Contextual Influences on Spoken-Word Processing:
An electrophysiological approach

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Contextual Influences on Spoken-Word Processing: An electrophysiological approach

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VOORWOORD

Eindelijk is de dag aangebroken waarop ik zeggen kan: "Mijn proefschrift is af!" Het spreekt voor zich dat, hoewel ik degene ben geweest die daadwerkelijk alle lettertjes die hier op papier verschenen zijn heb ingetikt, dit proefschrift niet enkel door mij tot stand is gekomen. Daarom wil ik de ruimte op deze twee pagina's benutten om de mensen te bedanken die mij in de loop van de afgelopen jaren een helpende hand hebben toegestoken.

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Introduction

CHAPTER 1

Understanding spoken language is a human cognitive skill that seems to require amazingly little effort. Nevertheless, several complex processes underlie spoken language comprehension. Consider that in a normal conversation a listener rapidly has to identify individual words, retrieve their meaning as well as their grammatical form and integrate this information to realize a higher-order meaning representation of the entire sentence or discourse. In doing so, the listener can rely on a number of different sources of knowledge he or she possesses. Linguistic knowledge available to the listener encompasses knowledge of the sound patterns of the utterance (phonology), knowledge of its grammatical structure (syntax), and of its meaning (semantics). In addition, language understanding is aided by non-linguistic knowledge about how things work in the world (pragmatics). Words are considered to be the building blocks of language understanding and as such play an important role in the comprehension process. This thesis presents a psychophysiological approach to the understanding of spoken-word processing. Of major interest is the time course of linguistic processes during spoken-word recognition as measured by manipulation of sentence-contextual information.

A THEORETICAL FRAMEWORK OF SPOKEN-WORD RECOGNITION

Information about the phonology, semantics and syntax of words is stored in a network of representations commonly referred to as the *mental lexicon*. In order to identify spoken words the auditory system first has to convert the sensory input it receives into a form that allows the listener to activate stored representations of words. It is still not fully understood how the auditory system achieves this. Theories about the nature of the representational units that mediate speech perception are diverse and include those that acknowledge phonemes, acoustic-phonetic features, syllables, articulatory gestures or even whole words as the *units of perception* (for a short review see Cutler and Clifton, 1999). For simplification purposes, in this thesis I will assume that the *phoneme* is the unit of perception. The phoneme is the smallest unit with which a phonological form of an utterance can be sequentially described. For instance, the word *thesis* can phonologically be represented as /θi:sɪs/, and *finished* as /fɪnɪʃt/. I thus assume that the auditory system extracts these phonemes from the acoustic waveform and matches them to those stored in the mental lexicon, thereby activating representations of words containing these phonemes. Activation of words allows the syntactic and semantic information related to these words to become available. But before the aforementioned words, when combined, can lead to the listener's reaction "*party time!*", the multiple words that are activated on the basis of the phonemes have to be reduced to the ones that were actually produced. These words further have to be recognized, and their meanings combined.

Models describing the auditory word comprehension process as sketched above commonly distinguish three subprocesses: lexical access, lexical selection and lexical integration (Marslen-Wilson, 1987; Zwitserlood, 1989). Although the functional architectures of many spoken-word recognition models describing these lexical processes differ, most models pose that during lexical access multiple lexical items that share word onset are activated in parallel on the basis of an analysis of the initial phoneme(s) of a word. For instance, according to both the Cohort model and the Shortlist model, the sound /θi:/ will activate the words *thief*, *thesis*, *theme*, etc. (Marslen-Wilson & Welsh, 1978; Norris, 1994). This is a purely autonomous or bottom-up process. As pronunciation of a word progresses over time, the activation level of a number of lexical items will decline as soon as they no longer correspond to the incoming acoustic signal, since the phonemes that are extracted from the acoustic waveform do not match those in these items. Selection of the proper candidate is said to take place when only one lexical item is left that matches the acoustic signal best. Word recognition in sentences or discourse additionally requires that the selected word is integrated into a higher-order meaning representation of the sentence context.

The impact of sentential-contextual information on the spoken-word recognition process is a matter of debate. Two key issues here concern the relative moment in time at which context starts to exert an effect on word recognition, and the time course of the use of different sources of knowledge obtained from the context. The present thesis describes experiments that were designed to investigate the time course of contextual effects on spoken-word recognition, and the electrophysiological manifestation of these effects. Since the timing aspect of contextual influence is of primary concern here, I will first discuss this aspect with respect to several models of spoken-word recognition.

Models of spoken-word recognition

In the literature on language comprehension there is sufficient evidence to suggest that contextual influences play a role in the on-line recognition of spoken words (see Zwitserlood, 1998 for a comprehensive review). However, models of word recognition differ in their claims concerning the exact moment at which contextual information starts to exert its influence. Theoretically, sentential context could begin to exert its influence on the spoken-word recognition process either prior to lexical access, when no phonological information is available, prior to lexical selection, that is, after activation of a set of lexical items on the basis of the analysis of some initial stretch of the speech signal, or prior to semantic integration, after one lexical item has been selected on the basis of the acoustic input. This temporal separation is not always strict (sometimes lexical selection is a by-product of the integration process, as in the case of semantically ambiguous words such as *bank*). However, this distinction between lexical selection and semantic integration is of importance for clarification of three contrasting kinds of speech recognition model: one in which bottom-up (i.e., acoustic input) and top-down (i.e., context) information are fully interactive, one where bottom-up information has partial priority over top-down information, and one where bottom-up information has full priority over top-down information.

In the first category we find the TRACE model by McClelland and Elman (1986) and the Logogen model by Morton (1969). These models claim that contextual influences already operate before instantiation of the set of lexical elements (referred to as nodes or logogens). Sentential context serves to raise the activation level of contextually appropriate lexical elements. Acoustic and higher-level context information are used interactively to home in on a single lexical element. The activation level of those elements that no longer correspond to the incoming acoustic signal or that are not plausible in the higher-level context given their semantic and syntactic properties is lowered. Lexical selection is said to take place when the activation level of a lexical element exceeds its threshold. Following selection, the meaning of the word is integrated into the meaning representation of the preceding context.

Examples of the second category are the Shortlist model by Norris (1994) and the Cohort model by Marslen-Wilson and Welsh (1978). These models claim that contextual information starts to exert its influence only after bottom-up activation of a set of lexical items or candidates on the basis of a stretch of initial sensory input. In other words, the lexical access process is autonomous and cannot be influenced by higher-level context information. Here too, a combination of bottom-up acoustic information, and top-down semantic and syntactic information derived from the context are used to select a lexical candidate from the word-initial cohort or shortlist. The selection process is completed as soon as the set of word-initial candidates is reduced to one that still matches the acoustic signal and that is most plausible given the preceding context.

Autonomous or modular models such as the autonomous search model by Forster (1979) are examples of the third category, which state that contextual information is only used during the integration process. Here, higher-level context information cannot affect lexical access nor lexical selection before the word form that matches the acoustic input has been selected. Only after this process has been completed contextual information is used and the semantic and syntactic information of the selected word form are integrated into the higher-level representation of the preceding context.

Although clear in their assumptions about the timing of the onset of sentential-contextual influence, the models mentioned above do not specify the time course of the use of different sources of higher-level context information in relation to lexical information during sentence processing. A fundamental claim within linguistics is that syntax and semantics are separable and independent sources of information. Thus, another issue important to spoken language comprehension pertains to the time course of the processing of these individual aspects of contextual information. Does the processing of semantic and syntactic information occur in parallel or is it serial in nature? At the level of auditory sentence comprehension, this dichotomy is represented by two kinds of model. "Syntax-first" models, for instance, claim that syntactic processing (i.e. syntactic structure building) takes place before semantic information from the context is used (Frazier, 1987; Friederici, 1995; 2002). These "syntax-first" or serial models can be contrasted with constraint-based or interactive models that claim that all sources of information exert their influence directly and in parallel on auditory sentence processing and that none of them have priority over another (cf. Trueswell & Tanenhaus, 1994). A parallel can be drawn at the level of lexical processing. Is semantic and syntactic information from the context used in parallel during spoken-word processing or does specific syntactic information have priority over semantic information?

The aforementioned models have all received varying degrees of support from experiments using several techniques, such as phoneme monitoring, lexical decision, shadowing, naming, and gating. However, since these techniques require the subject to perform a specific task, the results of these experiments might be influenced by task-specific processes (cf. Brown, Hagoort, & Chwilla, 2000). In this thesis, the time course of the interplay between sentence-level processing and spoken-word recognition will be investigated with an experimental technique that yields a high temporal resolution in measuring the on-line recognition of words, and in addition does not require the subject to perform a potentially intrusive task. This technique involves the registration of *event-related brain potentials* (ERPs). Because the temporal resolution of these registrations is in the order of milliseconds, through ERP analysis one can accurately measure when processing activities take place in the human brain (see Rugg and Coles, 1995, for an extensive discussion of the use of ERP recording in cognitive psychology).

EVENT-RELATED BRAIN POTENTIALS

ERPs are part of the registration of electrical activity measured on the scalp, known as the electroencephalogram (EEG). The EEG reflects the small voltage fluctuations that are caused by simultaneous post-synaptic activity of a large population of neurons in the cerebral cortex and thalamocortical connections that fire in synchrony. ERPs are averages of parts of the EEG that are time-locked to specific psychological or experimental events, thus explaining the term event-related potential. Voltage fluctuations are measured with electrodes placed at specific locations on the scalp.

The amplitude of ERPs are very small, measuring from less than 1 to 10 microvolts. In comparison, the spontaneous EEG can range from 10 to 100 microvolts. In order to visualize the ERPs that are time-locked to the events, the non-event-related activity has to be eliminated from the EEG. This is typically done by averaging a number of EEG epochs that are time-locked to the same stimulus event. The procedure for extracting ERPs from the EEG is illustrated in Figure 1. The assumption behind this procedure is that all neural activity that is not related to the processing of the stimulus event varies randomly with respect to the time of the stimulus onset. Averaging over a number of EEG epochs time-locked to similar stimulus events then cancels out the randomly distributed activity and thus improves the signal-to-noise ratio of the ERP relative to the spontaneous EEG. The number of epochs needed for a reliable ERP depends upon the amplitude of the ERP of interest. Generally speaking, in language research 25 trials per condition should be considered a minimum (Kutas & Van Petten, 1994).

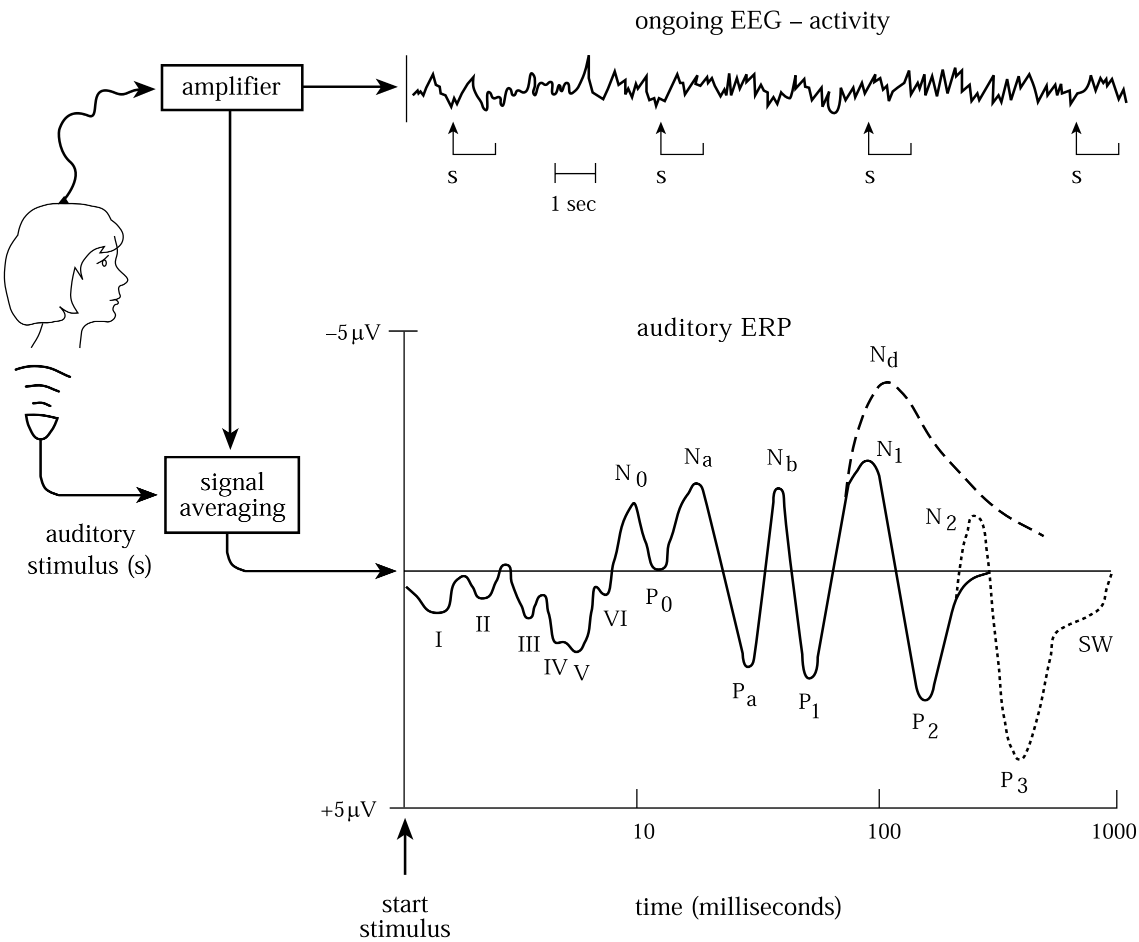

Figure 1-1. *Idealized waveform of the averaged auditory event-related potential (ERP) to a brief auditory stimulus. The ERP is generally too small to be detected in the ongoing EEG (top) and requires computer averaging over a large number of stimulus presentations to achieve an adequate signal-to-noise ratio. The logarithmic time display allows visualisation of the early brainstem potentials (Waves I to VI), the middle-latency components (N_o to N_b), exogenous long-latency components (P_1, N_1, and P_2), and endogenous long-latency components (N_d, N_2, P300, and slow wave).(After Hillyard & Kutas, 1983.)*

