal analysis of the input and the resulting output. Furthermore, a meter perception theory has to be dynamic, as the temporal regularities of the input are often fluctuating and/or varying from an isochronous template. The theoretical framework describing meter perception mechanisms underlying this thesis is the Dynamic Attending Theory (Large & Jones, 1999). According to this theory the perception of metrical structures is due to internal or cognitive oscillations that synchronize - via self-entrainment - with external oscillations. This synchronization results in a building of *stable attractor states*, an isochronous pattern that can be thought of as a 'framework' that helps the listener in sequencing the input similarly to hierarchies in syntactic structure that organize an incoming speech stream. Attractors are therefore certain points in time that "attract" focus of attention. Thus, these events are preferably processed.

Self-entrainment per se seems to be an important characteristic in human behavior and a general feature of cognitive systems as coupling of oscillations at simple harmonic ratios

"is a ubiquitous and intrinsic property of animal control systems" (Port et al., 1999).
The key questions of this thesis were: How relevant is metric competence in auditory language processing, especially in syntactic processing? As both processes underly hierarchical structures and certain rules - do meter and syntax interact during sentence processing? Does the described theoretical framework of meter perception fit the current experimental data? What is the role of the basal ganglia in auditory sentence processing?

With regard to the enormous speed in which speech production as well as perception takes place, it seems to be plausible that exact timing is necessary for both processes. However, its necessity concerning syntactic processing has been perhaps not too obvious. First electrophysiological evidence suggesting the necessity of timing competence in syntactic processing comes from data by Frisch et al. (2003) and Kotz, Gunter, and Wonneberger (2005). The authors were able to show that patients with focal lesions of the basal ganglia do not show a P600 in response to syntactic violations, while this component could be re-evoked as soon as the patients were "primed" with an external 'taktgeber'. This indeed very simple method to re-initiate syntactic reanalysis gave reason to hypothesize that the capacity to perceive and synchronize with isochronous intervals is indispensable for the processing of syntactic information. In the first experimental series (1a and 1b) the influence of speech external timing cues on auditory language processing in healthy participants was examined. For this purpose, the interstimulus-interval, i.e. the pause between two subsequent words, was held constant in Experiment 1a, whereas in Experiment 1b the stimulus-onset-asynchrony (SOA), i.e. the period of time from the onset of one word to the onset of the preceding word remained the same. The manipulations tested

- whether the language system is sensitive to such manipulations, and
- which manipulation had the highest impact on syntactic processing.

Four ERP-components were evoked by the manipulations in Experiment 1a and 1b: As hypothesized, word-category violations elicited an ELAN and a P600, and furthermore an anteriorly distributed late and sustained negativity. Semantic violations resulted in an N400-effect. While semantic processing was not influenced by all timing manipulations (no change in amplitude size, nor latency) syntactic processing led to different results dependent on the manipulations in Experiment 1a and Experiment 1b. The ELAN was affected by the timing manipulations as the effect was only elicited in the random timing condition in both experiments. This is in line with the results of former studies that stated the ELAN to be time-sensitive. As the ELAN is thought to be an electrophysiological index for initial phrase structure building this process has been interpreted to require fast and fluent input.

With regard to the P600, the critical time unit seems to be the SOA, as the P600 in Experiment 1b was evoked by all three timing manipulations after the onset of the participle, although the parser could have detected the syntactic violation already at the onset of the pause preceding the participle in the chunked condition. This finding suggests that the listener is synchronized by the predictability of a word's onset in Experiment 1b and consequently the processing speed is matched with the given external tactus. Alternatively, the percipient awaits a certain time period before initiating the reanalysis. This is consistent with studies on beat perception that suggest that internal oscillations are adapted to external beats so that they are activated at the time a beat is expected (Gasser et al., 1999). As Large (2001) noted, a listener's perception of duration categories in an auditory sequence is influenced by the underlying meter and one and the same auditory sequence can be interpreted to have different rhythmic patterns when presented in different metrical contexts. So, an external 'taktgeber' can influence information processing.

Another interesting finding concerns the significant differences in the amplitude of the P600 dependent on whether participants are learning or reading with or without music. Only in the first group, the P600 was significant. This implies that people who are familiar with coupling music and language processing are more competent in syntactic reanalysis. These data further support a strong relationship between music and language processing. Many studies revealed evidence that music and language processes have much in common or influence each other, respectively. Both processes show relatively fixed developmental time courses and all known human societies use music and speech regardless of technological sophistication (Zatorre, Belin, & Penhune, 2002; Patel, 2003). For example, Wallin, Merker, and Brown (2000) stated that music and language have common roots in the so-called "musilanguage". Furthermore, it has been reported that musical training facilitates the perception of changes in fundamental frequency in music *as well as* in language (Magne, Schön, & Besson, 2003; Schön, Magne, & Besson, 2004) and experiments with dyslexic children provide evidence that music lessons do benefit rhythm coping as well as phonological and spelling abilities (Overy, 2003). Besides similarities of music and language, several studies have shown parallel rhythmic processing in both domains. It has been reported that linguistic rhythm seems to leave an imprint on the preferred musical rhythm of a certain language. Patel and Daniele (2003) investigated the relationssship between musical and speech rhythms in English and French, two languages that belong to different rhythmic groups (stress-timed vs. syllable-timed). They found that even in the case of purely instrumental music, composers are influenced by the rhythm of their native language. Furthermore, in accordance to language acquisition in which metrical cues are initially used for language segmentation, metrical structure is also used in bootstrapping the children's knowledge in music learning (Hannon & Johnson, 2005). Electrophysiological data also underline the similarity between musical and linguistic rhythm processing: In both domains rhythmic changes result in a late positivity which the authors (Besson, Faita, Czternasty, & Kutas, 1997) assume to be a P600 reflecting a domain-general process dealing with temporal information. In sum, there is cumulating evidence that music competence may strongly influence syntactic and metric processing in speech. In this thesis, all participants in each of the experiments were asked whether he/she was musically experienced or not. However, no significant group differences were found in Experiment 2a, 2b, and 3. This may have been due to the fact that only a simple trochaic meter was constructed in the material of the following experiments, while differences between two groups may become apparent with more complex meter. It has been shown that musically experienced people have increased hierarchical levels in which rhythmical sequences can be perceived (Jongsma, Desain, & Honing, 2004), and that musicians have strong advantages to synchronize to expressive music compared to non-musicians because pulse finding is more difficult in this sort of music (Snyder & Krumhansl, 2001). Thus, the advantages of musicians may become apparent in metrically more complex speech.

The late and long sustained negativity which appeared in both experiments 1a and 1b in response to syntactic violations was interpreted as an index of re-orientation in analogy to Schröger and Wolff (1998). In both experiments participants had to do a correctness-judgment with regard to possible semantic and syntactic violations. However, the syntactic violation coincides with a prosodic violation, as it entails a sentence ending prosody where not expected (instead of an NP one listens to a 'ge'-participle). Thus, subjects are confronted with a conflicting additional violation and they have to re-orientate to the task-relevant information. This may cause a sustained negativity.

In sum, the results suggest that in healthy participants syntax processing can be influenced by an external 'taktgeber' as well. Furthermore, the critical time window seems to be the SOA, i.e. an isochronous time window from the onset of one word to the onset of a subsequent word. The influence of an external meter on auditory sentence processing is thereby indisputable. However, in daily communication it is unlikely to encounter such external devices during syntactic processing. Therefore, the aim of the following experiments was to shed light on the issue whether language has internal cues which are used during sequencing speech input and furthermore to check if the detection of such cues is necessary to initiate syntactic reanalysis. Additionally - due to previous results in the patient studies - a potential interaction between metric and syntactic processing was investigated, as patient data suggested that an isochronous metrical grid appears to be crucial for syntactic reanalysis. As in previous studies syntactic violations always coincided with metric violations, Experiment 2a was conducted with the following motivation:

- Metric and syntactic violations should be separated to measure the brain response to purely metric and purely syntactic violations.
- If pure metric violations evoke a P600 as well, this would indicate that the P600 has subcomponents that do not only react to syntactic violations. These subcomponents could in turn be responsible for the break-down of the P600 in BG-patients.
- If the P600 would be evoked by both single violations, a double violation condition could serve as control condition to prove whether both violations behave additive or whether the underlying processes interact.
- In sum Experiment 2a was to specify the role of syllable stress and trochee respectively during auditory syntactic processing.

Two ERP-components were elicited in response to the manipulations of Experiment 2a - an early negativity and a late positivity. The early negativity was evoked in all three violation conditions as well as in both tasks. In response to morphosyntactic violations a LAN was elicited that is comparable to the LAN reported in several experiments (Coulson et al., 1998; Deutsch & Bentin, 2001; Gunter et al., 2000; Friederici et al., 1993; Penke et al., 1997). Metric as well as double violations evoked a negativity that deflected earlier than the LAN and was interpreted as a metric error detector or harder lexical access, as the stress pattern of the critical item did not match with the stress pattern in the mental lexicon (Magne et al., 2004).

With regard to the P600, the results of Experiment 2a support the hypothesis that syntax and meter interact during language processing as both single violations evoked a P600 whose amplitude was comparable to the double violation condition. This interpretation follows from the Helmholtz law which maintains that evidence of additivity implies independence of the underlying neural sources. Consequently, non-additivity argues for an interpretation that both violations could not be traced back to separate processes. This finding suggests that in previous studies two processes were confounded. Therefore, it remained an open question as to which of the processes is vulnerable to BG lesions (Experiment 3). As Experiment 2a was conducted with two different tasks it was shown that the latency and the amplitude size of the P600 - of the 'syntactic' as well as of the 'metric' P600 - was dependent on the attentional focus given the respective task. The process in attentional focus evokes the largest P600 with an earlier onset. It is of further interest that the *metric P600* in the syntactic task deflects at the same time as the *syntactic P600*, while the *syntactic P600* in the metric task deflects much later than the *metric P600*. This indicates that even if the attention is not directed to the metric structure of a sentence the processing and reanalysis is so relevant that it has to take place at the same point in time as the process that is in the focus of a given task. However, syntactic reanalysis seems not to be as crucial in the metric task. This finding supports the importance of the use of metric cues in German language processing. It is thus important to note that the system registers deviants from the expected regular stress pattern and this results in the same electrophysiological component as syntactic violations. This is in line with the proposed theoretical framework, the **Dynamic Attending Theory**. This theory predicts that a period adjustment has to be accomplished if the overall temporal rate of successive beats has changed, that means one has to establish new *attractor states* (which seem to be relevant for syntactic processing as well) and therefore one has to re-synchronize with the external oscillations. This re-synchronization or period-adjustment is interpreted to be reflected in the metric P600. To sum up, both ERP-effects - negativity as well as positivity - deflected earlier in response to the metric violation compared to the syntactic violation. This results support the high importance of metric cues in structuring and processing auditory sentence perception.