The averaged ERP signal includes a series of positive and negative electrical waves referred to as *components*. These components have specific latencies and particular distributions across the scalp and are hypothesized to be related to specific cortical events. In turn, these cortical events are hypothesized to be closely related to psychological processes. In general, the early components of the ERP that occur within 10 ms after stimulus onset are thought to reflect information processing in the primary sensory pathways. For example, the auditory brain stem ERP arises from neural impulses traveling from the cochlea through the auditory brain stem centers. So-called *middle latency* components (roughly 10 to 100 ms), on the other hand, seem to reflect activity in the thalamus and possibly the earliest cortical processing. These early and middle-latency components are called *exogenous* ERP components because their amplitude and peak latency vary as a function of physical properties of the stimulus event, such as intensity and rate of presentation. In contrast, the later components of the ERP, the so-called *endogenous* components, represent processing of information at higher cognitive levels, such as a shift of attention, surprise to a novel stimulus or resolution of a semantic ambiguity. As a consequence it is the endogenous components that are of more interest to cognitive psychologists investigating higher cognitive functions such as memory and language.

The two basic aspects of the ERP component are its peak-amplitude and its peak-latency measured from stimulus onset. For amplitude measures, the most common approach is to define a window surrounding the peak and use the average activity within this window as the amplitude measure. These time ranges are defined on the basis of the results of previous studies and visual inspection of the waveform. With respect to timing, the relationship between ERP components and underlying cognitive processes is to some extent unclear. In general it is assumed that the latency of the onset of the component, as opposed to its peak-latency, is most informative as it provides an upper-bound estimate of the timing of the underlying process.

The nomenclature for ERPs is usually based on the component's polarity and peak-latency. For example, the P300 that typically is elicited when an improbable target stimulus is detected in a series of standard stimuli is a positive deflection peaking at 300 ms after stimulus onset (Picton, 1992). Another system for labeling components is based on their polarity and ordinal position in the ERP waveform (e.g., P1, N1, P2). Also, components can be named according to their assumed cognitive function. For example, the Syntactic Positive Shift (SPS) is another name for the P600 that is assumed to reflect syntactic processing (Hagoort, Brown & Groothusen, 1993; Osterhout & Holcomb, 1992). Special attention should be given to figure reading. In the ERP literature some researchers plot waveforms with negative voltages up and others do the opposite. Throughout this thesis, negative polarity is plotted upward.

A clear distinction should be made between a *component* and an *effect*. For example, in this thesis, a component with a negative polarity peaking at 200 ms after word onset, called the N200 is described. Despite the fact that the component itself is most clearly visible at frontal sites, modulation of the amplitude by means of experimental conditions does not necessarily lead to a maximum difference between the conditions, or effect, at frontal sites. The N200 itself might be the result of multiple generators. However, it may be the case that not all of these generators are involved in modulation of the amplitude. Therefore, cognitive scientists are most interested in effects between experimental conditions, as they are most informative about modulation of an underlying cognitive process.

The recording of ERPs requires the small voltage fluctuations to be recorded at the scalp by means of electrodes. Nowadays the electrodes are usually mounted in an elastic cap that is worn by the subject. Placement of the electrodes typically follows an accepted system such as the *10-10 Standard System* of the American Electroencephalographic Society (1994) in which maximally 75 electrodes are placed over the frontal, central, temporal, parietal and occipital areas of the scalp. The electrode sites are labeled in terms of the underlying cortical areas (e.g., F = frontal, C = central, P = parietal), and their position in the lateral plane (odd numbers refer to the left hemisphere, even numbers to the right hemisphere, and z to midline positions). By way of illustration, F7 refers to a left frontal electrode site and Cz to the central electrode site (exactly in the middle between the nasion and inion, and left and right ear canal).

For each electrode site, the signal is amplified, filtered and digitized according to standard rules (cf. Picton, Lins & Scherg, 1995). Also, ERPs are measured differentially. This means that the electric potential measured at each electrode site is measured in reference to a common electrode placed on or near the scalp that is assumed not to have electrical activity occurring as a result of brain activity (e.g., at the mastoid bone behind the ear). This common electrode is referred to as the reference electrode. In addition to neural activity, undesirable electrical activity may show up in the EEG as a result of eye movements, blinks, muscle activity in face and neck and other excessive motor activity. In order to identify the most common artifacts, namely those related to blinks and eye movement, extra electrodes are placed near the eyes: a supra- to suborbital bipolar montage for vertical eye movements and blinks, and a right to left canthal bipolar montage for horizontal eye movements. Trials containing such artifacts are most commonly rejected for further analysis.

There are both strengths and weaknesses inherent to the use of ERPs in the study of cognitive neuropsychology. The strengths relate to the high temporal resolution in the order of milliseconds, the non-invasive nature of the procedure, and the fact that ERPs can be investigated in the absence of an experimental task. This makes the ERP suitable for on-line monitoring of individual cognitive processes in the absence of task-induced effects and, thus, facilitates drawing inferences about the timing of these processes. One weakness of the ERP technique is a direct consequence of the physical characteristics necessary for picking up electrical activity at the scalp. In addition to having to be synchronously active, the population of cortical cells have to be aligned in a parallel orientation in order to produce a dipolar field with positive and negative charges between which current flows. Such a configuration of cortical cells is known as an *open-field configuration*. Neural activity that does not meet these criteria cannot be picked up by the electrodes. Consequently, not all neural processes underlying cognitive functions are reflected in the ERP. Another weakness, especially compared to some other brain-imaging techniques, relates to the poor spatial resolution for identifying cortical sources that are thought to be responsible for the measured activity, and the uncertainty of the underlying cortical generators (dipoles) that account for the scalp topographical distribution. Potentials recorded at particular scalp locations do not necessarily reflect activity in the cortical area that lies directly underneath the electrode site. This is referred to as the *inverse problem*. There is no unique solution for a particular pattern of voltage distribution across the scalp.

With recent developments in cognitive neuroscience the *inverse problem* can be partly overcome. First, spatial localization can be improved by *high-density ERP recording*, using dense arrays with as many as 128 or even 256 electrodes. Second, a better spatial resolution of local cortical sources reflected on the scalp topography is realized by quantitative techniques using dipole modeling (e.g., *Brain Electrical Source Analysis*, Scherg, 1990) which have improved considerably over the years. Finally, recording techniques with a high spatial resolution such as PET and fMRI can be used as constraints on deriving a sensible solution for source localization.

In spite of the fact that identifying cortical generators of cognitive functions remains difficult, recording ERPs is still is a very suitable method for studying individual cognitive processes as they unfold over time. When interpreting ERP waveforms the following two general guide-lines are very useful. First, differences in polarity and/or scalp distribution between two conditions are usually interpreted as reflecting the activity of, at least partly, non-overlapping neural populations, subserving qualitatively different processes. Second, differences in amplitude between two conditions are usually interpreted as modulations in the activity in the same neural populations subserving processes that differ quantitatively. A final problem that needs to be considered is the possible overlapping of multiple effects elicited in the same latency range (see Coles & Rugg, 1995). In the ERP waveform the voltages of these effects are simply added. Dissociation of these different effects has to take place on the basis of their topographic distributions and by means of experimental manipulations.

Electrophysiology of Language Processing

Of interest to the topic of this thesis, several ERP components have proven to be related to the processing of different types of information, necessary for language comprehension. A central finding in the ERP literature on language is a negative-going component, the N400, which typically peaks at 400 ms after stimulus onset. As first reported by Kutas and Hillyard, the amplitude of the component seemed to increase when the semantics of the eliciting words did not match with the semantics of the preceding sentence context, as in “He spread his warm bread with *socks*” (cf. Kutas & Hillyard, 1980). Over the past two decades numerous studies have demonstrated that the N400 component is related to semantic processing of the eliciting word and can be observed in both the visual and the auditory modality. Although N400 effects have sometimes been related to lexical access (Kutas & Federmeier, 2000), today the most widely held view is that in sentence contexts, the N400 amplitude indexes the relative ease with which the meaning of a word is integrated into the overall meaning representation of the preceding context (Brown & Hagoort, 1993, Hagoort & Brown, 2000; Holcomb, 1993): Words that are semantically incongruent or less fitting given the preceding sentence frame typically elicit a much larger N400 than words that fit well within the context. This N400 effect has a posterior scalp distribution and an onset around 200-250 ms after word onset (for reviews see Kutas & Van Petten, 1988, 1994; Osterhout & Holcomb, 1995).

In contrast to the N400, both a left anterior negativity (LAN), with a latency window of 100 to 500 ms after stimulus onset, and a later, more posterior positive shift, referred to as P600 or SPS, with a latency window of 500 to 800 ms after stimulus onset have been reported to be sensitive to syntactic processing. The P600 has been known to be elicited by several syntactic violations, such as violations in agreement of number, gender and case, phrase-structure violations, and even violations of structural preference (cf. Hagoort, Brown & Osterhout, 1999; Friederici, 2002). LANs are also elicited in situations involving several types of syntactic violations, such as morpho-syntactic and word category violations (cf. Hahne & Friederici, 1999; Hagoort et al., 1999). Recently, a further subdivision has been proposed between two negativities within this early time window, because of a difference in latency and possible functional roles, namely an early left anterior negativity (ELAN) between 100 and 200 ms after stimulus onset, related to word category processing, and a somewhat later left anterior negativity (LAN) between 300 and 500 ms after stimulus onset, related to morpho-syntactic processing (Friederici, 2002; Hahne & Jescheniak, 2001).

Finally, it should be noted that most researchers do not claim that the components or effects mentioned above are all language-specific, but rather that in the context of language processing, modulation of these components can be related to distinct aspects of language processing and as such can be helpful in the investigation of these aspects (cf. Hagoort et al., 1999).

AIMS AND STRUCTURE OF THE THESIS

In the present study the process-specific sensitivity of aforementioned ERP components is exploited in an attempt to investigate different aspects of spoken-word and sentence processing. The next three chapters contain descriptions and discussions of several experiments. Each chapter is written in such a way that it can be read independently from the other chapters. Chapter 2 relates to the first issue raised in this introduction concerning the relative moment in time at which context starts to exert an influence on spoken-word processing. In particular, the experiment described seeks to validate an early electrophysiological manifestation of the processing interface between words and their context. This chapter has been published in *Journal of Cognitive Neuroscience*. Chapter 3 takes a closer look at the nature of the lexical selection process. More specifically, it describes an investigation of whether during the selection process lexical items are individually assessed with respect to their goodness-of fit within the preceding context on the basis of their semantic features, or whether initial assessment takes place on a field of semantic features that at that moment are not linked to specific lexical items. In addition, the temporal relationship between the lexical selection and the lexical integration process is evaluated. The issue at hand relates to whether there is some "magic moment" where lexical selection ends and lexical integration begins, or whether these processes are of a cascading nature (i.e. overlap to some extent). Chapter 4 focuses on the investigation of the time course of the processing of individual aspects of information (i.e. phonological, semantic and syntactic) during lexical selection and integration in spoken-word comprehension. Chapters 3 and 4 are under submission. Chapter 5 presents a summary and general discussion of the main findings in the thesis. In addition, implications for theories of spoken-word comprehension are discussed.

Electrophysiological Evidence for Early Contextual Influences during Spoken-Word Recognition: N200 versus N400 Effects

CHAPTER 2

Daniëlle van den Brink, Colin M. Brown, and Peter Hagoort[1]

ABSTRACT

An event-related brain potential experiment was carried out to investigate the time course of contextual influences on spoken-word recognition. Subjects were presented with spoken sentences that ended with a word that was either (a) congruent, (b) semantically anomalous, but beginning with the same initial phonemes as the congruent completion, or (c) semantically anomalous beginning with phonemes that differed from the congruent completion. In addition to finding an N400 effect in the two semantically anomalous conditions, we obtained an early negative effect in the semantically anomalous condition where word onset differed from that of the congruent completions. It was concluded that the N200 effect is related to the lexical selection process, where word-form information resulting from an initial phonological analysis and content information derived from the context interact.

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1. Slightly adapted version of this chapter has been published in *Journal of Cognitive Neuroscience, 13:7* (2001), pp. 967-985

INTRODUCTION

In everyday speech, people hear words in the context of other words, usually in the form of sentences. In the literature on language comprehension there is evidence to suggest that contextual influences play a role in the on-line recognition of spoken words (Morton, 1969; Marslen-Wilson & Tyler, 1980; Salasoo & Pisoni, 1985). In the recognition of words spoken in isolation, a number of spoken-word recognition models converge on the idea that multiple lexical candidates that share word onset are accessed on the basis of an analysis of the initial phoneme(s) of a word (Goldinger, Luce, & Pisoni, 1989; Goldinger, Luce, Pisoni, & Marcario, 1992; Marslen-Wilson, 1987; Marslen-Wilson & Welsh, 1978; McClelland & Elman, 1986; McQueen, Norris, & Cutler, 1994; Norris, McQueen, & Cutler, 1995; Norris, 1994). As pronunciation of a word progresses over time, lexical candidates are dropped as soon as they no longer correspond to the incoming acoustic signal. Selection of the proper candidate is said to take place when only one candidate is left that still matches the acoustic signal.

Word recognition in sentences additionally requires that the selected word is integrated into a higher-order meaning representation of the sentence context. The impact of sentential-contextual information on the recognition process is a matter of debate, with several models assuming a high degree of interactivity between contextual and acoustic information, and other models assigning priority to the acoustic analysis. A key issue here concerns the relative moment in time at which context starts to exert an effect on word recognition. The present study was designed to investigate the time course of contextual effects on spoken-word recognition. The focus of our study is on the electrophysiological manifestation of these effects, and less on the empirical separation of competing word recognition models. We seek to validate an early electrophysiological manifestation of the processing interface between words and their context, which will provide a real-time measure with which to test competing spoken-word recognition models.

ERPs reflect the sum of simultaneous post-synaptic activity of a large number of neurons, recorded at the scalp as small voltage fluctuations in the electroencephalogram. A central finding in the ERP literature on language is a negative-going component that typically peaks at 400 ms after stimulus onset, the N400 (cf. Kutas & Hillyard, 1980). The N400 component is related to semantic processing of the eliciting word and is observed in both the visual and the auditory modality. Although N400 effects have sometimes been related to lexical access (Kutas & Federmeier, 2000), today the most widely held view is that in sentence contexts the N400 amplitude indexes the relative ease of semantic integration (e.g., Brown & Hagoort, 1993, 2000; Holcomb, 1993): Words that are incongruent or less fitting given the preceding sentence frame typically elicit a much larger N400 than words that fit well within the context. This N400 effect has a posterior scalp distribution and an onset around 200-250 ms after word onset (for reviews, see Kutas & Van Petten, 1988, 1994; Osterhout & Holcomb, 1995). However, semantic integration of the perceived word into the sentence context is one of the last subprocesses in spoken-word recognition. If the N400 effect solely reflects the semantic integration process, is there any other evidence in the electrophysiological signal that context exerts an influence prior to semantic integration? Or does the N400 effect not only reflect integration processes, but also early semantic processing at a level where lexical and contextual information interact? A number of recent ERP studies on spoken-word processing have addressed these issues.

Connolly and Phillips (1994) carried out a study to investigate the possibility of the existence of a separate ERP component in the auditory modality, preceding the N400, that, in their terminology, might reflect some kind of 'preprocessing phase' related to contextual influences. In earlier studies Connolly and colleagues had found a negativity peaking at 200 ms (Connolly, Phillips, Stewart, & Brake, 1992; Connolly, Stewart, & Phillips, 1990). In their 1994 study, they hypothesized that this N200 was related to a phonological process that assessed whether the initial sounds of a word fit the sentential context. On the basis of the preceding context a semantic expectation of a particular word is formed, and if the initial phonemes of the perceived word do not match the initial phonemes of the expected word, an N200 is elicited. The underlying idea is that, certainly in the auditory modality, the semantic system could benefit from such an early process. To test their account of an early negativity reflecting a phonological process, Connolly and Phillips (1994) included four conditions in their design. The experimental items consisted of medium to high constraining sentences that ended with a semantically correct or anomalous word. The semantically correct sentence-final words were either the highest cloze probability words and therefore the expected endings (e.g., "The piano was out of *tune*") or words that were of a lower cloze probability (e.g., "Don caught the ball with his *glove*", where *hand* would have been expected).[2] The semantically anomalous sentence-final words began with phonemes that were either similar to those of the expected word (e.g., "The gambler had a streak of bad *luggage*", where *luck* would have been expected) or different (e.g., "The dog chased the cat up the *queen*", where *tree* would have been expected).

In the two conditions where the onset of the word did not match that of the highest cloze probability word, Connolly and Phillips obtained an early negativity (now peaking between 270 and 300 ms). They did not find an early nega-

2. Cloze probability of a word is defined as the percentage of subjects who use that word to end a particular sentence (see Bloom and Fischler, 1980).

tivity in the remaining two conditions, not even in the semantically anomalous condition where word onset was identical to the highest cloze probability word, and where they did obtain an N400. Therefore, Connolly and Phillips claimed that the early negativity was a *phonological mismatch negativity* (PMN), reflecting a discrepancy between the initial phonemes of the expected word and the actually perceived word. Their results seem to support the notion that a semantic expectation of a particular word is formed on the basis of the preceding context. Subsequently, the incoming signal is matched against the phonemic template of the expected word. If the initial phonemes do not match, a PMN is elicited.

Van Petten, Coulson, Rubin, Plante, and Parks (1999) performed a study somewhat similar to that of Connolly and Phillips (1994). In this study they made use of information about the isolation points (IP) of words, i.e., the minimum amount of acoustic signal necessary to identify a spoken word in the absence of contextual information (cf. Grosjean, 1980). The IPs were established with the gating technique, in which subjects hear increasingly longer fragments of a word, and report after each fragment which word they think is being presented. Van Petten et al. hypothesized that "... if semantic processes begin to operate on the partial and incomplete results of perceptual analyses, then the influence of semantic context might begin before the IP, as soon as the acoustic input becomes discrepant with semantic expectations" (p. 397). Their experimental items consisted of high to low constraining sentences that ended either (a) with the highest cloze probability word, (b) with a word that rhymed with the highest cloze probability word, (c) with a semantically anomalous word that shared the same initial phonemes as the highest cloze probability word, or (d) with an anomalous word of which the initial phonemes differed from those of the highest cloze probability word. For example: "It was a pleasant surprise to find that the car repair bill was only seventeen *dollars*/*scholars*/*dolphins*/*bureaus*".

The results revealed that the sentence-final words in the three anomalous conditions all elicited a significantly larger N400 than the high-cloze probability endings. Moreover, the onset of the N400 effect differed between conditions. In the fully anomalous and rhyme conditions, the onset of the N400 effect preceded the IP of the sentence-final words. Relative to these two conditions, the onset of the N400 effect in the condition where the anomalous word shared its phonemic onset with the highest cloze probability word, was found to be delayed by some 200 ms and corresponded to the IP. It was concluded that the onset of the N400 effect was related to the moment at which the acoustic input first diverged from semantic expectation. Van Petten and colleagues claimed that the N400 effect reflects the semantic incompatibility between the semantic expectation that is derived from the sentence context and the meaning of the acoustic word input. This account assumes that the incoming acoustic information is semantically analyzed and contrasted with the semantic expectation. This aspect was not further elaborated in terms of specific lexical representations, or more general semantic expectations. Van Petten and colleagues concluded that the N400 effect reflects semantic processing of the perceived word and that this semantic processing begins on partial and incomplete information about the perceived word.

The different results obtained in these studies, i.e. an early negativity versus an early onset of the N400 effect, resulted in different interpretations. The finding of an early negativity led Connolly and Phillips to conclude that on the basis of the preceding context a specific phonological expectation is formed. The early onset of the N400 effect in Van Petten and colleagues' study led them to conclude that a semantic expectation is formed. Despite these contrasting results, both studies provide evidence for early contextual influences during word recognition. However, neither a phonological nor a semantic expectation account necessarily implies that context already influences word recognition prior to lexical access. Suppose that, following the Shortlist model (Norris, 1994), contextual influences arise only after the bottom-up activation of a number of lexical candidates on the basis of the initial phonemes of the perceived word. If the contextual specifications do not support any of the lexical candidates in the set (e.g. on the basis of their semantic features), a congruity effect occurs, showing up either as an N400 effect (Van Petten et al., 1999) or as an early negativity (Connolly & Phillips, 1994).

This account fits with how Hagoort and Brown (2000) interpreted their results of a recent ERP study. The authors presented their subjects with spoken sentences that ended with a semantically congruent or anomalous word that did not have the same phonemic onset as the congruent completions. A biphasic negative shift was observed to the semantically anomalous endings. This biphasic shift was composed of two effects, an early effect that peaked around 250 ms (the N250 effect), and the N400 effect. The authors suggested that the N250 effect occurs whenever "... the contextual specifications do not support the form-based activation of a lexical candidate ..." (p. 1528).

The fact that these studies yield contrasting results (early negativity versus early onset of the N400 effect) remains somewhat surprising, and a few remarks are in order. The grand average waveforms of Connolly and Phillips are rather noisy, and identification of separate components is therefore difficult. On the other hand, although Van Petten and colleagues claim not to have found an early negativity, inspection of the waveforms of their Experiment 3 does reveal the possibility of an early negativity, at least in the rhyme and fully anomalous conditions. In itself this finding would not harm their account, but it could add evidence to the existence of a separate early negativity.

The issue of the exact time course of contextual influences on spoken-word recognition is important for our understanding of the underlying cognitive architecture of the language system. ERP research allows us to investigate this underlying cognitive architecture through identification of electrophysiological correlates of spoken-word recognition processes. The three studies mentioned above indicate that context has an early effect on spoken-word recognition. The present study follows on from these studies and was designed to give a better insight into this early context effect.

The time course of contextual influences on spoken-word recognition was evaluated with ERPs. Taking into account the possibility of some delay between underlying processes and their manifestation in the ERP waveform, the latest moment at which context starts to exert its influence was assumed to be revealed as the onset of a congruity effect in the waveforms, as indicated by the divergence between a congruent and an incongruent condition. We used semantically constraining Dutch sentences with sentence-final words that differed across three conditions (see Appendix for full set of experimental materials). In the Fully Congruent (FC) condition sentences ended with the highest cloze probability word for that sentence: “De schilder kleurde de details in met een klein *penseel*” (“The painter colored the details with a small [*paint brush*]”). The other two conditions both ended anomalously, but the point at which the sentence-final words became incongruent differed between these two conditions. The completions of the sentences in the Initially Congruent (IC) condition began with the same phonemes as the highest cloze probability words in the FC completions: “De schilder kleurde de details in met een klein *pensioen*” (“The painter colored the details with a small *pension*”). In contrast, the Fully Incongruent (FI) sentence-final words had initial phonemes that differed from the highest cloze probability word: “De schilder kleurde de details in met een klein *doolhof*” (“The painter colored the details with a small *labyrinth*”). We hypothesized that the onset of the congruity effect between the FC and FI conditions should precede the onset of the congruity effect between the FC and IC conditions. We were also curious to see how this congruity effect would manifest itself; as the onset of a monophasic N400 effect as in the Van Petten et al. study, or as a biphasic negative shift consisting of an early negative shift and an N400 effect as in the Connolly and Phillips study (1994) and the Hagoort and Brown study (2000).

We also investigated ERP effects as a function of the moment at which the sentence-final words in the FC and IC conditions started to acoustically diverge from each other. This moment was labeled the divergence point. We were interested in whether the manifestation of the congruity effect based on word onset (FC vs. FI) would differ from the congruity effect based on the divergence point (FC vs. IC). This line of investigation provides an additional perspective on the validity of the distinction between an early negative shift and the N400 effect during spoken-word recognition.

METHOD

Subjects

The experiment was conducted with 21 native speakers of Dutch (18 female, mean age 22, range 19-26 years) from the subject pool of the Max Planck Institute for Psycholinguistics. All had normal to corrected-to-normal vision and were right-handed (3 subjects reported having a left-handed parent or sibling). None of the subjects had any neurological impairment or had experienced any neurological trauma. Nor had any of the subjects participated in the pretest (see below). The data of 5 additional subjects were not analyzed (see Results section). Subjects were paid for their participation.

Materials

The experimental items consisted of a set of 261 triplets of semantically constraining sentences across three experimental conditions. The sentences in each triplet were identical up to the final word. In the Fully Congruent (FC) condition, sentences ended with a high cloze probability word, e.g., “De schilder kleurde de details in met een klein *penseel*” (“The painter colored the details with a small [*paint brush*]”). In the Initially Congruent (IC) condition, sentences ended with a semantically anomalous word that had the same initial phonemes (and lexical stress) as the highest cloze probability word, e.g., “De schilder kleurde de details in met een klein *pensioen*” (“The painter colored the details with a small *pension*”). The third condition served as a control condition where sentences ended with a word that was semantically anomalous and also had initial phonemes that were totally unexpected given the sentential context, e.g., “De schilder kleurde de details in met een klein *doolhof*” (“The painter colored the details with a small *labyrinth*”). This condition is called the Fully Incongruent (FI) condition.