Another open question concerns the experiment conducted by Magne et al. (2004). In this study no 'metric P600' was evoked in an implicit task (semantic task). Against the setting of the actual data this finding may be due to the fact that although a metric template is crucial to process syntactic information it is not relevant to process semantic information. But why? As meter as well as syntax represent rule-based organizational principles which are necessary for information processing, semantics do not provide such a structural or hierarchical character. Thus, the results of Magne et al. do well agree with the proposed theory. A following experiment (Experiment 2b) was conducted in order to clarify whether minimal metric deviations - which are thought to correspond to small phase-adjustments in the theoretical framework - are also detected especially as they are very frequent in natural language. Therefore, the same trochaic sentences were used as in the previous experiment, but in this case the critical item was a real existing three-syllabic German word that was originally stressed on the second instead of the first syllable. In this experiment, only a late positivity emerged but no early negativity. This result further supports the interpretation of the metric negativity as a correlate of difficult lexical access, as in this experiment items do have a lexical entry and are therefore easier to process than the metrically critical items of Experiment 2a. However, the metric negativity can also be interpreted as a subcomponent of the LAN reflecting a general rule-based sequencing mechanism as a function of error detection in a hierarchically structured sequence (according to Hoen & Dominey, 2000). Within this theoretical framework metric deviations in Experiment 2b appear not to violate the hierarchy of the structured sequence as no negativity is elicited to a metrically non-salient item. Thus, it should be the aim of future studies to clarify this issue (for further discussion see Chapter 10).

Furthermore, this manipulation elicited - next to a syntactic P600 - a metric P600 in the metric task, indicating that as soon as attention is directed to the metric structure of a sentence metric reanalysis is initiated even in the case of subtle metric deviations. When meter is processed implicitly no resequencing of the metric information takes place which seems to be system-economically appropriate if one considers the large amount of metrical deviations in daily communication. This is also in line with the proposed Dynamic Attending Theory, as small phase-adjustments (Figure 1.2, Chapter 1) should be handled effortless in healthy subjects. Consequently, reanalysis of the metric structure is only initiated if metric deviations are pointed out to the participants, as it is the case in the metric task.
All four studies with healthy participants thus support the hypotheses that

- an external 'taktgeber' influences syntactic reanalysis and builds stable *attractor states* for language processing,
- both, external 'taktgeber' as well as speech internal metric cues (as a regular stress pattern) serve as external oscillations with which internal cognitive oscillations are synchronized in healthy subjects,
- in German as a stress-timed language, word accent or its regularity and predictability, respectively, is an important cue for syntactic sequencing and re-analysis,
- the P600 contains subcomponents which react sensitive to different modules such as meter and syntax, i.e. mechanisms that have to do with hierarchical structuring and rule-based processing of the incoming speech stream, and
- meter and syntax interact during sentence processing.

With this knowledge the role of the basal ganglia - also described as the internal clock of the human organism - in these processes was investigated in the fifth and last experiment of the present thesis. As neurobiological theories (e.g. Gibbon et al., 1997) pointed out basal ganglia dysfunction does increase variability in timing and time perception. Furthermore, it has been stated that PD patients lack neuromotor control that results in missing synchrony for coupling of oscillators (Paula Soares & Silva, 2003).
To further investigate the role of the basal ganglia in metric processes, especially with regard to language processing, 19 patients with focal lesions of the BG were tested with the paradigm of Experiment 2a. However, the experiment was reduced to one session. Utilizing the *syntactic task*, a P600 effect was evoked in both, the patient and the control group, in response to the syntactic as well as to the double violation condition. With regard to the metric violation condition, BG patients failed to show a P600 whereas in the control group a small metric P600 was evoked. The amplitude decrease as well as the latency delay of the metric P600 compared to results of Experiment 2a can be explained with the increased age

of the participants in Experiment 3. As Fjell and Walhovd (2003) pointed out, increased age causes inter alia amplitude decrease of late positivies.

Data provide clear evidence for the contribution of the BG in metric but not in syntactic processing as patients did show a clear positivity in response to the morphosyntactic violations. This positivity does neither vary significantly in size nor latency from the positivity in healthy controls. Furthermore, the results support the theory that an underlying metric template is fundamental for syntactic information reanalysis, as BG-patients obviously profit from the metric regularity accompanying the sentences to the extent that a constant trochee compensates a metric deficit. This is in accord with an external 'taktgeber' reported by Kotz, Gunter, and Wonneberger (2005). It follows from the results that BG-patients must have a metric deficit, as they do not show a positive deflection in response to the metric violation (in contrast to healthy controls). The elicited P600 in the double violations condition in both groups was interpreted to be only syntactically pushed in patient group. As the regular stress pattern up to the critical item compensates their deficient internal clock by building up stable attractor states, they are capable to do syntactic reanalysis in the double violation condition. Thus, the BG-patients do not seem to have a primary syntactic deficit. Furthermore, the relevance of the BG in timing is not limited to motoric activities but also applies to speech perception. Therefore, the perception of temporal structures or the property of a metric reference pattern, respectively, is important for syntactic processing.

The data could be well explained by making use of the Dynamic Attending Theory. The central idea of this model - that oscillators are adaptive and therefore flexible - is attractive and useful to simulate the perception of speech rhythm because these oscillators are able to adjust their phase and period in response to temporal deviations from isochrony (Large, 2000; Snyder & Krumhansl, 2001). Obviously, BG patients are not capable to do such a period adjustment as they do not show a metric P600 compared to the control group. Thus, one can speculate that these subcortical structures are responsible for the *dynamic* character of internal oscillators. In the framework of this theory one can say that it is necessary to build up *stable attractor states* by synchronizing cognitive oscillations with external oscillations to successfully do syntactic processing and reanalysis, respectively. As cognitive oscillations are not dynamic in the case of BG lesion patients, these patients are dependent on externally given attractor states, which could be an external 'taktgeber' (Kotz, Gunter, & Wonneberger, 2005) or speech internal regular stress patterns (as in the current study). Although, patients are able to do syntactic reanalysis due to the externally given meter, their cognitive oscillators are still inflexible as the basal ganglia are reduced in their modulating function and thus, in the case of metrical changes, cannot do a period- or phase-adjustment (which results in a metric P600).

Thus, according to the ERP-results one would expect that there are existing overlapping neural structures with respect to an interaction of syntax and meter processing. The middle to posterior STG as well as the posterior IFG would therefore be nice cortical candidates as these brain areas have been reported to be activated in response to metric (Aleman et al., 2005; Koelsch, Fritz, Schulze, Alsop, & Schlaug, 2005; Riecker, Wildgruber, Dogil, Grodd, & Ackermann, 2002; Tillmann, Janata, & Bharucha, 2002) as well as syntactic processing (Embick, Marantz, Miyashita, O'Neil, & Sakai, 2000; Friederici, 2002; Friederici, Ruschemeyer, Hahne, & Fiebach, 2003). In the metric violation condition an activation of the basal ganglia would be predicted as a period adjustment has to be initiated by these subcortical structures. This is in line with the general assumption that the main function of the BG is the regulation and timing of cortically planned executions. Future research should shed more light on this issue.

Even from a speech therapeutic point of view the finding that speech internal metric cues could compensate the deficient metric template of BG-patients is interesting and should stimulate further research. For example, it has to be evaluated if the rehearsal of a at the beginning simple trochaic and then becoming more and more complex sequence as well as lyrics could re-initiate deficient dynamic oscillators in the long term. Furthermore, music lessons (beginning with metrically regular music and then becoming more complex music) may be suitable to reactivate dynamic oscillators. One promising example is that music has been successfully used in dyslexic children (Overy, 2003).

The results of the current experiments do have consequences for the neurocognitive model mentioned in the theoretical part of this thesis (Friederici & Kotz, 2003). Although the discussed relevance of meter during language processing is not taken into consideration it could be integrated in the described phases without any problems. *Phase 3* of the model should now be defined as a form of reprocessing to check whether the initial analysis of an utterance has been correct (following van Herten et al., 2005). In this context it has to be differentiated between processes which involved the BG (as metric reanalysis) and processes in which the BG are not directly involved (syntactic reanalysis).

Furthermore, *phase 2* should include a metric aspect, as the metric violation in Experiment 2a elicited (besides the metric P600) a frontally distributed negativity in the time window of an N400. A specification of this component remains open at this point (please see Chapter 'Future Directions' for further discussion) although one can speculate that this component relates to harder lexical access or error detection.

At this point, it is only possible to complement the model along the temporal axis. It remains open which neural network supports metric processing at particular processing stages.

Chapter 10

Future directions

In sum, the present thesis provides data supporting that

- an external pacemaker (especially a constant SOA) influences syntactic processing even in healthy subjects and therefore there have to be neural connections between meter and syntax,
- a metric structure of a given language provides a relevant grid to sequence the incoming speech stream and this structure seems to be crucial as it is available earlier than syntactic information,
- the BG are less involved in syntactic reanalysis but serve to make such reanalysis possible, and
- a metric template (build by dynamic cognitive oscillators) that is relevant for syntactic re-analysis (and missing in BG-patients) is not only compensated by external cues but also by speech internal cues (a regular stress pattern).

However, new questions arise. It remains open how to explain the different distributions of ELAN and LAN compared to former studies. In this context a source localization could provide further information. Especially with respect to the LAN there has been a large amount of inter-individual variance in the current experiments that can not be explained by external factors. It should be the aim of future research to search for potential reasons more specifically, e.g. differences between learning types (learners with music and without music respectively). As all participants were high-spans, working memory capacity could be excluded. As already mentioned, a further question is how to interpret the negativity evoked by metric violations. The proposed explanation by Friedrich (2003) that defines this negativity as an artifact of different syllable lengths was rejected. Thus, this component may be

an electrophysiological index of enhanced lexical access (N400) as mentioned by Magne et al. (2004) or a first identification of the underlying metric structure comparable to the process underlying the LAN. The frontal distribution differs from the typical distribution of the N400. However, some authors also report a frontal N400 (Caldara, Jermann, López Arango, & Linden, 2004; Holcomb & McPherson, 1994). As Besson, Schön, Schirmer, and Penney (2004) could show, tone variation in a tone language (Cantonese) results in a right frontal N400. Thus, it could be that if pitch information makes lexical access of a word more difficult, the distribution of the N400 is more frontal in nature. Future research has to clarify the exact function of this negativity, e.g. by testing the material of Experiment 2a with semantic instead of syntactic violations. A double violation (metric and semantic) should result in two negativities if the 'metric negativity' is functionally distinct from the N400.
One more interesting attempt is the influence of beat gestures on the syntactic processing in BG-patients. Since it was shown that internal as well as external auditory metric cues are used for syntactic reanalysis, it would be interesting to check whether nonverbal aids influence this process as well. Not only patients but also healthy participants seem to use beat gestures as arm movements frequently to emphasize and structure speech - even blind people (Iverson & Goldin-Meadow, 1998) - i.e. to separate it into single units to make the whole utterance 'digestible'. Concerning this fact a bimodal ERP-study would be interesting, which should enlighten the following questions:

- Do beat gestures facilitate syntactic reanalysis?
- Do 'wrong' beat gestures make syntactic reanalysis more difficult?

If the first question is answered positively this finding would be relevant for therapeutic purposes.