The 261 triplets were derived from a larger set of sentence materials that had been submitted to a cloze test. Thirty subjects from the subject pool of the Max Planck Institute for Psycholinguistics were given a list of 350 sentences with the final word omitted. Subjects were asked to carefully read the sentences and to fill in the first word that came to mind at the position of the omitted sentence-final word. On the basis of the results, a set of 261 sentences with a cloze probability of .50 or higher formed the basis for the 261 triplets used in this experiment. Items for the IC condition were constructed by replacing the sentence-final word by a word that did not fit the semantic constraints of the preceding context, but began with the same phonemes (mean length of overlap was 2.6 phonemes, range 2 to 4, always including a full vowel) and had the same lexical stress and number of syllables as the high cloze probability word, which was used in the FC condition. The items for the FI condition were constructed by replacing the sentence-final word with a semantically anomalous word with word-initial phonemes that differed from the beginning phonemes of the high cloze probability word and other congruent words.

Because the sentences within each triplet were identical up to the final word, they had the same length (mean length of 10.8 words; range 5-15) and were equally constraining; the critical words in the FC condition had a mean cloze probability of .84 (range: .50-1.0). All sentence-final words were reasonably well-known nouns selected from a Dutch word corpus called CELEX (Baayen, Piepenbrock & Van Rijn, 1993); all critical words had a frequency of at least 30 counts per 42 million or 1.48 log, with a mean duration of 516 ms and a mean log frequency of 2.87 in the FC condition, 538 ms and 2.62 in the IC condition, and 515 ms and 2.49 in the FI condition. Each sentence-final word began with a plosive. This provided a clear physical marker that facilitated the alignment of the ERP-waveform to the onset of the sentence-final word.

Three lists were constructed to ensure that no subject heard the same sentence or target word more than once. In addition to the set of 261 experimental items (87 per condition per list), a set of 87 fillers was constructed. These fillers were all semantically congruent, to balance the number of sentences that ended anomalously and congruently. Finally, the experimental lists were preceded by a practice list of 20 items, which reflected the experimental materials. The practice list was used to familiarize the subjects with the experimental situation.

The experimental sentences, fillers and practice sentences were all spoken by a female speaker, with normal intonation at a normal speaking rate, and were recorded in one recording session. The sentences were recorded in triplets, making sure intonation and speaking rate were kept constant within each triplet. No specific voice changes marked the sentence-final anomalies as odd in the IC and FI condition. Sentences were spoken in a sound-attenuating booth and recorded on a digital audio tape. The DAT-recordings were sampled at 16 kHz mono and stored on computer disk. A speech waveform editing system was used to mark the onset of the sentence-final words. Also, the moment at which the sentence-final words in the FC and IC conditions started to acoustically diverge from each other, was marked as the divergence point for each word individually. This acoustic divergence point was assessed on the basis of phonetic transcriptions of the sentence-final words.

Procedure

Subjects were tested individually in a dimly illuminated sound-attenuating booth. They were seated in a comfortable reclining chair, instructed to move as little as possible, and told that they would hear a number of sentences. Their task was to attentively listen to these sentences and to try to understand them. In addition they were told that several sentences would be semantically anomalous. No additional task demands were imposed.

Each trial began with a 300 ms warning tone, followed after 1200 ms silence by the spoken sentence. The next trial began 4100 ms after sentence offset. To ensure that subjects would not blink during and shortly after presentation of the sentence, 1000 ms prior to the beginning of the sentence a fixation point (an asterisk) was displayed on the computer screen. The asterisk remained on the screen until 1600 ms after offset of the spoken sentence. Subjects were instructed to fixate on the asterisk during presentation of the sentences, but were free to blink and move their eyes when the asterisk was not displayed on the screen. Subjects listened to the stimuli via closed-ear headphones. After the practice session, the trials were presented in 5 blocks of approximately 10 minutes.

EEG-recording

The EEG was recorded from 29 Ag/AgCl-sintered electrodes mounted in an elastic cap, each referred to the left mastoid. See Figure 2-1 for the electrode distribution. Five electrodes were placed according to the 10-10 Standard System of the American Electroencephalographic Society over midline sites at Fz, FCz, Cz, Pz, and Oz locations, along with 9 lateral pairs of electrodes over standard sites on frontal (AF3, AF4, F3, F4, F7 and F8), fronto-central (FC3 and FC4), fronto-temporal (FT7 and FT8), central (C3 and C4), centro-parietal (CP3 and CP4), parietal (P3 and P4), and occipital (PO7 and PO8) positions. Three additional pairs were placed laterally over symmetrical positions: (a) a temporal pair (LT and RT) placed laterally to Cz, at 33% of the interaural distance, (b) a temporo-parietal pair (LTP and RTP) placed 30% of the interaural distance lateral and 13% of the nasion-inion distance posterior to Cz, and (c) a parietal pair midway between LTP/RTP and PO7/PO8 (LP and RP). Vertical eye movements were monitored via a supra- to sub-orbital bipolar montage. A right to left canthal bipolar montage was used to monitor for horizontal eye movements. Activity over the right mastoid bone was recorded on an additional channel to determine if there were differential contributions of the experimental variables to the presumably neutral mastoid site. No such differential effects were observed.

The EEG and EOG recordings were amplified with a SynAmp Model 5083 EEG amplifier (NeuroScan Inc., Herndon, Va, USA), using a hi-cut of 30 Hz (notch filter 60 Hz) and a time constant of 8 s (0.02 Hz). Electrode impedances were kept below 3 kOhm for the EEG recording and below 5 kOhm for the EOG recording. The EEG and EOG signals were digitized on-line with a sampling frequency of 200 Hz.

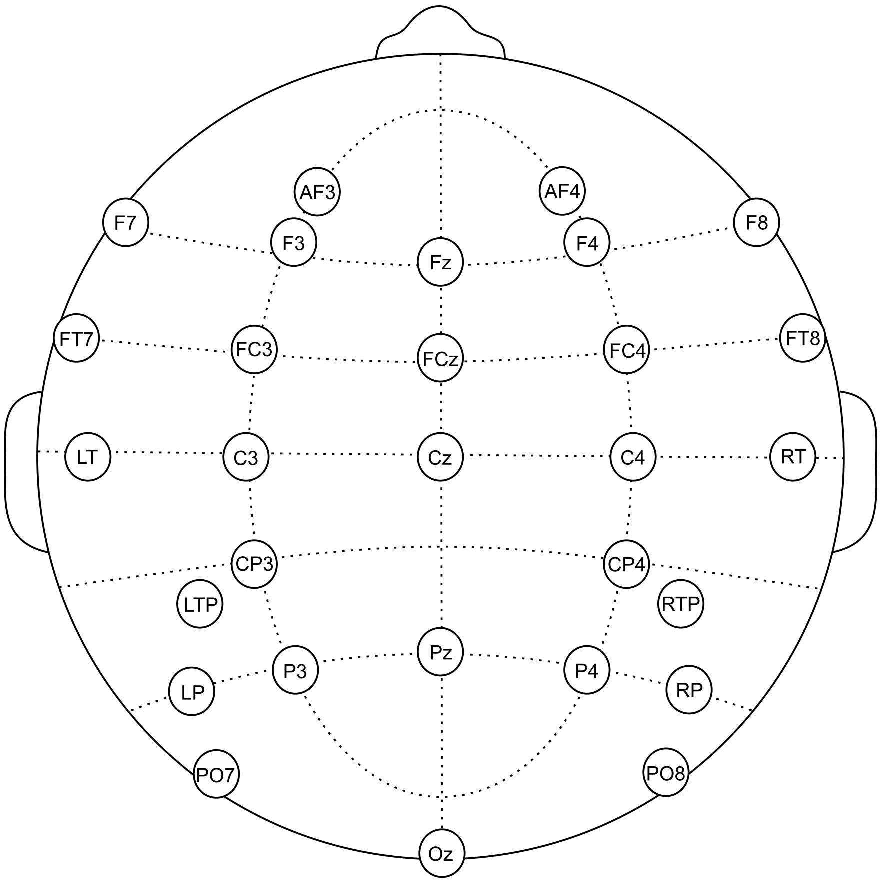

Figure 2-1. *Distribution of the 29 electrodes across the scalp.*

RESULTS

The data of 5 subjects were not analyzed: the data of one subject were lost because of a computer malfunction and the data of 4 others showed excessive alpha activity (a pronounced 10 Hz rhythm throughout the waveforms). As this study was designed to investigate the possible existence of a relatively small and short-lived early negativity, we were concerned that excessive alpha would distort the signals in this early latency window to such an extent that it would influence the results. For the remaining 21 subjects, data from critical trials were analyzed according to the following procedure. Prior to off-line averaging, all single-trial waveforms were screened for eye movements, electrode drifting, amplifier blocking, and EMG artifacts in a critical window that ranged from 150 ms before onset of the sentence-final word, to 1900 ms after onset of the sentence-final word. Trials containing artifacts were rejected (12.8% in FC, 13.4% in IC, and 11.8% in FI). For each subject, average waveforms were computed across all remaining trials per condition after applying baseline correction to the waveforms of the individual trials on the basis of the averaged activity of 150 ms before onset of the sentence-final word.

Figure 2-2 displays the grand average waveforms by electrode site time-locked to the onset of the sentence-final word. There are several things to note. First, in all three conditions, the sentence-final words elicited an N100 component. This component appears to be larger (but is in fact not) in the IC condition than in the FC and FI conditions. This is most visible in the frontal to central electrodes.[3] It is not common to find a clear N100 component in a study using natural connected speech, given the continuous nature of the speech signal (Connolly et al., 1990, 1992, 1994). However, in our study all sentence-final words began with a plosive, which is a relatively clear onset marker in connected speech. In addition, the homogeneity of the sentence-final word onsets presumably added to the clear presence of the N100 component in the averaged waveforms. Second, a negativity at approximately 200 ms is visible in the waveforms. This negativity is apparent in all three conditions, but is largest in the FI condition and is most visible over the frontal sites (see also Figure 2-3). Third, the semantically anomalous sentence-final words in the IC and FI conditions elicit a broad negativity peaking at approximately 400 ms, which is more negative than the ERP elicited in the FC condition. In turn, this broad negativity is larger in the FI condition than in the IC condition. Its latency characteristics and morphology are similar to previously reported N400 effects. Finally, Figure 2-2 shows a late positivity between 600 and 1000 ms, which is largest in the IC condition. This late positivity reaches maximal amplitude at around 800 ms and is maximal over parietal sites. In the literature there are indications that late positivities reflect wrap-up processes at the end of sentences (cf. Juottonen, Revonsuo, & Lang, 1996).

Statistical analyses of the congruity effects consisted of a number of repeated measures analyses of variance (ANOVAs) with mean amplitude values computed for each subject and each electrode in different latency windows: (a) 150-250 ms after critical-word onset for the early negativity (N200), (b) 300-500 ms after final-word onset for the N400, and (c) 600-1000 ms after final-word onset for the late positivity. The latency windows were determined after careful visual inspection of the grand average waveforms. The latency window for the early negativity corresponds to the onset of the ascending flank and the offset of

3. We do not expect a differential N100 effect to occur (sentences and task demands were identical in all conditions), and in fact this amplitude difference did not reach significance ($p = .103$). Nevertheless we were concerned that the IC condition in later latency windows might still be affected by this early difference. To assess the possible effect of the non-significant N100 amplitude difference, we applied a baseline correction to a latency window surrounding the N100, and performed full statistical analyses based on this alternative baseline correction procedure. Apart from a few details in the onset analyses (IC now diverged at 370 ms from FC), the results on the basis of this alternative baseline correction procedure were the same as the results based on the prestimulus baseline.

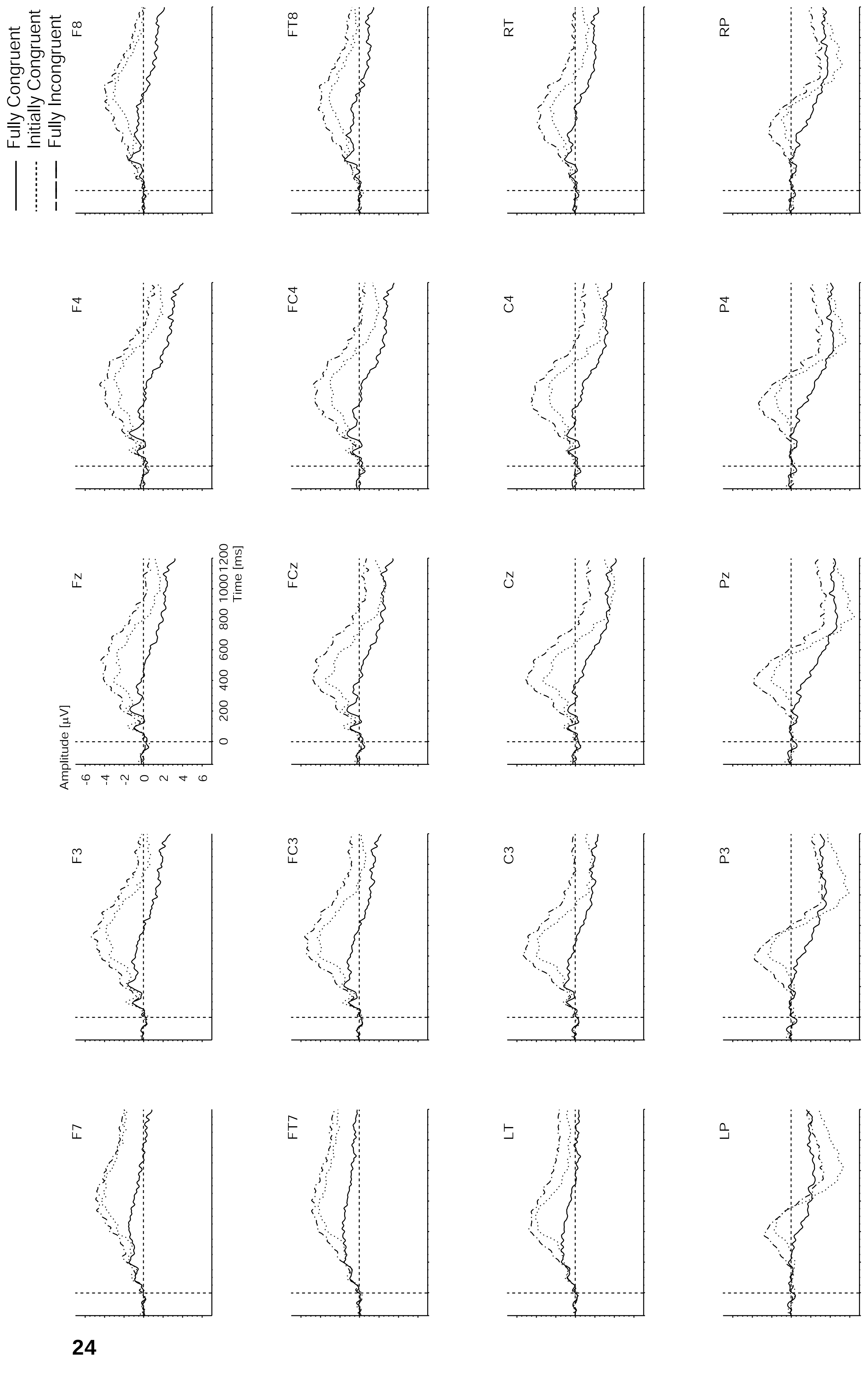

Figure 2-2. *Grand average ERPs to critical words in three conditions. Time 0 is the onset of critical words. Negative polarity is plotted upwards*

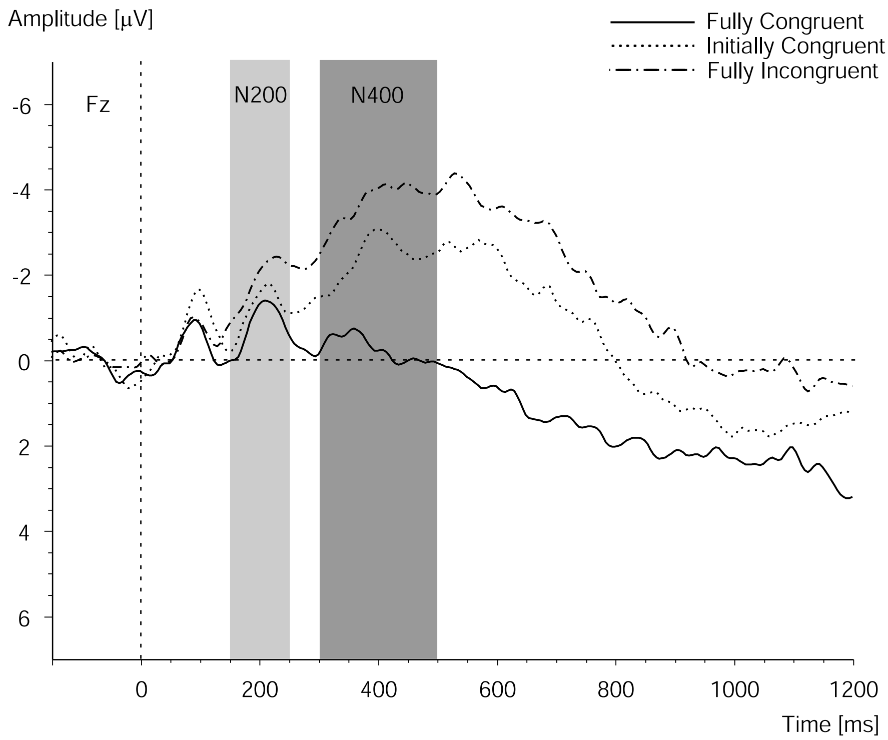

Figure 2-3. *Grand average ERPs from the Fz electrode to critical words in three conditions. Time 0 is the onset of sentence-final words.*

the descending flank. The N400 latency window corresponds to the onset of the ascending flank and 100 ms after its maximal amplitude. This 300 to 500 ms interval is a standard time window for measuring N400 effects. The latency window for the Late Positivity corresponds to the onset of the ascending flank and 200 ms after its maximal amplitude. For each latency window, the results were first analyzed in an omnibus ANOVA that crossed all three levels of the congruity factor (fully congruent, initially congruent, and fully incongruent) with the 29-level electrode factor. In addition to the omnibus ANOVA, a priori pairwise comparisons between the congruity conditions were tested using ANOVAs with a 2-level congruity factor. For the N200 latency window we expected the ERP in the FC condition (baseline) to differ in amplitude from the ERP in the FI condition (FC vs. FI), but not from the one in the IC condition (FC vs. IC). In the N400 latency window as well as the late positivity latency window we expected the ERP in the FC condition to differ in amplitude from the ERPs in both the FI (FC vs. FI) and the IC condition (FC vs. IC), but these latter were not expected to differ from each other (FI vs. IC). Scalp distributions of the congruity effects were subsequently explored in three separate ANOVAs: an ANOVA on anterior versus posterior, with a site (anterior/posterior) by electrode design (anterior: Fz, FCz, F3, F4, F7, F8, FC3, FC4, FT7, FT8, posterior: Cz, Pz, CP3, CP4, LTP, RTP, P3, P4, LP, RP); anterior left versus anterior right, with a site (left/right hemi-

Table 2-1. *ANOVA on mean ERP amplitude in the 150-250 ms latency range (N200)*

	source	df	*F*	*MSE*	*p*
		Omnibus ANOVA (29 electrodes)			
Overall	Con	2, 40	4.25	19.79	.023 *
	Con x El	56, 1120	1.98	0.30	.075
FC vs. FI	Con	1, 20	6.90	22.42	.016 *
	Con x El	28, 560	2.15	0.33	.100
FC vs. IC	Con	1, 20	0.43	21.30	.521
	Con x El	28, 560	2.30	0.28	.080
		Anterior vs. posterior (2 x 10 electrodes)			
FC vs. FI	Con x Site	1, 20	0.08	2.34	.786
		Anterior left vs. anterior right (2 x 5 electrodes)			
FC vs. FI	Con x Site	1, 20	0.05	0.92	.820
		Posterior left vs. posterior right (2 x 5 electrodes)			
FC vs. FI	Con x Site	1, 20	0.44	1.03	.515

Note. Con = Congruity Type; El = Electrode. * $p < .05$

sphere) by electrode design (anterior left: AF3, F3, F7, FC3, FT7, anterior right: AF4, F4, F8, FC4, FT8); posterior left versus posterior right, with a site (left/right hemisphere) by electrode design (posterior left: CP3, LTP, P3, LP, PO7, posterior right: CP4, RTP, P4, RP, PO8). Univariate *F* tests with more than one degree of freedom in the numerator were adjusted by means of the Greenhouse-Geisser/Box's epsilon hat correction (Maxwell & Delaney, 1990). The original degrees of freedom and adjusted *p* values will be reported.

The Early Negativity/N200 latency window: 150-250 ms

Table 2-1 displays the results of the mean ERP amplitude ANOVAs in the 150-250 ms latency range. The omnibus ANOVA for the N200 latency window resulted in a significant main effect of congruity. The a priori pairwise comparisons revealed that the FI completions elicited a larger N200 than the FC completions (corresponding to an effect of 0.71 µV), and that the ERPs in the FC and IC conditions did not significantly differ in amplitude (a difference of 0.17 µV). In these pairwise analyses, none of the interactions of congruity with electrodes reached significance. Topographical analyses of the FC versus FI condition revealed no significant interactions of congruity with site.

Table 2-2. *ANOVA on mean ERP amplitude in the 300-500 ms latency range (N400)*

	source	df	*F*	*MSE*	*p*
	Omnibus ANOVA (29 electrodes)				
Overall	Con	2, 40	47.71	36.35	.000 ***
	Con x El	56, 1120	8.96	0.48	.000 ***
FC vs. FI	Con	1, 20	66.46	51.66	.000 ***
	Con x El	28, 560	12.00	0.65	.000 ***
FC vs. IC	Con	1, 20	45.52	26.04	.000 ***
	Con x El	28, 560	9.22	0.45	.000 ***
IC vs. FI	Con	1, 20	18.62	31.35	.000 ***
	Con x El	28, 560	2.82	0.34	.047 *
	Anterior vs. posterior (2 x 10 electrodes)				
FC vs. FI	Con x Site	1, 20	8.34	5.75	.009 **
FC vs. IC	Con x Site	1, 20	7.14	3.80	.015 *
IC vs. FI	Con x Site	1, 20	0.95	3.09	.340
	Anterior left vs. anterior right (2 x 5 electrodes)				
FC vs. FI	Con x Site	1, 20	0.47	1.04	.502
FC vs. IC	Con x Site	1, 20	0.52	0.89	.481
IC vs. FI	Con x Site	1, 20	3.47	0.55	.077
	Posterior left vs. posterior right (2 x 5 electrodes)				
FC vs. FI	Con x Site	1, 20	0.16	1.70	.691
FC vs. IC	Con x Site	1, 20	0.81	1.27	.379
IC vs. FI	Con x Site	1, 20	4.51	0.53	.046 *

Note. Con = Congruity type; El = Electrode. * $p < .05$; ** $p < .01$; *** $p < .001$

The N400 latency window: 300-500 ms

Table 2-2 displays the results of the mean ERP amplitude ANOVAs in the 300-500 ms latency range. The omnibus ANOVA indicated that the basic congruity effect in the N400 latency window was significant. Further analysis revealed that both the FI and the IC completions elicited a larger N400 than the FC completions (corresponding to effects of 3.36 μV and 1.97 μV, respectively). In addition, the FI and the IC conditions differed significantly from each other in the N400 latency window (corresponding to a 1.38 μV average amplitude difference), and an interaction with electrodes was found as well. Topographical analyses showed that the congruity effects in relation to the baseline condition were significantly larger

Table 2-3. *ANOVA on mean ERP amplitude in the 600-1000 ms latency range*

	source	df	*F*	*MSE*	*p*
		Omnibus ANOVA (29 electrodes)			
Overall	Con	2, 40	26.45	31.62	.000 ***
	Con x El	56, 1120	26.83	0.64	.000 ***
FC vs. FI	Con	1, 20	36.44	44.82	.000 ***
	Con x El	28, 560	33.84	0.62	.000 ***
FC vs. IC	Con	1, 20	7.10	30.70	.015 *
	Con x El	28, 560	32.47	0.87	.000 ***
IC vs. FI	Con	1, 20	33.99	19.35	.000 ***
	Con x El	28, 560	5.80	0.44	.001 **

Note. Con = Congruity type; El = Electrode. * $p < .05$; ** $p < .01$; *** $p < .001$

over posterior than anterior regions of the scalp. Only in the posterior left versus posterior right analysis a hemispheric difference was found between the IC and FI conditions, indicating that the difference in N400 amplitude is larger over right than left posterior areas.

To establish whether the unexpected difference in ERP amplitude between the FI and IC conditions might be due to an early differential effect in the N200 latency window, we performed additional analyses in the N400 latency window after averaging the waveforms in the 250-300 ms interval. This time interval corresponds to the period involving the offset of the N200 component. Figure 2-4 shows the grand average waveforms after this alternative baseline correction procedure. The omnibus ANOVA indicated that the basic congruity effect in the N400 latency window was still significant, $F(2, 40) = 16.70$, $MSE = 27.43$, $p < .001$. The pairwise comparisons revealed that both the FI and the IC completions elicited a larger N400 than the FC completions (both $p < .001$). However, the FC and the IC conditions did not significantly differ from each other, $F(1, 20) < 1$.