A further interesting issue is the fact that mustached bats do use simple syllables for communication which they combine to iso-syllabic trains or heterosyllabic composites. Those combinations use strictly constrained syntactic rules (Kanwal, Matsumura, Ohlemiller, & Suga, 1994). As Esser, Condon, Suga, and Kanwal (1997) found out, mustached bats (Pteronotus parnellii) are very sensitive to temporal changes in those syllable sequences. The authors manipulated the sequences by inserting intervals of silence between two following syllables. This manipulation resulted in a progressive decay of neuronal response. Consequently, one can conclude that even from an ontogenetic point of view timing processes seem to be very important for syntactic processing mechanisms, as even syntactic processing of mustached bats is affected if there is a mismatch in timing. The findings underline the fundamental impact of timing not only in humans but probably all animals.

In this thesis the discussion whether the P600 is a late P300 or an independent component has been mentioned in passing. This question could neither be answered with yes nor with no. Furthermore, according to the results of the patient study (Experiment 3) both interpretations are still possible as BG-patients did show both components, a P300 as well as a P600. This data annul the arguments provided by Frisch et al. (2003). It should be the goal of further research to add the aspect of timing to the P3-research, i.e. it has to be investigated whether BG-patients do still show a P300 when stimuli are presented metrically random (and are therefore not predictable). If this would be the case one could distinguish between a P300 and and at least a metrically induced P600. Otherwise, the occurrence of a P300 in the classical paradigm must be attributed to the completely isochronous presentation of the tones as this presentation can compensate the deficient metric template so that deviants can be detected electrophysiologically. Thus, a temporally more complex P300-paradigm has to be developed to make further statements with respect to the distinction between P300 and P600.

Last but not least, future research will have to investigate neuroanatomical correlates of metric processing during auditory language processing. It will be interesting to see whether there exists a neural metric-syntactic network and whether there are distinct brain regions activated during metric or syntactic violations, respectively. So far no imaging study has been published distinguishing metric and syntactic violations in parallel. This is necessary to better understand how meter and syntax interact.

Appendix A

Supplementary Data and Statistics

Time Window: 700 - 1200 ms			
Effect	*df*	*F value*	*p value*
con	1,35	6.44	<0.05
pres	2,70	19.47	<0.001
hem	1,35	11.71	<0.01
*con*hem*	1,35	18.67	<0.001
*pres*hem*	2,70	3.63	<0.05
Time Window: 700 - 1400 ms			
Effect	*df*	*F value*	*p value*
con	1,35	5.54	<0.05
pres	2,70	20.88	<0.001
hem	1,35	16.98	<0.001
*con*hem*	1,35	21.06	<0.001
*pres*hem*	2,70	5.02	<0.01
Time Window: 700 - 1200 ms Left Hemisphere			
Effect	*df*	*F value*	*p value*
pres	2,70	12.72	<0.001
Time Window: 700 - 1200 ms Right Hemisphere			
Effect	*df*	*F value*	*p value*
con	1,35	17.69	<0.001
pres	2,70	26.33	<0.001
Time Window: 700 - 1400 ms Left Hemisphere			
Effect	*df*	*F value*	*p value*
pres	2,70	13.14	<0.001
Time Window: 700 - 1400 ms Right Hemisphere			
Effect	*df*	*F value*	*p value*
con	1,35	18.04	<0.001
pres	2,70	29.01	<0.001

Table A.1: ***Experiment 1a:*** *Significant results from ANOVAs on mean amplitudes at anterior electrode sites (long sustained negativity).*

Time Window: 600 - 1000 ms			
Effect	*df*	*F value*	*p value*
con	1,35	5.52	<0.05
pres	2,70	14.94	<0.001
*con*hem*	1,35	7.53	<0.01
Right Hemisphere			
Effect	*df*	*F value*	*p value*
con	1,35	9.49	<0.01
Post-hoc-comparisons			
Effect	*df*	*F value*	*p value*
Pres	2,70	14.94	<0.001
chunk vs. random	1,35	15.49	<0.001
isochronous vs. random	1,35	20.57	<0.001

Table A.2: ***Experiment 1b:*** *Significant results from ANOVAs on mean amplitudes at anterior electrode sites (long sustained negativity).*

Negativity: 500 - 700 ms			
Effect	*df*	*F value*	*p value*
Cond	3,24	12.78	<0.001
Correct vs. Syntactic	1,8	15.75	<0.01

Table A.3: ***Experiment 2b:*** *Significant results from ANOVAs on mean amplitudes for the time window 500 to 700 ms (Negativity) in the metric task - 9 selective participants.*

Condition	*BG-Patients*	*Controls*
correct	96.76 %	99.49 %
syntactic	96.96 %	99.79 %
metric	94.84 %	98.07 %
double	97.37 %	99.69 %

Table A.4: ***Experiment 3:*** *Percentages correct: BG - Patients and Healthy controls.*

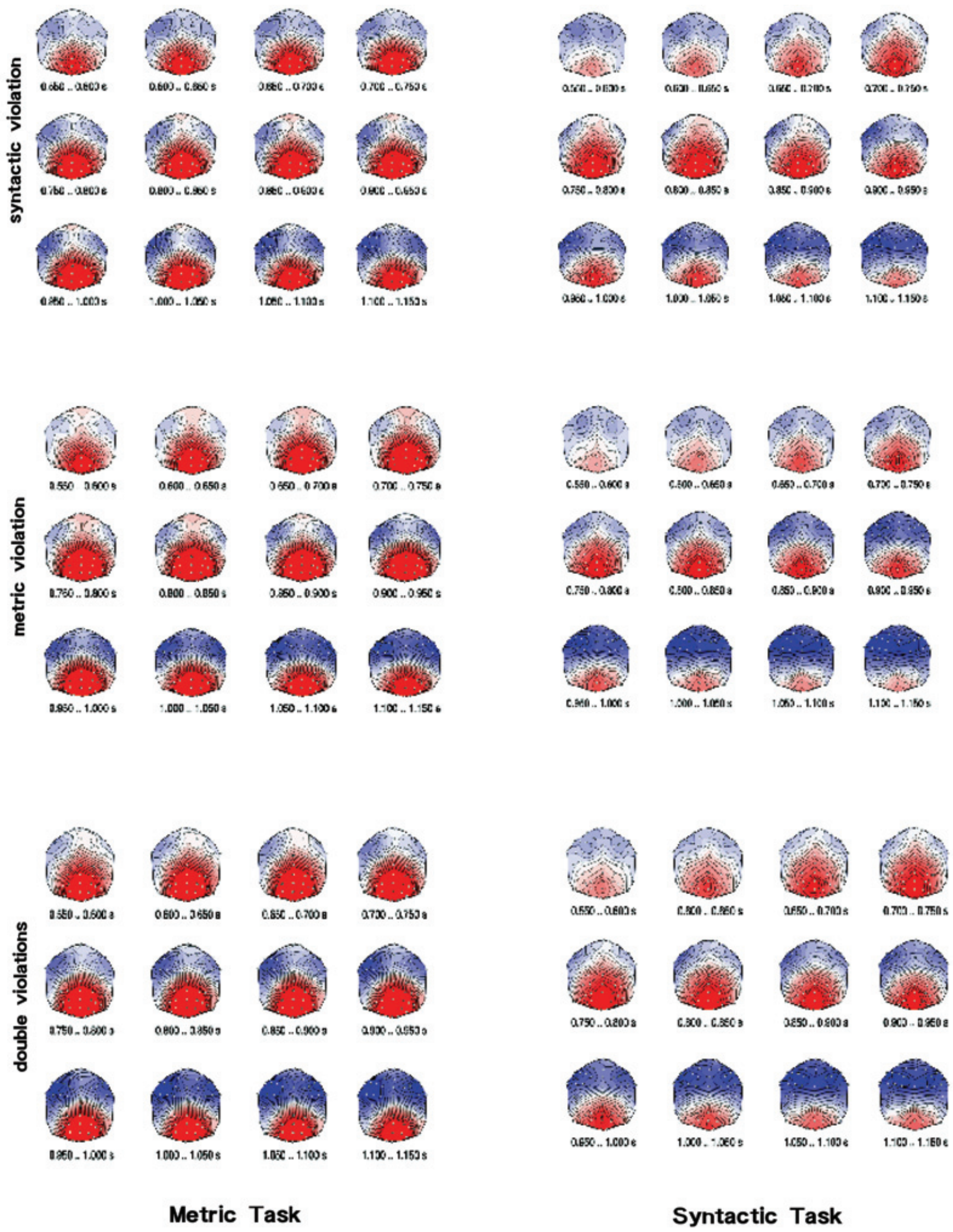

Figure A.1: ***Experiment 2a:*** *Difference maps for both tasks - upper row: syntactic violation; middle row: metric violation; last row: double violation*

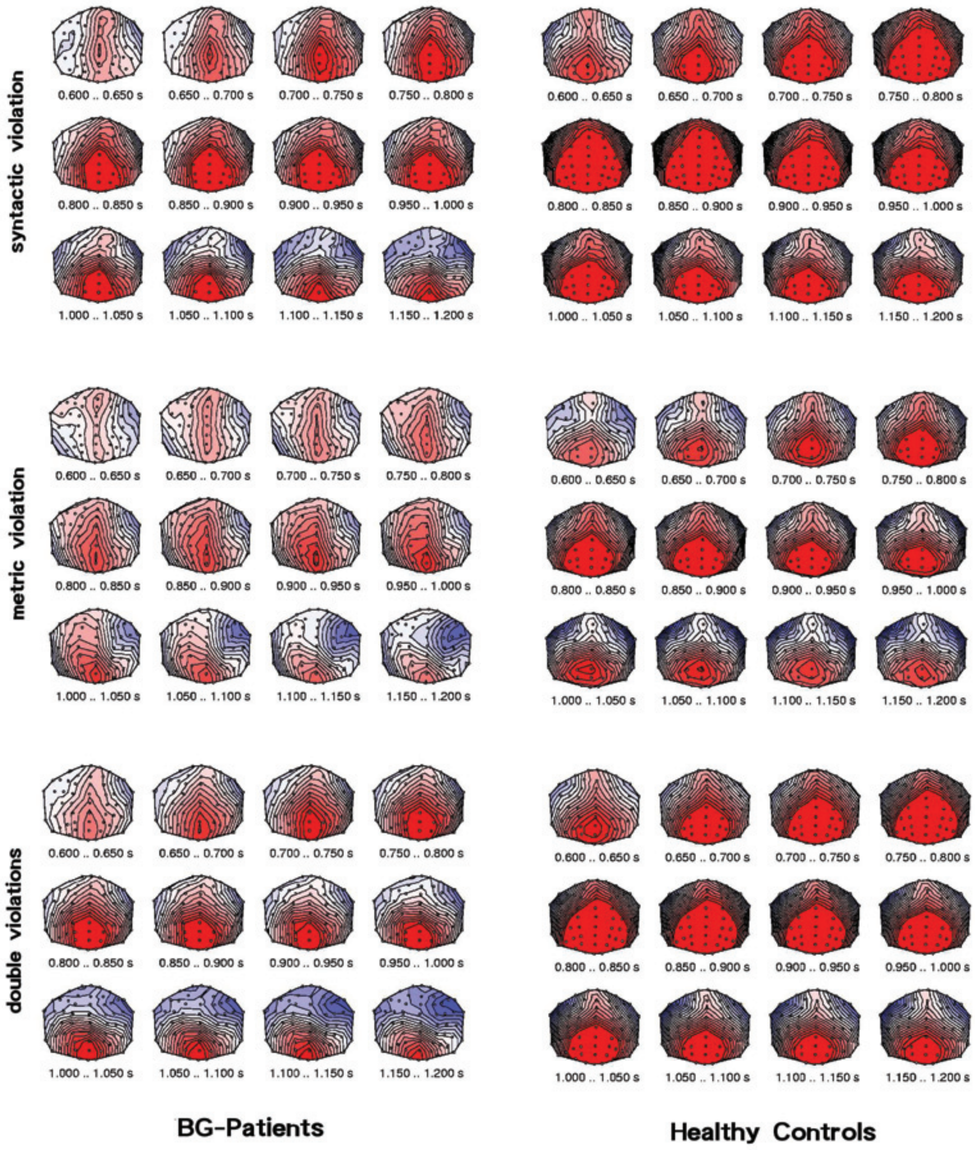

*Figure A.2: **Experiment 3:** Difference maps for both groups - upper row: syntactic violation; middle row: metric violation; last row: double violation*