The Late Positivity latency window: 600-1000 ms

Table 2-3 displays the results of the mean ERP amplitude omnibus ANOVAs in the 600-1000 ms latency range. The omnibus ANOVA on mean amplitudes resulted in a significant main effect of congruity. Pairwise analyses revealed that the IC completions differed significantly from both the IC completions and the IC completions. The ERP amplitude in the FI condition also differed significantly from the ERP amplitude in the IC condition. Again, because of the possibility of amplitude effects in this latency window as a consequence of earlier

Table 2-4. *ANOVA on mean ERP amplitude in the 600-1000 ms latency range after baseline correction in the 250-300 ms interval*

	source	df	*F*	*MSE*	*p*
		Omnibus ANOVA (29 electrodes)			
Overall	Con	2, 40	1.26	44.37	.292
	Con x El	56, 1120	22.84	0.67	.000 ***
FC vs. FI	Con	1, 20	1.73	62.08	.204
	Con x El	28, 560	28.49	0.73	.000 ***
FC vs. IC	Con	1, 20	0.33	32.98	.569
	Con x El	28, 560	27.83	0.88	.000 ***
IC vs. FI	Con	1, 20	1.30	38.06	.268
	Con x El	28, 560	1.77	0.49	.142
		Anterior vs. posterior (2 x 10 electrodes)			
FC vs. FI	Con x Site	1, 20	53.16	5.07	.000 ***
FC vs. IC	Con x Site	1, 20	68.67	5.25	.000 ***
IC vs. FI	Con x Site	1, 20	2.89	2.27	.104
		Anterior left vs. anterior right (2 x 5 electrodes)			
FC vs. FI	Con x Site	1, 20	0.01	1.48	.938
FC vs. IC	Con x Site	1, 20	1.24	1.81	.279
IC vs. FI	Con x Site	1, 20	3.04	0.65	.097
		Posterior left vs. posterior right (2 x 5 electrodes)			
FC vs. FI	Con x Site	1, 20	23.49	1.63	.000 ***
FC vs. IC	Con x Site	1, 20	12.74	2.05	.002 **
IC vs. FI	Con x Site	1, 20	1.39	0.84	.252

Note. Con = Congruity type; El = Electrode. ** $p < .01$; *** $p < .001$

differential effects in the N200 latency window, we performed further analyses after the alternative baseline correction procedure in the 250-300 ms interval.

Table 2-4 displays the results of the mean ERP amplitude omnibus ANOVAs in the 600-1000 ms latency range after baseline correction in the 250-300 ms interval (Figure 2-4). The omnibus ANOVA on mean amplitudes did not result in a significant main effect of congruity. None of the conditions differed significantly from each other. However, Figure 2-4 reveals that this is possibly due to the difference in effects between the anterior and posterior electrodes. Topographical analyses indeed revealed that the effects in relation to the FC con-

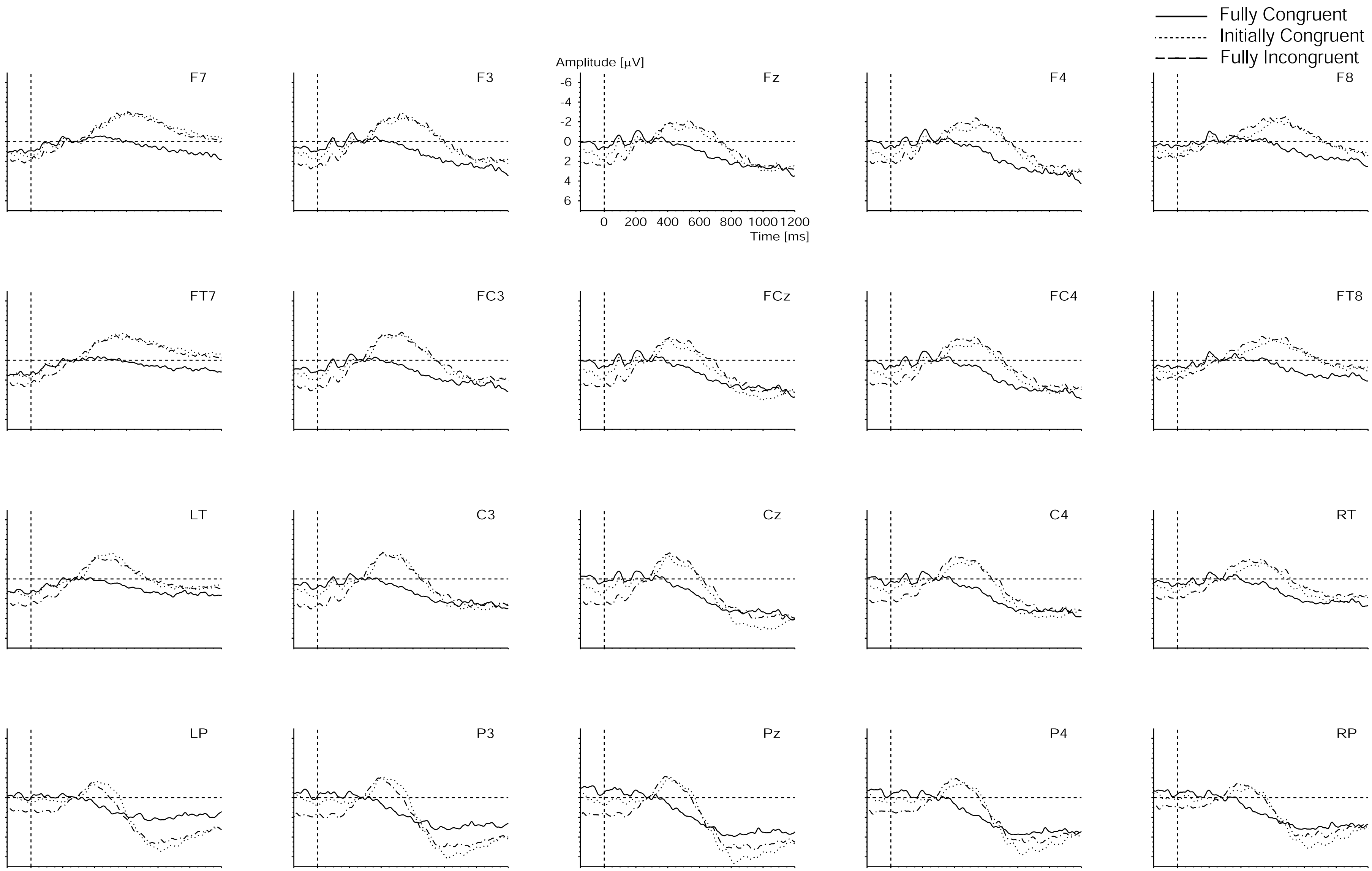

Figure 2-4. *Grand average ERPs to critical words in three conditions, after baseline correction in the 250 to 300 ms interval. Time 0 is onset of critical words.*

yses, the interaction of the factors Congruity by Site reached significance both in the FC vs. FI comparison and the FC vs. IC comparison.

Onset latencies

Figure 2-2 shows that the onset of the effects is most clearly visible over frontal electrodes. Therefore, we decided to analyze this frontal band. Onset latencies were estimated by first separately computing the mean amplitude values for five frontal electrodes (Fz, F4, F3, F8, and F7) in 20 ms latency ranges (bins) that shifted in steps of 10 ms from target onset until 500 ms after target onset (e.g., 0-20, 10-30, etc.). The values for the latency bins were submitted to ANOVAs that tested against the null-hypothesis of zero difference between the a priori selected conditions FC vs. FI and FC vs. IC.

The onset latency analyses for the FC vs. FI comparison on the amplitudes of the two waveforms in the 3 consecutive bins of 140-160, 150-170 and 160-180 ms revealed a significant congruity effect (p = .05, p = .02, p = .02, respectively). This indication of an early congruity effect disappeared in the following bins but emerged again at 220 ms, at which point the congruity effect remained significant over the entire test region (500 ms). In the FC vs. IC comparison the congruity effect did not start until 270 ms. So, at 150 to 180 ms after word onset, the waveforms of the FI condition momentarily departed from the FC condition. After this short-lived congruity effect, the waveforms of the FI condition significantly increased in amplitude approximately 50 ms earlier than the waveform of the IC words (i.e., 220 vs. 270 ms after word onset).

N200 vs. N400

Figure 2-5 shows the topography of mean amplitude effects between the FC and FI conditions in the N200 and the N400 window after our standard baseline correction procedure (150 ms prestimulus interval). Although the N200 component is most clearly visible over frontal sites, the figure reveals that the N200 effect is equally distributed across the scalp, whereas the N400 effect is largest over centro-parietal sites. To establish whether these two congruity effects have statistically distinct scalp distributions, we performed topographical analyses. First, for every subject difference scores between the FC and FI conditions were computed for every electrode in the N200 latency window and the N400 latency window. Second, a scaling procedure was performed to avoid that differential amplitude effects between the two latency windows would be incorrectly interpreted as distribution effects. In this procedure, the electrode-specific difference scores were z-transformed for each latency window separately (Rösler, Heil, & Glowolla, 1993; see also McCarthy & Wood, 1985). The z-transformed values were entered into an ANOVA that crossed the 2-level latency window factor

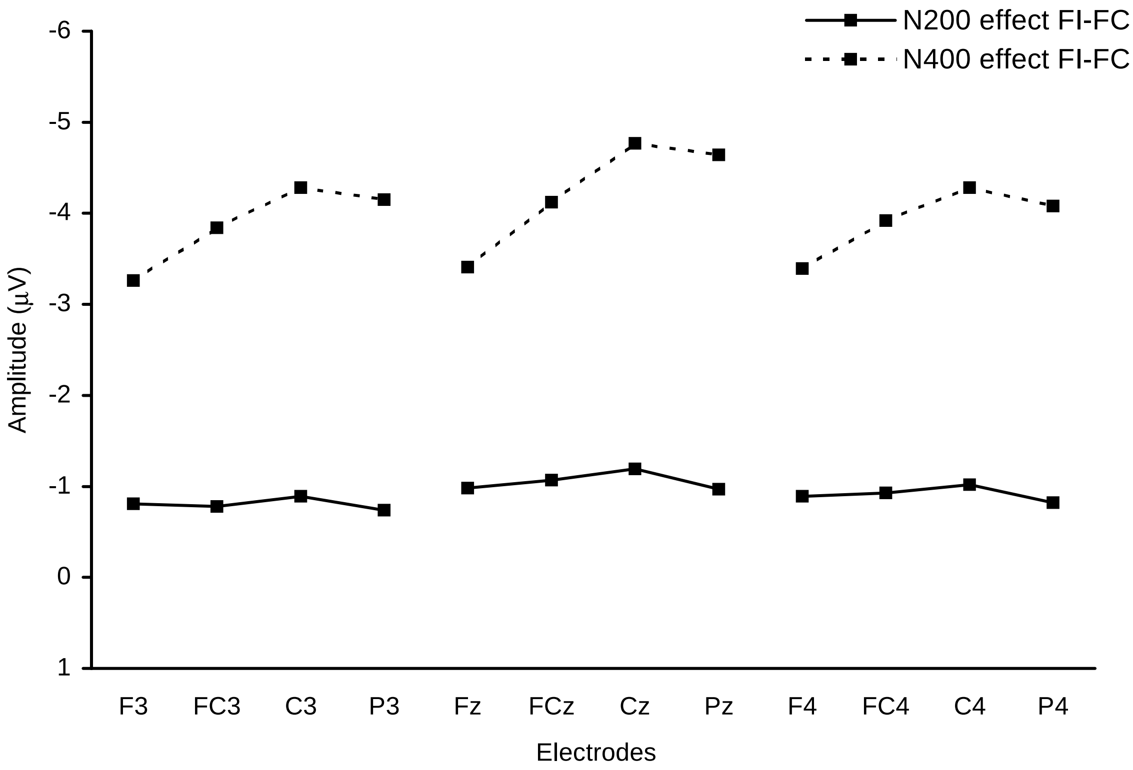

Figure 2-5. *Distribution of the N200 and N400 effects for four left hemisphere sites (F3, FC3, C3, P3), four midline sites (Fz, FCz, Cz, Pz), and four right hemisphere sites (F4, FC4, C4, P4). The N200 effect was determined by subtracting the mean amplitude in the 150-250 ms latency window of the grand average ERP for the semantically congruent sentence-final words from the mean amplitudes of the grand average ERP for the semantically anomalous sentence-final words. The N400 effect was determined in the same manner on the basis of the mean amplitudes in the 300-500 ms latency window.*

(N200 and N400) with the 29-level electrode factor. A significant interaction of latency window by electrodes ($F(28, 560) = 6.01$, $MSE = 0.36$, $p < .001$) revealed that the congruity effects found in the two latency windows indeed have different spatial distributions across the scalp. This difference in scalp distributions was subsequently explored in three additional topographical ANOVAs (using the same electrode configurations as previously described). In the anterior/posterior analysis a significant interaction of window by site was obtained ($F(1, 20) = 9.61$, $MSE = 2.17$, $p < .01$). In the anterior left/right and the posterior left/right analyses no significant interaction of window by site was obtained (both Fs < 1). The significant interaction of window by site in the anterior/posterior analysis underscores that the N200 and N400 effects have different spatial distributions, with the N400 effect having a more posterior distribution and the N200 effect having a flat distribution across the scalp.