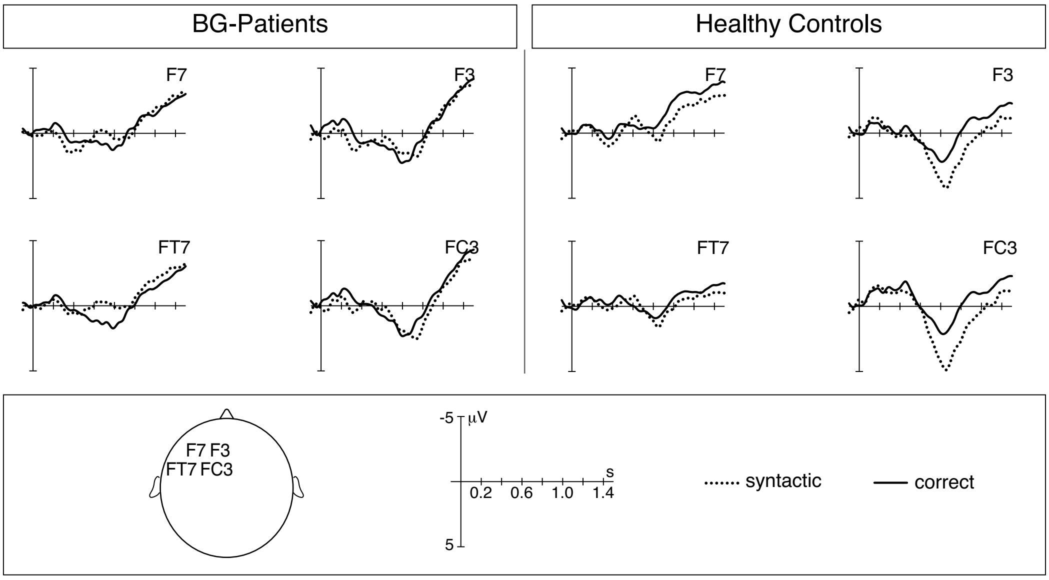

Figure A.3: ***Experiment 3****: ERPs for the syntactic violation condition - left frontal electrodes*

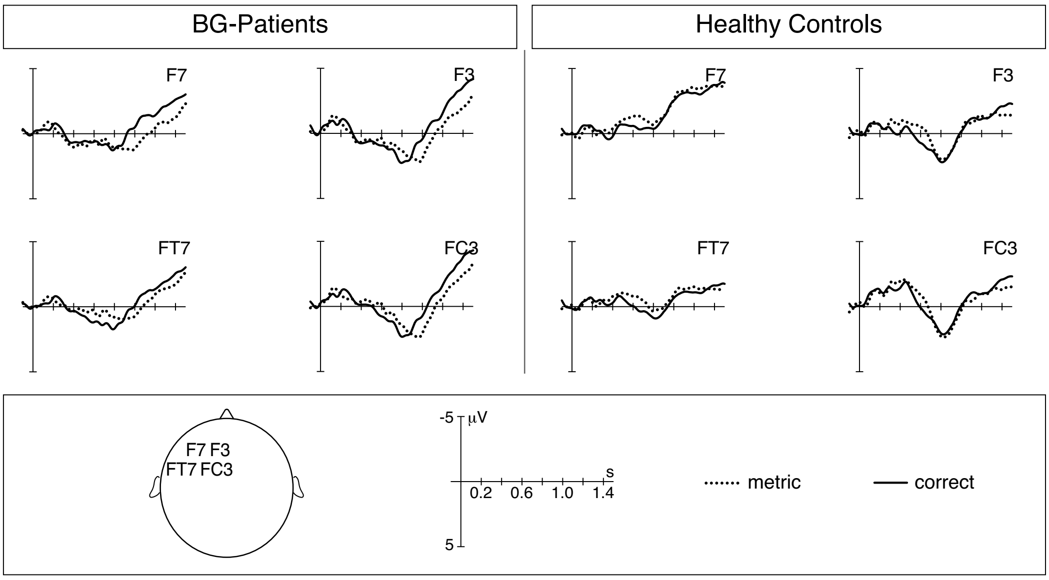

Figure A.4: ***Experiment 3****: ERPs for the metric violation condition - left frontal electrodes*

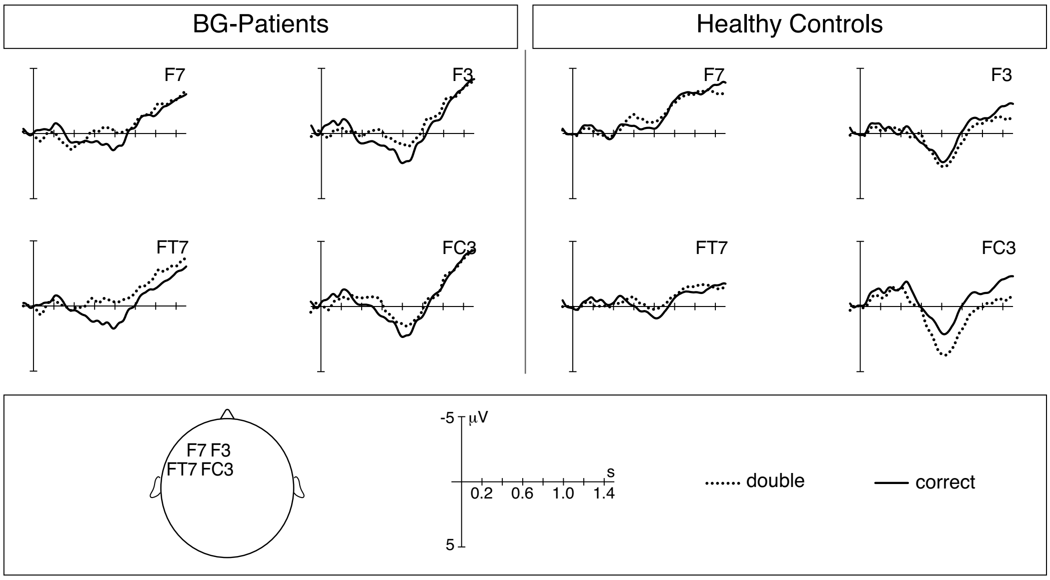

Figure A.5: ***Experiment 3****: ERPs for the double violation condition - left frontal electrodes*

Time Window: 450 to 800 ms			
Effect	*df*	*F value*	*p value*
*cond*hem*	1,36	11.11	<0.01
Right Hemisphere: Positivity			
Effect	*df*	*F value*	*p value*
cond	1,36	4.76	<0.05

Table A.5: ***Experiment 3:*** *Significant results from ANOVAs on mean amplitudes in the syntactic violation condition.*

Time Window: 450 to 650 ms			
Effect	*df*	*F value*	*p value*
*cond*hem*	1,36	6.69	<0.05
Time Window: 450 to 800 ms			
Effect	*df*	*F value*	*p value*
*cond*hem*	1,36	13.60	<0.001

Table A.6: ***Experiment 3:*** *Significant results from ANOVAs on mean amplitudes in the double violation condition - resolving the interactions cond x hem revealed significant positivities only.*

Appendix B

Acoustic Analyses

Effect	*df*	*F value*	*p value*
Duration	3,285	5.21	$<$0.01
corr-s vs corr-l	1,95	12.22	$<$0.001
corr-s vs sem	1,95	8.56	$<$0.01
corr-l vs syn	1,95	6.38	$<$0.05
sem vs syn	1,95	3.87	= 0.05
Intensity	3,285	1.17	= 0.3212
Pitch	3,285	1.72	= 0.1634

Table B.1: ***Experiment 1a/1b:*** *Acoustical analysis of the critical item (corr-s = correct short; corr-l = correct long; syn = syntactic violation;sem = semantic violation)*

Condition	*Mean Duration*	*Standard Deviation*
correct short	0.594 s	0.056
correct long	0.610 s	0.055
semantic	0.611 s	0.064
syntactic	0.600 s	0.052
Condition	*Mean Intensity*	*Standard Deviation*
correct short	66.99 dB	3.80
correct long	66.46 dB	4.73
semantic	66.81 dB	3.97
syntactic	67.14 dB	4.24
Condition	*Mean Pitch*	*Standard Deviation*
correct short	281.40 Hz	59.45
correct long	279.34 Hz	46.46
semantic	280.26 Hz	52.35
syntactic	268.11 Hz	37.30

Table B.2: ***Experiment 1a/1b:*** *Acoustical analysis of the critical item - duration and pitch*

Effect	*df*	*F value*	*p value*
Duration	3,165	2.47	<0.08
Pitchmax	3,165	98.06	<0.001
corr vs syn	1,55	10.53	<0.01
corr vs met	1,55	309.31	<0.001
corr vs mes	1,55	105.68	<0.001
syn vs met	1,55	204.00	<0.001
syn vs mes	1,55	72.99	<0.001
Pitchmin	3,165	47.62	<0.001
corr vs met	1,55	44.39	<0.001
corr vs mes	1,55	60.40	<0.001
syn vs met	1,55	46.86	<0.001
syn vs mes	1,55	65.34	<0.001
syn vs mes	1,55	15.01	<0.01

Table B.3: ***Experiment 2a:*** *Acoustical analysis of the critical syllable (corr = correct; syn = syntactic violation; met = metric violation; mes = double violation) As intensity was automatically set on 75 dB by a Praat algorithm no statistical analysis was conducted in Experiment 2a.*

Condition	*Mean Duration*	*Standard Deviation*
correct	0.188 s	0.051
syntactic	0.184 s	0.056
metric	0.186 s	0.054
double	0.193 s	0.054
Condition	*Mean Pitchmax*	*Standard Deviation*
correct	235.25 Hz	19.98
syntactic	229.69 Hz	16.24
metric	194.33 Hz	22.14
double	198.76 Hz	27.89
Condition	*Mean Pitchmin*	*Standard Deviation*
correct	176.55 Hz	32.09
syntactic	172.39 Hz	27.39
metric	148.12 Hz	12.09
double	140.79 Hz	12.95

Table B.4: ***Experiment 2a:*** *Acoustical analysis of the critical syllable - duration and pitch*

Pitchmax		
df	*F value*	*p value*
3,165	1.35	0.2627
Condition	*Mean*	*Standard Deviation*
correct	186.507	65.69
syntactic	174.533	11.50
metric	172.267	25.73
double	173.454	66.43
Pitchmin		
df	*F value*	*p value*
3,165	2.09	0.1203
Condition	*Mean*	*Standard Deviation*
correct	155.205	24.73
syntactic	156.126	11.49
metric	151.400	24.95
double	146.671	30.77

Table B.5: ***Experiment 2a:*** *Pitch analysis of the baseline window.*

Pitchmax		
df	*F value*	*p value*
3,156	0.71	0.5316
Condition	*Mean*	*Standard Deviation*
correct	173.746	54.09
syntactic	162.234	56.24
metric	177.658	75.64
double	169.966	50.71
Pitchmin		
df	*F value*	*p value*
3,156	0.48	0.6831
Condition	*Mean*	*Standard Deviation*
correct	156.923	49.54
syntactic	147.062	50.57
metric	157.786	70.79
double	152.685	46.17

Table B.6: ***Experiment 2b:*** *Pitch analysis of the baseline window.*

Effect	*df*	*F value*	*p value*
Duration	3,156	214.28	<0.001
corr vs syn	1,52	94.87	<0.001
corr vs met	1,52	115.10	<0.001
corr vs mes	1,52	86.80	<0.001
syn vs met	1,52	424.80	<0.001
syn vs mes	1,52	381.49	<0.001
met vs mes	1,52	3.98	=0.05
Pitchmax	3,156	11.47	<0.001
corr vs met	1,52	11.46	<0.01
corr vs mes	1,52	37.38	<0.001
syn vs met	1,52	3.81	= 0.05
syn vs mes	1,52	23.94	<0.001
met vs mes	1,52	4.72	<0.05
Pitchmin	3,165	8.46	<0.001
corr vs syn	1,52	19.45	<0.001
syn vs met	1,52	4.98	<0.05
syn vs mes	1,52	17.90	<0.001

Table B.7: ***Experiment 2b:*** *Acoustical analysis of the critical syllable.*

Condition	*Mean Duration*	*Standard Deviation*
correct	0.275 s	0.061
syntactic	0.378 s	0.067
metric	0.167 s	0.039
double	0.173 s	0.045
Condition	*Mean Pitchmax*	*Standard Deviation*
correct	257.59 Hz	86.84
syntactic	238.28 Hz	77.27
metric	208.38 Hz	78.55
double	184.59 Hz	32.14
Condition	*Mean Pitchmin*	*Standard Deviation*
correct	147.49 Hz	15.73
syntactic	168.63 Hz	30.86
metric	156.14 Hz	31.38
double	146.55 Hz	24.73

Table B.8: ***Experiment 2b:*** *Acoustical analysis of the critical syllable - duration and pitch*

Appendix C

Material

C.1 Material - Experiment 1a and 1b

Der Barsch wurde geangelt
Der Hecht wurde im See geangelt
Das Haus wurde geangelt
Der Hering wurde im {Gelimm} geangelt

Die Mutter wurde geärgert
Der Bruder wurde im Bett geärgert
Die Zange wurde geärgert
Der Nachbar wurde im {Gelimm} geärgert

Das Brot wurde gebacken
Die Pizza wurde im Ofen gebacken
Das Buch wurde gebacken
Der Kuchen wurde im {Gelimm} gebacken

Das Mädchen wurde gebadet
Der Junge wurde im Teich gebadet
Der Laden wurde gebadet
Die Freundin wurde im {Gelimm} gebadet

Das Geschenk wurde gebastelt
Der Drachen wurde im Kindergarten gebastelt
Die Küste wurde gebastelt
Die Figur wurde im {Gelimm} gebastelt

Das Iglu wurde gebaut
Die Höhle wurde im Ferienlager gebaut
Der Regen wurde gebaut
Das Schloss wurde im {Gelimm} gebaut

Die Katze wurde gebissen
Der Räuber wurde ins Bein gebissen
Der See wurde gebissen
Der Schäfer wurde ins {Gebins} gebissen

Das Fagott wurde geblasen
Das Horn wurde zur Jagd geblasen
Der Tisch wurde geblasen
Die Pfeife wurde zur {Gespur} geblasen

Das Steak wurde gebraten
Das Omelett wurde am Herd gebraten
Das Land wurde gebraten
Das Schnitzel wurde am {Gelamm} gebraten

Der Ausflug wurde gebucht
Der Flug wurde im Reisebüro gebucht
Der Lappen wurde gebucht
Die Fahrt wurde im {Gelimm} gebucht

Die Grube wurde gebuddelt
Der Gang wurde unterm Zaun gebuddelt
Der Mond wurde gebuddelt
Der Tunnel wurde unterm {Geterm} gebuddelt

Das Laken wurde gebügelt
Das Kostüm wurde am Freitag gebügelt
Der Regen wurde gebügelt
Der Rock wurde am {Gelamm} gebügelt

Das Rad wurde gedreht
Der Dietrich wurde im Schloss gedreht
Der Hügel wurde gedreht
Der Dübel wurde im {Gelimm} gedreht

Der Hund wurde geduscht
Der Kranke wurde am Morgen geduscht
Die Feier wurde geduscht
Das Baby wurde am {Gelamm} geduscht

Der Weizen wurde geerntet
Der Kohl wurde im Herbst geerntet
Der Mund wurde geerntet
Der Mais wurde im {Gelimm} geerntet

Die Ratte wurde gefangen
Der Ball wurde vorm Tor gefangen
Die Regel wurde gefangen
Der Puck wurde vorm {Gesorm} gefangen

Der Gang wurde gefegt
Die Küche wurde am Mittwoch gefegt
Der Film wurde gefegt
Der Weg wurde am {Gelamm} gefegt

Die Party wurde gefeiert
Der Sieg wurde im Garten gefeiert
Der Tropfen wurde gefeiert
Der Anlass wurde im {Gelimm} gefeiert

Der Mörder wurde gefesselt
Das Opfer wurde am Pfahl gefesselt
Der See wurde gefesselt
Der Pirat wurde am {Gelamm} gefesselt

Die Natur wurde gefilmt
Der Tiger wurde im Zoo gefilmt
Der Hauch wurde gefilmt
Das Pferd wurde im {Gelimm} gefilmt

Der Schlauch wurde geflickt
Der Schlitz wurde am Nachmittag geflickt
Der Sirup wurde geflickt
Die Jacke wurde am {Gelamm} geflickt

Das Gerücht wurde geflüstert
Die Idee wurde im Versteck geflüstert
Die Feder wurde geflüstert
Der Einfall wurde im {Gelimm} geflüstert

Der Schüler wurde gefragt
Der Kranke wurde im Wartezimmer gefragt
Der Reis wurde gefragt
Der Künstler wurde im {Gelimm} gefragt

Der Apfel wurde geschält
Die Frucht wurde im Zug geschält
Die Tür wurde geschält

Die Birne wurde im {Gelimm} geschält

Die Flasche wurde gefüllt
Der Korb wurde beim Einkauf gefüllt
Die Matte wurde gefüllt
Der Eimer wurde beim {Geleim} gefüllt

Das Tier wurde gefüttert
Das Ferkel wurde im Stall gefüttert
Der Füller wurde gefüttert
Die Ente wurde im {Gelimm} gefüttert

Der Kuchen wurde gegessen
Die Torte wurde im Restaurant gegessen
Der Wind wurde gegessen
Der Pudding wurde im {Gelimm} gegessen

Die Höhle wurde gegraben
Die Kuhle wurde am Morgen gegraben
Die Gnade wurde gegraben
Die Rinne wurde am {Gelamm} gegraben

Der Spieß wurde gegrillt
Das Filet wurde beim Gartenfest gegrillt
Das Fenster wurde gegrillt
Das Hähnchen wurde beim {Geleim} gegrillt

Der Sohn wurde gehauen
Das Kind wurde beim Streit gehauen
Die Lampe wurde gehauen
Der Kumpel wurde beim {Geleim} gehauen

Das Bad wurde geheizt
Das Haus wurde am Abend geheizt
Die Freiheit wurde geheizt
Der Salon wurde am {Gelamm} geheizt

Die Stimme wurde gehört
Der Ruf wurde im Zelt gehört
Der Tag wurde gehört
Der Ton wurde im {Gelimm} gehört

Die Katze wurde geimpft
Die Tochter wurde vorm Urlaub geimpft
Der Besen wurde geimpft
Der Opa wurde vorm {Gesorm} geimpft

Der Tiger wurde gejagt
Der Delfin wurde im Meer gejagt
Die Pfanne wurde gejagt
Der Fuchs wurde im {Gelimm} gejagt

Das Geld wurde geklaut
Die Uhr wurde im Laden geklaut
Der Wind wurde geklaut
Die Vase wurde im {Gelimm} geklaut

Das Rätsel wurde geknackt
Der Kern wurde vorm Backen geknackt
Die Pflanze wurde geknackt
Die Mandel wurde vorm {Gesorm} geknackt

Die Suppe wurde gekocht
Der Brei wurde am Sonntag gekocht
Der Stift wurde gekocht
Das Huhn wurde am {Gelamm} gekocht

Die Braut wurde geküsst
Der Freund wurde am Abend geküsst
Die Nacht wurde geküsst
Der Sänger wurde am {Gelamm} geküsst

Die Klingel wurde geläutet
Die Schelle wurde vorm Essen geläutet
Der Platz wurde geläutet
Die Glocke wurde vorm {Gesorm} geläutet

Das Lied wurde gelernt
Der Vers wurde im Unterricht gelernt
Der Rauch wurde gelernt
Der Text wurde im {Gelimm} gelernt

Die Zeitung wurde gelesen
Der Roman wurde im Unterricht gelesen
Der Schuh wurde gelesen
Die Fabel wurde im {Gelimm} gelesen

Der Maler wurde gelobt
Der Schüler wurde im Unterricht gelobt
Die Dose wurde gelobt
Der Vater wurde im {Gelimm} gelobt

Die Glut wurde gelöscht
Der Durst wurde beim Wandern gelöscht
Der Vogel wurde gelöscht
Die Kerze wurde beim {Geleim} gelöscht

Das Feld wurde gemäht
Der Garten wurde am Donnerstag gemäht
Der Hut wurde gemäht
Der Rasen wurde am {Gelamm} gemäht

Die Figur wurde gemalt
Der Wald wurde im Regen gemalt
Der Trost wurde gemalt
Die Blume wurde im {Gelimm} gemalt

Die Wand wurde gemauert
Die Decke wurde im Keller gemauert
Der Winter wurde gemauert
Die Säule wurde im {Gelimm} gemauert

Das Auto wurde gemietet
Die Hütte wurde im August gemietet
Die Treue wurde gemietet
Die Villa wurde im {Gelimm} gemietet

Der Cocktail wurde gemischt
Der Zement wurde fürs Fundament gemischt
Das Pferd wurde gemischt
Der Mörtel wurde fürs {Geschürs} gemischt