Time-locking to the divergence point

Figure 2-6 displays the grand average waveforms by electrode site time-locked on a trial-by-trial basis to the time point at which the sentence-final words in the FC and IC conditions started to acoustically diverge from each other. This acoustical divergence point was assessed on the basis of phonetic transcriptions of the sentence-final words. The time period preceding this divergence point corresponds to the mean time period of segmental overlap between the two conditions, which was 220 ms. Therefore, in the alignment in Figure 2-6, the zero point roughly corresponds to word onset. However, since information about the exact onset of each sentence-final word is lost in this time-locking procedure, baseline correction cannot take place on the basis of information related to word onset. Therefore, we applied a baseline correction to the waveforms on the basis of the averaged activity of 150 ms preceding the divergence point. What can be seen in this figure is that approximately 80 ms after the divergence point, the waveform of the IC condition shows a steep ascending flank, resulting in what appears to be a biphasic N400.[4] This biphasic morphology is most apparent at the frontal and fronto-central electrodes. Parietal electrodes reveal that the N400 component in the IC condition is followed by a late positive shift.

DISCUSSION

This study investigated the time course of contextual influences on spoken-word recognition. We used ERPs to investigate the presence of markers in the electrophysiological signal that reveal the moment at which context starts to have an effect on word recognition. We hypothesized that if context exerts an influence early on in the signal, the ERP of the Fully Incongruent (FI) condition should diverge earlier than the ERP of the Initially Congruent (IC) condition, compared to the Fully Congruent (FC) condition. The moment at which the FI condition starts to diverge provides an upper estimate of the onset of contextual influences on spoken-word recognition. As hypothesized, the onset of the congruity effect between the FC and the FI conditions preceded that of the FC and the IC conditions. The waveforms of the FI condition first diverged momentarily from the FC

4. Investigation of this biphasic N400 revealed that the second peak is related to word offset. When we time-locked the waveforms to word offset, we discovered a large negative peak at word offset, followed by a smaller positive peak in the signal. This profile was apparent in all three conditions. This leads us to posit that we are not looking at a biphasic N400, but rather a monophasic N400 followed by an offset potential on the descending flank of the N400.

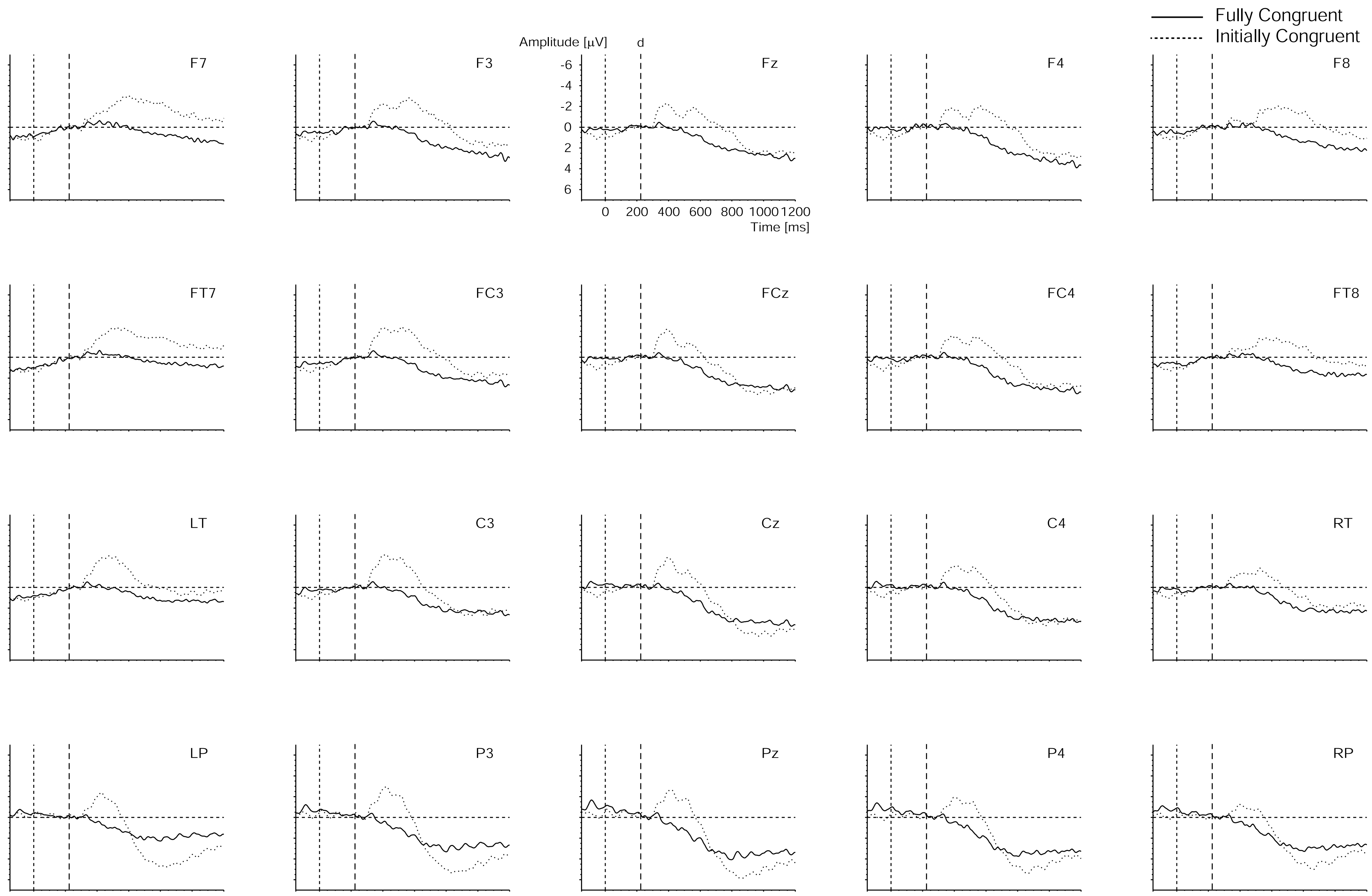

Figure 2-6. *Grand average ERPs to critical words in two conditions, after time locking to the divergence point (marked by line*

condition in the latency interval of 140 to 180 ms. This short-lived effect disappeared, but emerged again at 220 ms and persisted throughout the entire test region. The congruity effect between the FC and IC conditions did not start until 270 ms. These results indicate that at least at 220 ms, but possibly already at 140 ms, sentential context has an influence on the auditory word recognition process.

We were particularly interested in the manifestation of this congruity effect. Would it be a monophasic N400 effect as in the Van Petten et al. study (1999), or a biphasic negative shift consisting of an early negative shift and an N400 effect as in the Connolly and Phillips study (1994) and the Hagoort and Brown study (2000)? These ERP profiles can be linked to different functional interpretations of the elicited components. The single N400 effect hypothesis suggests that the monophasic N400 effect is a reflection of overall semantic processing, without fractionation into lexical selection and integration. The alternative position suggests that the early negative shift and the N400 effect are two distinct effects, reflecting different aspects of the spoken-word recognition process. Our grand average waveforms (Figures 2-2 and 2-3) revealed two clear negative deflections, one peaking at 200 ms and the other at 400 ms. This supports the hypothesis of a separate effect preceding the N400 in the auditory domain.

The early negativity or N200 component was visible in all three conditions with its morphology most pronounced over frontal sites. Statistical analyses revealed that the N200 in the FI condition was larger than the N200 in the FC condition and that the latter did not differ in amplitude from the N200 obtained in the IC condition. The finding that an early negativity could be obtained in all three conditions with the amplitude differentially modulated by the experimental conditions, could be an indication that the N200 effect reflects a distinct aspect of the spoken language comprehension process.

However, the single N400 effect hypothesis could still be maintained on the basis of the obtained electrophysiological profile. One could argue that the N200 effect is not a separate effect, but instead is the first part of a biphasic N400 effect, and that this biphasic N400 effect reflects an undifferentiated semantic process. This would imply that the modulation brought about by the experimental conditions is due to a differential onset of the biphasic N400. We report several findings that provide evidence for the claim that the early negative shift is in fact a separate effect.

The notion of the N200 effect as a separate effect was enhanced by the dissociation with the N400 effect in the IC condition relative to the FC condition. The N200 did not differ in amplitude, however, we did obtain a highly significant N400 effect, with a large N400 amplitude in the IC condition compared to the FC condition. This finding by itself could also be accounted for by the biphasic N400 effect hypothesis. One could argue that the difference in onset of the congruity effects is due to the N400 component setting in later, namely when the anomaly is first detected. However, if the early negativity is an integral part of the electrophysiological profile of the N400 that varies in onset, then the entire biphasic negative deflection should shift in time as a function of anomaly detection. In other words, in the IC condition, where the anomaly is detected later compared to the FI condition, the early negativity should also occur later. This is not the case.

The alternative time-locking procedure that aligned the waveforms of the FC and IC conditions to the moment at which these two signals started to acoustically diverge (the divergence point), provides information about the morphology of the onset of the congruity effects. Figure 2-6 revealed that at frontal sites, where the morphology of the N200 was most pronounced, the N400 in the IC condition had a steep and uniform ascending slope. This in contrast to the manifestation of the congruity effect in the FI condition in Figure 2-2, where an early negativity was obtained in the ascending slope. The finding that after the alternative time-locking procedure the N400 in the IC condition was not preceded by a component similar to the early negativity in the FI condition, indicates that the early negative shift reflects a process that occurs at or around 200 ms after word onset and is not part of the N400 effect.

Finally, the topographical anterior versus posterior analysis after scaling of the absolute size of the effects revealed that the N200 and N400 effects have significantly different spatial distributions. Figure 2-5 shows that the N200 effect had an equal distribution from front to back, whereas the N400 effect had a centro-parietal distribution. Statistically significant differences in scalp distribution are usually interpreted as reflecting the activity of at least partly distinct neuronal populations.

Taken together, these four findings, (a) an early negativity visible in all conditions, but larger in the FI condition, (b) absence of an early negativity effect, together with the presence of an N400 effect in the IC condition relative to the FC condition, (c) the early negativity strictly time-locked to word onset and not affected by the divergence point, and (d) different scalp distributions of the early negative shift and the N400 effect, provide evidence in support of the hypothesis that the N200 effect is separate from and precedes the N400 effect.

The presence of an early negativity is in line with the findings of Connolly and Phillips (1994) and Hagoort and Brown (2000). However, it does not provide evidence for the account given by Connolly and Phillips. They assumed that on the basis of the sentence context an expectation of a particular word would be formed, and that the early negativity would be elicited when the initial phonemes of the perceived word did not match the initial phonemes of the expected word. The major finding that argues against this account is the elicitation of an N200 in all of our conditions, irrespective of whether the phonemes corresponded to the initial phonemes of the highest cloze word. Therefore, the N200 component cannot truly be a *phonological mismatch negativity* (PMN). Even though we cannot rule out the possibility that contextual information can be used on-line to specifically predict a unique lexical item, the conclusion by Van Petten and colleagues (1999) seems more compatible with our findings. They concluded on the basis of an onset of the N400 that could precede the eliciting word's Isolation Point, that semantic processing begins on partial and incomplete information about the perceived word. However, instead of an early onset of the N400 effect, a separate negative shift preceding the N400 effect was obtained in our study as well as in the recent study by Hagoort and Brown (2000). It is not clear why our findings differ in this respect from those of Van Petten and colleagues, especially since the two studies are rather similar. An important difference between the studies could be that all of our sentence-final words began with plosives, whereas Van Petten and colleagues used many different consonants. The use of plosives in our study makes the onsets of the sentence-final words more similar. The clear N100 component in our waveforms provides evidence for this. Although we used natural connected speech, after averaging across trials the waveforms still revealed a clear exogenous marker of word onset. Similarly, the chances of finding the separate N200 effect may become greater if word onsets across trials are fairly homogeneous. In most other studies different consonant types have been used, which might have introduced a latency jitter in the averaged waveforms, masking potential N200 effects.

The early negativity we obtained is reminiscent of another negativity that emerges in the 200 ms range, the Mismatch Negativity (MMN). This component is related to physical mismatches in primary auditory processing (cf. Näätänen, 1990; Näätänen & Alho, 1997). However, next to the primary fact that the manipulation in our experimental conditions was semantic in nature rather than physical, there are several other arguments why our obtained N200 effect is not an MMN. First, the MMN has a topographical distribution that is different from the observed N200 effect; it is maximal at frontal electrode sites, whereas the N200 effect has a flat distribution across the scalp. Second, it shows a polarity inversion at the lateral electrodes, which is absent in the N200 in our study. Third, the electrophysiological profile of the MMN is different. It has an earlier onset and is not as sharply peaked as the N200. Therefore, we propose that the early negative shift in our study has a functionality that is distinct from both the MMN and the N400 effect and that reflects a process in word recognition that precedes the integration of a selected word into the sentential context.[5]

5. We do not claim that the N200 effect is language-specific (cf. Pritchard, Shappell, & Brandt, 1991), but rather that in the context of spoken-word processing, modulation of the N200 component can be related to a distinct aspect of language processing.