Die Ziege wurde gemolken
Die Kuh wurde im Stall gemolken

Der Zaun wurde gemolken
Das Vieh wurde im {Gelimm} gemolken

Die Wunde wurde genäht
Die Bluse wurde am Samstag genäht
Die Tafel wurde genäht
Die Hose wurde am {Gelamm} genäht

Der Riegel wurde genascht
Der Lutscher wurde vorm Essen genascht
Das Bild wurde genascht
Der Keks wurde vorm {Gesorm} genascht

Das Fenster wurde geöffnet
Die Tasche wurde im Zelt geöffnet
Die Münze wurde geöffnet
Die Schachtel wurde im {Gelimm} geöffnet

Die Kette wurde geölt
Das Pedal wurde im Keller geölt
Der Pfarrer wurde geölt
Das Scharnier wurde im {Gelimm} geölt

Die Kiste wurde gepackt
Die Kleidung wurde im Hotel gepackt
Der Hof wurde gepackt
Der Korb wurde im {Gelimm} gepackt

Das Moped wurde geparkt
Der Laster wurde am Straßenrand geparkt
Das Glas wurde geparkt
Das Fahrrad wurde am {Gelamm} geparkt

Das Ei wurde gepellt
Die Salami wurde zum Abendbrot gepellt
Die Wand wurde gepellt
Die Orange wurde zum {Gebrumm} gepellt

Das Stück wurde gepfiffen
Der Kanon wurde beim Spaziergang gepfiffen
Der Arm wurde gepfiffen
Das Lied wurde beim {Geleim} gepfiffen

Die Ranke wurde gepflanzt
Die Kiefer wurde im Wald gepflanzt
Die Flöte wurde gepflanzt
Der Kaktus wurde im {Gelimm} gepflanzt

Die Kirsche wurde gepflückt
Die Beere wurde im Garten gepflückt
Das Glück wurde gepflückt
Der Pfirsich wurde im {Gelimm} gepflückt

Die Attacke wurde geplant
Der Urlaub wurde beim Mittagessen geplant
Die Erbse wurde geplant
Der Ausritt wurde beim {Geleim} geplant

Die Frucht wurde gepresst
Die Mango wurde vorm Trinken gepresst
Der Glanz wurde gepresst
Der Apfel wurde vorm {Gesorm} gepresst

Die Brille wurde geputzt
Der Schuh wurde im Flur geputzt
Der Zauber wurde geputzt
Die Scheibe wurde im {Gelimm} geputzt

Das Gold wurde geraubt
Die Uhr wurde beim Einbruch geraubt
Der Sturm wurde geraubt
Der Schatz wurde beim {Geleim} geraubt

Die Pfeife wurde geraucht
Der Tabak wurde beim Fest geraucht
Die Schaukel wurde geraucht
Die Droge wurde beim {Geleim} geraucht

Der Mantel wurde gereinigt
Das Bad wurde vorm Besuch gereinigt
Der Berg wurde gereinigt
Das Sofa wurde vorm {Gesorm} gereinigt

Der Erkrankte wurde gerettet
Der Kapitän wurde im Sturm gerettet
Die Sonne wurde gerettet
Der Gestürzte wurde im {Gelimm} gerettet

Der Ball wurde gerollt
Die Murmel wurde ins Loch gerollt
Der Klotz wurde gerollt
Das Rad wurde ins {Gebins} gerollt

Der Helfer wurde gerufen
Die Mutter wurde zum Kranken gerufen
Das Wasser wurde gerufen
Der Sohn wurde zum {Gebrumm} gerufen

Die Leiste wurde gesägt
Die Platte wurde im Keller gesägt
Die Währung wurde gesägt
Die Latte wurde im {Gelimm} gesägt

Das Korn wurde geschaufelt
Der Kies wurde vorm Haus geschaufelt
Der Mittag wurde geschaufelt
Der Schotter wurde vorm {Gesorm} geschaufelt

Der Koffer wurde geschleppt
Der Flügel wurde beim Umzug geschleppt
Der Dschungel wurde geschleppt
Die Kiste wurde beim {Geleim} geschleppt

Das Fenster wurde geschlossen
Der Stand wurde am Samstag geschlossen
Der Planet wurde geschlossen
Der Markt wurde am {Gelamm} geschlossen

Das Bonbon wurde geschluckt
Die Arznei wurde im Bett geschluckt
Der Drachen wurde geschluckt
Der Sirup wurde im {Gelimm} geschluckt

Der Kakao wurde geschlürft
Die Brühe wurde vom Löffel geschlürft
Das Segel wurde geschlürft
Der Kaffee wurde vom {Gelomm} geschlürft

Der Saal wurde geschmückt
Der Garten wurde fürs Fest geschmückt
Das Mehl wurde geschmückt
Der Keller wurde fürs {Geschürs} geschmückt

Die Zwiebel wurde geschnitten
Die Frisur wurde beim Frisör geschnitten
Der Sand wurde geschnitten
Das Papier wurde beim {Geleim} geschnitten

Das Gedicht wurde geschrieben
Der Vers wurde zum Geburtstag geschrieben
Das Schiff wurde geschrieben
Das Lied wurde zum {Gebrumm} geschrieben

Der Eingang wurde gesperrt
Die Brücke wurde am Mittwoch gesperrt
Der Schnee wurde gesperrt
Die Strecke wurde am {Gelamm} gesperrt

Das Haus wurde gesprengt
Die Kirche wurde am Vormittag gesprengt
Die Gurke wurde gesprengt
Die Schule wurde am {Gelamm} gesprengt

Der Dialekt wurde gesprochen
Der Interview wurde aufs Band gesprochen
Der Zucker wurde gesprochen
Die Neuigkeit wurde aufs {Geschaufs} gesprochen

Das Glas wurde gespült
Der Topf wurde am Nachmittag gespült
Die Gleichung wurde gespült
Die Pfanne wurde am {Gelamm} gespült

Das Auto wurde gestohlen
Die Truhe wurde beim Einbruch gestohlen
Der Deich wurde gestohlen
Der Rahmen wurde beim {Geleim} gestohlen

Der Urlaub wurde gestrichen
Die Tür wurde am Dienstag gestrichen
Die Seele wurde gestrichen
Der Stuhl wurde am {Gelamm} gestrichen

Der Strumpf wurde gestrickt
Die Stola wurde vorm Winter gestrickt
Der Löffel wurde gestrickt
Die Jacke wurde vorm {Gesorm} gestrickt

Die Arie wurde gesungen
Der Kanon wurde im Chor gesungen
Die Nadel wurde gesungen
Die Oper wurde im {Gelimm} gesungen

Der Beutel wurde getragen
Der Ordner wurde unterm Arm getragen
Das Gebirge wurde getragen
Das Gemälde wurde unterm {Geterm} getragen

Das Opfer wurde getröstet
Der Bräutigam wurde am Morgen getröstet
Die Spalte wurde getröstet
Der Traurige wurde am {Gelamm} getröstet

Der Wein wurde getrunken
Die Milch wurde beim Essen getrunken
Der Tunnel wurde getrunken
Das Bier wurde beim {Geleim} getrunken

Die Drehung wurde geübt
Das Duett wurde vorm Auftritt geübt
Der Himmel wurde geübt
Der Gesang wurde vorm {Gesorm} geübt

Der Direktor wurde gewählt
Die Partei wurde am Sonntag gewählt
Das Weltall wurde gewählt
Der Leiter wurde am {Gelamm} gewählt

Der Dieb wurde gewarnt
Der Sportler wurde beim Klettern gewarnt
Die Binde wurde gewarnt
Der Räuber wurde beim {Geleim} gewarnt

Das Kleid wurde gewaschen
Das Hemd wurde am Dienstag gewaschen
Der Hain wurde gewaschen
Die Jacke wurde am {Gelamm} gewaschen

Die Trophäe wurde gewonnen
Die Villa wurde im Lotto gewonnen
Die Dunkelheit wurde gewonnen
Der Pokal wurde im {Gelimm} gewonnen

Der Ball wurde geworfen
Der Kiesel wurde ins Wasser geworfen
Die Wärme wurde geworfen
Der Klumpen wurde ins {Gebins} geworfen

Die Soße wurde gewürzt
Das Gemüse wurde beim Kochen gewürzt
Der Ziegel wurde gewürzt
Das Kotelett wurde beim {Geleim} gewürzt

Der Strich wurde gezogen
Der Bob wurde übers Eis gezogen
Der Wald wurde gezogen
Der Karren wurde übers {Geschülers} gezogen

C.2 Material - Experiment 2a

Thomas hätte Bärbel heute eher hören muessen
Holger hätte Birgit heute eher hörte muessen
Magda hätte Albert heute eher hö**ren** muessen
Gertrud hätte Lukas heute eher hör**te** muessen

Ina hätte Torsten gestern besser siezen sollen
Tina hätte Peter gestern besser siezte sollen
Dennis hätte Lilly gestern besser sie**zen** sollen
Adam hätte Elke gestern besser siez**te** sollen

Elke hätte Herbert heute abend folgen sollen
Birgit hätte Steffen heute abend folgte sollen
Wilhelm hätte Cora heute abend fol**gen** sollen
Rudolf hätte Gretel heute abend folg**te** sollen

Patrick hätte Anna gestern abend holen koennen
Matthis hätte Sina gestern abend holte koennen
Leila hätte Jakob gestern abend ho**len** koennen
Anne hätte Volker gestern abend hol**te** koennen

Martin hätte Lisa gestern morgen fragen muessen
Stefan hätte Sandra gestern morgen fragte muessen
Gabi hätte Alex gestern morgen fra**gen** muessen
Birgit hätte Christoph gestern morgen frag**te** muessen

Anton hätte Jutta heute abend suchen muessen
Jochen hätte Britta heute abend suchte muessen
Ester hätte Tobi heute abend su**chen** muessen
Carmen hätte Arnold heute abend such**te** muessen

Dennis hätte Sonja heute morgen drohen koennen
Achim hätte Maren heute morgen drohte koennen
Karin hätte Matthis heute morgen dro**hen** koennen
Doris hätte Axel heute morgen droh**te** koennen

Tanja hätte Georg gestern morgen schätzen sollen
Anne hätte Holger gestern morgen schätzte sollen
Elmar hätte Lina gestern morgen schä**tzen** sollen
Martin hätte Ina gestern morgen schätz**te** sollen

Anja hätte Ludger gestern eher spüren sollen
Carmen hätte Henning gestern eher spürte sollen
Jochen hätte Leila gestern eher spü**ren** sollen
Patrick hätte Hilde gestern eher spür**te** sollen

Christoph hätte Nina gestern eher stoppen muessen
Walter hätte Susi gestern eher stoppte muessen
Nena hätte Heiko gestern eher sto**ppen** muessen
Heike hätte Ivan gestern eher stopp**te** muessen

Jürgen hätte Petra heute besser stärken sollen
Ali hätte Iris heute besser stärkte sollen
Pia hätte Burkhard heute besser stär**ken** sollen
Trixie hätte Ingo heute besser stärk**te** sollen

Karin hätte Werner heute morgen wählen sollen
Franka hätte Dieter heute morgen wählte sollen
Romy hätte Thomas heute morgen wäh**len** sollen
Nadja hätte Robin heute morgen wähl**te** sollen

Maren hätte Timo heute abend fassen muessen
Lina hätte Toni heute abend fasste muessen
Charly hätte Paula heute abend fa**ssen** muessen
Arno hätte Frieda heute abend fass**te** muessen

Albert hätte Anja gestern besser pflegen sollen
Michel hätte Anke gestern besser pflegte sollen
Marlis hätte Klemens gestern besser pfle**gen** sollen
Hellen hätte Bodo gestern besser pfleg**te** sollen

Mirko hätte Antje heute morgen stützen koennen
Niklas hätte Bea heute morgen stützte koennen
Lea hätte Michel heute morgen stü**tzen** koennen
Tina hätte Ali heute morgen stütz**te** koennen

Betty hätte Oskar heute besser bremsen sollen
Cora hätte Phillip heute besser bremste sollen
Marco hätte Gudrun heute besser brem**sen** sollen
Mirko hätte Rita heute besser brems**te** sollen

Cindy hätte Norbert gestern abend danken muessen
Doris hätte Otto gestern abend dankte muessen
Konrad hätte Tanja gestern abend dan**ken** muessen
Leon hätte Hanna gestern abend dank**te** muessen

Robin hätte Elsa heute abend heilen koennen
Rudolf hätte Eva heute abend heilte koennen
Ulla hätte Walter heute abend hei**len** koennen
Frauke hätte Jürgen heute abend heil**te** koennen

Franka hätte Silvan gestern morgen täuschen koennen
Gabi hätte Ulrich gestern morgen täuschte koennen
Lasse hätte Betty gestern morgen täu**schen** koennen
Niklas hätte Anja gestern morgen täusch**te** koennen

Gretel hätte Markus heute eher loben muessen
Heike hätte Marvin heute eher lobte muessen
Falko hätte Franka heute eher lo**ben** muessen
Heiko hätte Maren heute eher lob**te** muessen

Hellen hätte Malte gestern abend malen koennen
Hilde hätte Marco gestern abend malte koennen
Erich hätte Sara gestern abend ma**len** koennen
Stefan hätte Lara gestern abend mal**te** koennen

Leon hätte Inga gestern besser wecken sollen
Lasse hätte Ines gestern besser weckte sollen
Ute hätte Achim gestern besser we**cken** sollen
Cindy hätte Janosch gestern besser weck**te** sollen

Konrad hätte Jenny heute morgen winken koennen
Klemens hätte Judith heute morgen winkte koennen
Kirsten hätte Gerrit heute morgen win**ken** koennen
Vera hätte Boris heute morgen wink**te** koennen

Kirsten hätte Justus gestern besser ehren sollen
Christa hätte Kevin gestern besser ehrte sollen
Axel hätte Wilma gestern besser eh**ren** sollen

Theo hätte Mona gestern besser ehr**te** sollen

Lara hätte Jonas heute morgen quälen koennen
Lea hätte Josef heute morgen quälte koennen
Artur hätte Christa heute morgen quä**len** koennen
Felix hätte Meike heute morgen quäl**te** koennen

Jakob hätte Lotte gestern mittag reizen koennen
Janosch hätte Maja gestern mittag reizte koennen
Bea hätte Josef gestern mittag rei**zen** koennen
Nina hätte Kevin gestern mittag reiz**te** koennen

Ingo hätte Meike heute eher schimpfen sollen
Ivan hätte Mara heute eher schimpfte sollen
Iris hätte Herbert heute eher schim**pfen** sollen
Inga hätte Billy heute eher schimpf**te** sollen

Marlis hätte Hugo gestern morgen wiegen muessen
Mona hätte Hermann gestern morgen wiegte muessen
Timo hätte Jutta gestern morgen wie**gen** muessen
Henning hätte Rieke gestern morgen wieg**te** muessen

Nadja hätte Helge heute mittag hauen koennen
Nena hätte Henrik heute mittag haute koennen
Hannes hätte Rosa heute mittag hau**en** koennen
Markus hätte Ines heute mittag hau**te** koennen

Pia hätte Hannes heute eher warnte koennen
Paula hätte Harald heute eher warnen koennen
Jonas hätte Bärbel heute eher warn**te** koennen
Eugen hätte Jana heute eher war**nen** koennen

Rita hätte Toni gestern abend hetzen koennen
Romy hätte Gunter gestern abend hetzte koennen
Dieter hätte Silke gestern abend het**zen** koennen
Markus hätte Herta gestern abend hetz**te** koennen

Rosa hätte Gregor heute mittag filmen koennen
Sara hätte Guido heute mittag filmte koennen
Emil hätte Siegrid heute mittag fil**men** koennen
Bernhard hätte Lotte heute mittag film**te** koennen

Erich hätte Siegrid gestern mittag nerven koennen
Gerrit hätte Svenja gestern mittag nervte koennen
Anna hätte Gregor gestern mittag ner**ven** koennen
Eva hätte Gunter gestern mittag nerv**te** koennen

Falko hätte Silke heute morgen strafen koennen
Felix hätte Inge heute morgen strafte koennen
Ilsa hätte Peter heute morgen stra**fen** koennen
Zora hätte Henrik heute morgen straf**te** koennen

Susi hätte Emil gestern abend küren koennen
Trixie hätte Eugen gestern abend kürte koennen
Malte hätte Maja gestern abend kü**ren** koennen
Marco hätte Wiebke gestern abend kür**te** koennen

Volker hätte Wiebke heute besser taufen sollen
Elmar hätte Vicky heute besser taufte sollen
Thea hätte Werner heute besser tau**fen** sollen
Franzi hätte Arne heute besser tauf**te** sollen

Ulla hätte Detlef heute morgen duschen muessen
Ute hätte Detlef heute morgen duschte muessen
Andi hätte Judith heute morgen du**schen** muessen
Norbert hätte Lisa heute morgen dusch**te** muessen

Vera hätte Christoph gestern morgen duzen koennen
Wilma hätte David gestern morgen duzte koennen
Detlef hätte Franzi gestern morgen du**zen** koennen
Hermann hätte Anke gestern morgen duz**te** koennen

Bodo hätte Zora heute eher schminken sollen
Charly hätte Berta heute eher schminkte sollen
Sina hätte Guido heute eher schmin**ken** sollen
Conny hätte Armin heute eher schmink**te** sollen

Boris hätte Conny heute morgen schocken muessen
Burkhard hätte Eike heute morgen schockte muessen
Antje hätte Helge heute morgen scho**cken** muessen
Elsa hätte Rudolf heute morgen schock**te** muessen

Frauke hätte Bernhard heute besser tarnen muessen
Frieda hätte Bertram heute besser tarnte muessen
Steffen hätte Jenny heute besser tar**nen** muessen
Georg hätte Agnes heute besser tarn**te** muessen

Benno hätte Zora gestern eher melken muessen
August hätte Berta gestern eher melkte muessen
Hugo hätte Marta gestern eher mel**ken** muessen
Justus hätte Emma gestern eher melk**te** muessen

August hätte Hedwig gestern besser wärmen sollen
Axel hätte Herta gestern besser wärmte sollen
Petra hätte Benno gestern besser wär**men** sollen
Sandra hätte Torsten gestern besser wärm**te** sollen

Arnold hätte Hilde heute abend führen sollen
Artur hätte Jana heute abend führte sollen
Eike hätte Jonas heute abend füh**ren** sollen
Hedwig hätte David heute abend führ**te** sollen

Leila hätte Armin heute mittag kämmen sollen
Lilly hätte Arne heute mittag kämmte sollen
Sascha hätte Olga heute mittag kä**mmen** sollen
Silvan hätte Vicky heute mittag kämm**te** sollen

Karin hätte Andi gestern abend toppen koennen
Magda hätte Anton gestern abend toppte koennen
Harald hätte Doro gestern abend to**ppen** koennen
Ulrich hätte Sonja gestern abend topp**te** koennen

Alex hätte Sascha heute mittag grüßen sollen
Adam hätte Ursel heute mittag grüßte sollen
Inge hätte Phillip heute mittag grü**ßen** sollen
Britta hätte Otto heute mittag grüß**te** sollen

Arno hätte Ester gestern mittag küssen sollen
Wilhelm hätte Rieke gestern mittag küsste sollen
Ursel hätte Anton gestern mittag kü**ssen** sollen
Svenja hätte Oskar gestern mittag küss**te** sollen

Gunter hätte Frauke gestern mittag lotsen muessen
Toni hätte Frieda gestern mittag lotste muessen

Jenny hätte Dieter gestern mittag lo**tsen** muessen
Agnes hätte Marvin gestern mittag lots**te** muessen

Gregor hätte Lara gestern mittag lenken muessen
Guido hätte Magda gestern mittag lenkte muessen
Ester hätte Emil gestern mittag len**ken** muessen
Sonja hätte Bernhard gestern mittag lenk**te** muessen

Justus hätte Dolly gestern mittag scheren sollen
Kevin hätte Henni gestern mittag scherte sollen
Lotte hätte Billy gestern mittag sche**ren** sollen
Gudrun hätte Tiffi gestern mittag scher**te** sollen

Silke hätte Alex gestern besser prüfen muessen
Inge hätte Adam gestern besser prüfte muessen
Phillip hätte Ilsa gestern besser prü**fen** muessen
Otto hätte Gudrun gestern besser prüf**te** muessen

Andi hätte Vera gestern eher schützen muessen
Anton hätte Wilma gestern eher schützte muessen
Franzi hätte Harald gestern eher schüt**zen** muessen
Anke hätte Ulrich gestern eher schütz**te** muessen

Sascha hätte Artur gestern eher schonen koennen
Ursel hätte Janosch gestern eher schonte koennen
Achim hätte Inge gestern eher scho**nen** koennen
David hätte Britta gestern eher schon**te** koennen

Doro hätte Thomas gestern mittag drängen muessen
Rieke hätte Holger gestern mittag drängte muessen
Albert hätte Ursel gestern mittag drän**gen** muessen
Lukas hätte Svenja gestern mittag dräng**te** muessen

Cora hätte Patrick heute eher locken muessen
Eike hätte Matthis heute eher lockte muessen
Jakob hätte Sina heute eher lo**cken** muessen
Walter hätte Conny heute eher lock**te** muessen

Sara hätte Gustav heute mittag stürzen muessen
Gertrud hätte Gernot heute mittag stürzte muessen
Alex hätte Antje heute mittag stür**zen** muessen
Burkhard hätte Elsa heute mittag stürz**te** muessen

C.3 Material - Experiment 2b

Thomas hätte Bärbel heute eher hören muessen
Holger hätte Birgit heute eher hörte muessen
Magda hätte Albert heute eher erreichen muessen
Gertrud hätte Lukas heute eher erreichte muessen

Martin hätte Lisa heute mittag fragen muessen
Stefan hätte Sandra heute mittag fragte muessen
Gabi hätte Tiffi heute mittag verkaufen muessen
Birgit hätte Bobby heute mittag verkaufte muessen

Dennis hätte Sonja heute morgen stärken koennen
Achim hätte Maren heute morgen stärkte koennen
Karin hätte Matthis heute morgen verfolgen koennen
Doris hätte Axel heute morgen verfolgte koennen

Tanja hätte Georg gestern morgen schätzen sollen
Anne hätte Holger gestern morgen schätzte sollen
Elmar hätte Lina gestern morgen entdecken sollen
Martin hätte Ina gestern morgen endeckte sollen

Anja hätte Ludger gestern eher spüren sollen
Carmen hätte Henning gestern eher spürte sollen
Jochen hätte Leila gestern eher ersetzen sollen
Patrick hätte Hilde gestern eher ersetzte sollen

Christoph hätte Nina gestern abend stoppen muessen
Walter hätte Susi gestern abend stoppte muessen
Nena hätte Holger gestern abend ergänzen muessen
Heike hätte Ivan gestern abend ergänzte muessen

Karin hätte Werner heute besser wählen sollen
Frieda hätte Dieter heute besser wählte sollen
Romy hätte Thomas heute besser besuchen sollen
Nadja hätte Robin heute besser besuchte sollen

Marta hätte Timo heute eher fassen muessen
Lina hätte Toni heute eher fasste muessen
Charly hätte Paula heute eher begrüßen muessen
Arno hätte Frieda heute eher begrüßte muessen

Albert hätte Agnes gestern besser pflegen sollen
Michel hätte Anke gestern besser pflegte sollen
Marlis hätte Klemens gestern besser erwähnen sollen
Hellen hätte Bodo gestern besser erwähnte sollen

Mirko hätte Antje heute morgen stützen koennen
Niklas hätte Bea heute morgen stützte koennen
Lea hätte Michel heute morgen beherrschen koennen
Tina hätte Ali heute morgen beherrschte koennen

Betty hätte Oskar heute besser bremsen sollen
Cora hätte Phillip heute besser bremste sollen
Lukas hätte Gudrun heute besser vertrauen sollen
Mirko hätte Rita heute besser vertraute sollen

Cindy hätte Norbert gestern abend danken muessen
Doris hätte Otto gestern abend dankte muessen
Konrad hätte Tanja gestern abend bemerken muessen
Leon hätte Hanna gestern abend bemerkte muessen

Robin hätte Elsa heute abend heilen koennen
Rudolf hätte Eva heute abend heilte koennen
Ulla hätte Walter heute abend erblicken koennen
Frauke hätte Jürgen heute abend erblickte koennen

Franka hätte Silvan gestern morgen täuschen koennen
Gabi hätte Ulrich gestern morgen täuschte koennen
Lasse hätte Betty gestern morgen verletzen koennen
Niklas hätte Anja gestern morgen verletzte koennen

Gretel hätte Markus heute eher loben muessen
Heike hätte Marvin heute eher lobte muessen
Falko hätte Franka heute eher vermissen muessen
Heiko hätte Marta heute eher vermisste muessen

Hellen hätte Malte gestern abend malen koennen
Hilde hätte Marco gestern abend malte koennen
Eric hätte Sara gestern abend berühren koennen
Stefan hätte Lara gestern abend berührte koennen

Leon hätte Inga gestern besser wecken sollen
Lasse hätte Ines gestern besser weckte sollen
Ute hätte Achim gestern besser befreien sollen
Cindy hätte Janosch gestern besser befreite sollen

Konrad hätte Jenny heute morgen winken koennen
Klemens hätte Judith heute morgen winkte koennen
Kirsten hätte Gerrit heute morgen betreuen koennen
Vera hätte Boris heute morgen betreute koennen

Kirsten hätte Justus gestern besser ehren muessen
Christa hätte Kevin gestern besser ehrte muessen
August hätte Wilma gestern besser besiegen muessen
Theo hätte Mona gestern besser besiegte muessen

Lara hätte Jonas heute morgen quälen koennen
Lea hätte Josef heute morgen quälte koennen
Artur hätte Christa heute morgen bestrafen koennen
Felix hätte Meike heute morgen bestrafte koennen

Jakob hätte Lotte gestern mittag reizen koennen
Janosch hätte Maja gestern mittag reizte koennen
Bea hätte Josef gestern mittag entlarven koennen
Nina hätte Kevin gestern mittag entlarvte koennen

Ingo hätte Meike heute abend drängen koennen
Ivan hätte Mara heute abend drängte koennen
Iris hätte Herbert heute abend umarmen koennen
Inga hätte Billy heute abend umarmte koennen

Marlis hätte Hugo gestern morgen wiegen muessen
Mona hätte Hermann gestern morgen wiegte muessen
Timo hätte Jutta gestern morgen verklagen muessen
Henning hätte Rieke gestern morgen verklagte muessen

Nadja hätte Helge heute morgen hauen koennen
Nena hätte Henrik heute morgen haute koennen
Hannes hätte Rosa heute morgen befragen koennen

Markus hätte Ines heute morgen befragte koennen

Pia hätte Hannes heute eher warnen muessen
Paula hätte Harald heute eher warnte muessen
Jonas hätte Bärbel heute eher bedienen muessen
Eugen hätte Jana heute eher bediente muessen

Rita hätte Gunter gestern abend hetzen koennen
Romy hätte Toni gestern abend hetzte koennen
Dieter hätte Silke gestern abend entbehren koennen
Marvin hätte Herta gestern abend entbehrte koennen

Rosa hätte Gregor heute mittag filmen muessen
Sara hätte Guido heute mittag filmte muessen
Emil hätte Siegrid heute mittag verbannen muessen
Bernhard hätte Lotte heute mittag verbannte muessen

Eric hätte Siegrid gestern mittag nerven sollen
Gerrit hätte Svenja gestern mittag nervte sollen
Anna hätte Gregor gestern mittag beglücken sollen
Eva hätte Gunter gestern mittag beglückte sollen

Falko hätte Silke heute morgen strafen koennen
Felix hätte Inge heute morgen strafte koennen
Ilsa hätte Peter heute morgen bekehren koennen
Zora hätte Henrik heute morgen bekehrte koennen

Thea hätte Emil gestern abend küren muessen
Trixie hätte Eugen gestern abend kürte muessen
Malte hätte Maja gestern abend belohnen muessen
Marco hätte Wiebke gestern abend belohnte muessen

Volker hätte Wiebke heute besser taufen sollen
Elmar hätte Vicky heute besser taufte sollen
Susi hätte Werner heute besser beschimpfen sollen
Berta hätte Arne heute besser beschimpfte sollen

Ulla hätte Dieter heute morgen duschen muessen
Ute hätte Detlef heute morgen duschte muessen
Andi hätte Judith heute morgen ermahnen muessen
Norbert hätte Lisa heute morgen ermahnte muessen

Vera hätte Christoph gestern eher duzen koennen
Wilma hätte David gestern eher duzte koennen
Detlef hätte Franzi gestern eher verhöhnen koennen
Hermann hätte Anke gestern eher verhöhnte koennen

Bodo hätte Zora heute besser schminken sollen
Charly hätte Berta heute besser schminkte sollen
Sina hätte Guido heute besser verjagen sollen
Conny hätte Armin heute besser verjagte sollen

Gudrun hätte Benno heute mittag schocken koennen
Gertrud hätte Billy heute mittag schockte koennen
Antje hätte Helge heute mittag belauschen koennen
Elsa hätte Rudolf heute mittag belauschte koennen

Frauke hätte Nernhard gestern besser tarnen muessen
Frieda hätte Bertram gestern besser tarnte muessen
Boris hätte Jenny gestern besser verhüllen muessen
Georg hätte Agnes gestern besser verhüllte muessen

Steffen hätte Berta gestern eher melken muessen
Burkhard hätte Emma gestern eher melkte muessen
Hugo hätte Maren gestern eher bestärken muessen
Justus hätte Ester gestern eher bestärkte muessen

August hätte Hedwig gestern abend wärmen sollen
Axel hätte Herta gestern abend wärmte sollen
Petra hätte Benno gestern abend beerben sollen
Sandra hätte Torsten gestern abend beerbte sollen

Leila hätte Armin heute besser kämmen sollen
Lilly hätte Arne heute besser kämmte sollen
Sascha hätte Olga heute besser dressieren sollen
Silvan hätte Vicky heute besser dressierte sollen

Iris hätte Andi gestern abend toppen muessen
Magda hätte Anton gestern abend toppte muessen
Harald hätte Eva gestern abend frisieren muessen
Ulrich hätte Sonja gestern abend frisierte muessen

Alex hätte Sascha heute abend grüßen sollen
Adam hätte Ursel heute abend grüßte sollen
Inge hätte Phillip heute abend versetzen sollen
Britta hätte Otto heute abend versetzte sollen

Arno hätte Emma gestern mittag küssen muessen
Wilhelm hätte Rieke gestern mittag küsste muessen
Ursel hätte Anton gestern mittag verzeihen muessen
Svenja hätte Oskar gestern mittag verzeihte muessen

Gunter hätte Frauke gestern mittag lotsen muessen
Toni hätte Frieda gestern mittag lotste muessen
Jenny hätte Dieter gestern mittag rasieren muessen
Marvin hätte Marvin gestern mittag rasierte muessen

Gregor hätte Lara gestern mittag lenken koennen
Guido hätte Magda gestern mittag lenkte koennen
Emma hätte Emil gestern mittag verfehlen koennen
Sonja hätte Bernhard gestern mittag verfehlte koennen

Justus hätte Dolly gestern mittag scheren muessen
Kevin hätte Henni gestern mittag scherte muessen
Lara hätte August gestern mittag verdammen muessen
Sara hätte Christoph gestern mittag verdammte muessen

Sascha hätte Artur gestern eher schonen muessen
Ursel hätte Jonas gestern eher schonte muessen
Arnold hätte Inge gestern eher beschützen muessen
David hätte Britta gestern eher beschützte muessen

Zora hätte Patrick heute eher locken muessen
Berta hätte Matthis heute eher lockte muessen
Jakob hätte Sina heute eher blockieren muessen
Volker hätte Conny heute eher blockierte muessen

Conny hätte Martin heute mittag stürzen sollen
Eike hätte Stefan heute mittag stürzte sollen
Alex hätte Antje heute mittag verführen sollen
Christoph hätte Elsa heute mittag verführte sollen

Arnold hätte Hilde heute abend führen sollen
Artur hätte Jana heute abend führte sollen

Dennis hätte Lilly gestern besser verhören sollen
Adam hätte Elke gestern besser verhörte sollen

Elke hätte Herbert heute abend folgen sollen
Birgit hätte Steffen heute abend folgte sollen
Wilhelm hätte Cora heute abend zensieren sollen
Rudolf hätte Gretel heute abend zensierte sollen

Patrick hätte Anna gestern abend holen koennen
Matthis hätte Sina gestern abend holte koennen
Lara hätte Jakob gestern abend enttäuschen koennen
Anne hätte Volker gestern abend enttäuschte koennen

Andi hätte Vera gestern eher schützen muessen
Anton hätte Wilma gestern eher schützte muessen
Albert hätte Ursel gestern eher verhexen muessen
Lukas hätte Svenja gestern eher verhexte muessen

Silke hätte Alex gestern mittag prüfen muessen
Inge hätte Adam gestern mittag prüfen muessen
Phillip hätte Ilsa gestern mittag beschenken muessen
Otto hätte Zora gestern mittag beschenkte muessen

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Selbständigkeitserklärung

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Maren Schmidt-Kassow
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