We envisage the spoken-word recognition process as follows (cf. Marslen-Wilson & Welsh, 1978; Norris, 1994; Zwitserlood, 1989): On the basis of an analysis of the initial phoneme(s) of the spoken word a number of lexical candidates are accessed. This is a purely form-driven, bottom-up process. After activation of these candidates top-down context information starts to exert its influence. On the basis of their semantic and syntactic features, candidates in the set are assessed with respect to their goodness of fit within the sentence frame. In the presence of semantic features in the activated set that fit the sentence context well, further incoming acoustic information and top-down contextual information are used to narrow down the number of candidates to the one that is most compatible with both form and content constraints. This candidate is subsequently integrated in the sentence context. If, however, none of the lexical candidates fit the context well and consequently the appropriate semantic features are not available, selection of the proper candidate is difficult and can only be done on the basis of the acoustic information. Once the incongruent word is selected from the set of candidates, integration is attempted. In this sense, semantic integration is a mandatory process: integration will be attempted for all words in a sentence.

It has been widely assumed that the amplitude of the N400 indicates whether the integration process runs smoothly: A small N400 indicates that integration of the selected word is easy, a large N400 indicates that integration is difficult. This account is supported by our results: We obtained a small N400 in the FC condition and a significantly larger N400 in the two semantically incongruent conditions. We propose that the amplitude modulation of the early negativity preceding the N400 effect reflects the lexical selection process that occurs at the interface of lexical form and contextual meaning (cf. Hagoort & Brown, 2000). Analogous to the functional interpretation of the N400, the amplitude of the N200 is indicative of whether the initial assessment of the form-based activated lexical candidates reveals the presence of the semantic features that are required by the contextual specifications. A small N200 is elicited when the set contains semantic features that fit the sentence context (as in FC and IC), a large N200 indicates that the set does not contain semantic features that fit the preceding sentence frame well (as in FI).

The exact nature of this early assessment process is not known. After an analysis of the initial sounds of a word, a number of lexical candidates are activated. Upon activation of these words, many semantic features that are associated with them become instantly available to the semantic processing system. At present it is impossible to distinguish between the following two accounts: Either the lexical candidates are individually assessed with respect to their goodness-of-fit within the sentence frame on the basis of their semantic features (a lexical-driven process), or initial assessment takes place on the basis of a field of semantic features that at that moment in time are not linked to specific lexical candidates in the set (feature-driven). The former account assumes that an increase of the N200 amplitude is seen when none of the lexical candidates fit the sentential context, whereas the latter assumes that a larger N200 is elicited when the semantic features that are required for congruity in the sentence frame are not (all) among the field of activated semantic features.

Although these two functional accounts of the N200 effect are speculative at this point, it is important to note that they do make different and testable predictions about the processing of words that vary in their contextual constraint in sentence contexts. The results of the present study show that in relatively highly constraining sentences congruent words elicit both a small N200 and a very reduced N400. In contrast, incongruent words elicit a larger N200 and an increased N400. There is evidence in the literature that the N400 is sensitive to contextual constraint. For example, taking into account that in semantically congruent sentences contextual constraint and cloze probability are tightly linked phenomena (cf. Kutas, Lindamood, & Hillyard, 1984), the studies by Kutas and Hillyard (1984) and Van Petten and colleagues (1999) reveal a sensitivity of the N400 to variations of contextual constraint. In these studies, when the contextual constraint of a sentence was low, congruent words (by definition of low cloze probability) elicited an N400 that was larger in amplitude than the N400 elicited to (high cloze) congruent words in highly constraining sentences. This indicates that although a word is congruent, the absence of highly constraining context makes the integration process to some extent more demanding. Suppose that, in accordance with the lexical-driven account of the N200, individual lexical candidates are assessed with respect to their possible fit within the preceding sentence. Analogous to the N400, we would expect a relatively large N200 to occur in response to congruent words in low constraint sentences: the absence of strong contextual constraints makes it more difficult to assess whether any candidate in the activated set fits the sentence frame very well. Note that this account also predicts a larger N200 in response to congruent words at earlier positions in the (high or low constraint) sentence, since contextual constraint is absent at the beginning of the sentence and increases as the sentence unfolds. However, if the modulation of the N200 amplitude reflects a process in which the presence of appropriate semantic features is assessed, we would expect a small N200 to occur, because most semantic features are compatible with low constraining sentences.

The functional interpretation of the N200 effect as reflecting an initial assessment process (irrespective of the feature-driven or lexical-driven account) also makes some predictions about words differing in cloze probability in equally constraining sentences. The present study revealed that high-cloze probability words elicit an N200 that is small in amplitude. From our claim it follows that words of a lower cloze probability should elicit larger N200s, since the lexical candidates or the field of semantic features in the activated set would not be considered to fit the sentence context very well. Words with low cloze probabilities (in low constraint sentences) should produce the largest N200, possibly very close to the N200 elicited by fully anomalous words in high constraint sentences. These predictions need to be evaluated in future research.

An issue that we have not yet touched upon but that needs some clarification, is the apparent differential N400 effect between the FI and IC conditions. It is not immediately clear why two sentence-final words that are both anomalous in a sentence frame should elicit N400s that differ in amplitude. One possibility is that the N400 effect is due to a lexical frequency effect, since the mean frequency of the words used in the two conditions differed, albeit only slightly (a log frequency of 2.62 per 42 million in IC and 2.49 per 42 million in FI). However, the work by Van Petten and Kutas (1990, see also Van Petten, 1995) has shown that frequency effects dissipate over the course of a sentence. Although low frequency words are usually associated with larger N400s than high frequency words, this frequency effect disappears when contextual constraint is increased as the sentence unfolds. Since the mean frequency of our critical words did not greatly differ across conditions and since these words were presented in sentence-final position, a lexical frequency effect does not seem to be a viable account for the N400 effect that we obtained.

Another suggestion comes from a word priming study by Praamstra, Meyer and Levelt (1994). They examined phonological priming effects in an auditory lexical decision task and found that the ERP waveforms were more negative for unrelated targets than for alliterating targets (e.g. *beeld-mast* [*statue-mast*] versus *beeld-beest* [*statue-animal*]). Also, in another experiment waveforms to unrelated targets were more negative than to rhyming targets (e.g. *graaf-steeg* [*duke-alley*] versus *graaf-staaf* [*duke-rod*]). Praamstra and colleagues concluded that the N400 amplitude is sensitive to phonological as well as semantic manipulations. It is unclear how these form-priming effects for words presented in isolation relate to the processing of words in sentences. Note that in the study by Van Petten and colleagues (1999), the phonological manipulation in the rhyming condition did not elicit an N400 of lower amplitude than in the anomalous condition.

We propose a different view of the apparent N400 effect, namely that the observed shift is carried over from the preceding N200 effect. Figure 2-3 shows that the onset of the N400 in the FI and IC conditions occurs at about 275 ms. As a result of the N200 effect, at 275 ms the FI condition is already larger in amplitude than in the IC condition. This differential N200 effect between the two conditions might then lead to an add-on amplitude effect in the N400 latency window. We performed additional analyses in this latency window after applying a baseline correction in the 250 to 300 ms latency interval to remove the differential N200 effect between the FI and IC conditions, to see what the effect would be on the waveforms in the N400 latency window. Figure 2-4 shows that after baseline correction in the 250 to 300 ms interval, the relative amplitudes of the two conditions actually did not differ from each other, and the statistical analyses revealed that an N400 effect in fact was absent.

Figure 2-4 also shows that after the alternative baseline correction procedure in the 250 to 300 ms interval, the difference in the size of the late positivity effect that we observed between the FI and IC conditions disappears. This was confirmed by our statistical analyses. Late positivity effects to sentence-final words are thought to be related to post-lexical wrap-up processes (cf. Juottonen et al., 1996). Presumably, after the sentence-final word has been integrated in the context, an evaluation of the overall message takes place. The late positivity, which is largest in the FI and IC conditions, indicates that overall evaluation of the sentence is difficult, since sentence-final words in these conditions were anomalous.

Overall, the results obtained in this experiment suggest that the N200 effect reflects a process that occurs at the interface of lexical form and contextual meaning, in which form-based activated lexical candidates are assessed with respect to their semantic goodness-of-fit with the sentential contextual specifications. After this early assessment process, selection of one specific candidate takes place on the basis of additional acoustic input and supporting context. The N400 effect reflects semantic integration of the selected candidate into the higher-order meaning of sentence context. Even though it remains possible that context already has an influence before any bottom-up information has been received, our findings seem most compatible with word identification models that claim that there is bottom-up priority of acoustic processing of the initial signal of the perceived word before top-down information exerts its influence.

The Cascaded Nature of Lexical Selection and Integration in Spoken Words Revealed by N200 and N400 Effects

CHAPTER 3

Daniëlle van den Brink, Colin M. Brown, and Peter Hagoort[1]

ABSTRACT

Two event-related brain potential experiments were carried out to investigate the exact nature of the lexical selection process and the temporal relationship between lexical selection and the semantic integration processes in spoken-word recognition as revealed by N200 and N400 effects. Results indicated that during lexical selection, instead of merely checking for appropriate features, lexical candidates as a whole are assessed with respect to their goodness of fit within the preceding sentence frame. This study also revealed that lexical selection and semantic integration are cascading processes in that semantic integration processing can start before the acoustic information allows the selection of a unique candidate, and thus, seems to be attempted in parallel for multiple candidates that are still compatible with the bottom-up acoustic input.

1. This chapter has been submitted for publication.

INTRODUCTION

Understanding spoken language happens seemingly effortlessly. However, in reality it is no feeble exercise. On the contrary, when we hear a spoken word, numerous brain areas work together to analyze the acoustic information, select the proper word by mapping the sensory input onto stored lexical knowledge, extract the meaning of that word and integrate it into an ongoing sentential context. All of this in half a second. This study addresses the following theoretical questions: a) How does selection of the proper word take place? More specifically, what is the nature of the selection process, and b) are lexical selection and semantic integration of the word's meaning into the preceding context two sequential processes or do they, to a certain extent, overlap?

A technique that seems especially suitable for studying brain processes in real time is the recording of event-related potentials (ERPs). ERPs reflect the sum of simultaneous postsynaptic activity of a large population of neurons recorded at the scalp as small voltage fluctuations in the electroencephalogram. Because of the high temporal resolution of this technique it has proven to be a sensitive measure of real-time language processing. In a previous study investigating early contextual influences on spoken-word recognition (Van den Brink, Brown & Hagoort, 2001) we obtained two ERP effects that were psychophysiologically distinguishable. Both were negative deflections, one peaked at 200 ms after word onset and was labeled the N200 effect, the other was the well-documented N400 effect, peaking at 400 ms after word onset (cf. Kutas & Hillyard, 1980). The N400 effect is related to semantic processing of the eliciting word. On the basis of our previous study and studies by Brown and Hagoort (1993), Hagoort and Brown (2000), and Holcomb (1993) we concluded that the N400 amplitude indexes the relative ease with which the meaning of a word is integrated in the context. We further concluded that the preceding N200 effect reflects the lexical selection process, where word-form information resulting from an initial phonological analysis and content information derived from the context interact. In this study we want to shed a light on the exact nature of this early process.

The spoken-word recognition process is assumed to consist of the following subprocesses (cf. Marslen-Wilson & Welsh, 1978; Norris, 1994; Zwitserlood, 1989): On the basis of an analysis of the initial phoneme(s) of the spoken word multiple lexical candidates that share word onset are accessed. This is a purely form-driven, bottom-up process. After activation of these candidates top-down context information starts to exert its influence. On the basis of their semantic and syntactic features, candidates in the set are assessed with respect to their goodness of fit within the sentence frame. In the presence of candidates in the activated set that fit the sentence context well, further incoming acoustic information and top-down contextual information are used to narrow down the number of candidates to the one that is most compatible with both form and content constraints. This candidate is subsequently integrated in the sentence context. If, however, none of the lexical candidates fit the context well and consequently the appropriate semantic features are not available, selection of the proper candidate is difficult and can only be done on the basis of the acoustic information.

Previous studies have shown that the amplitude of the N400 indicates whether the integration process runs smoothly: A small N400 indicates that integration of the selected word is easy, a large N400 indicates that integration is difficult. We have proposed that the N200 effect reflects the lexical selection process that occurs at the interface of lexical form and contextual meaning (Hagoort & Brown, 2000; Van den Brink et al., 2001). Analogous to the functional interpretation of the N400, the amplitude of the N200 is indicative of whether the initial assessment of the form-based activated lexical candidates reveals the presence of semantic features that fit the contextual specifications. A small N200 is elicited when the set contains semantic features that fit the sentence context, a large N200 indicates that the set does not contain semantic features that fit the preceding sentence frame well. This study addresses the issue of the exact nature of the building blocks used in this early process.

During the lexical selection process, multiple lexical candidates that share word onset are activated on the basis of the acoustic analysis of the initial sounds of a spoken word (McQueen, Norris, & Cutler, 1994; Norris, 1994; Norris, McQueen, & Cutler, 1995; Goldinger, Luce, & Pisoni, 1989; Goldinger, Luce, Pisoni, & Marcario, 1992; Marslen-Wilson, 1987, Marslen-Wilson & Welsh, 1978; McLelland & Elman, 1986). Upon activation of these words, many semantic features that are associated with them become quickly available. At present it has been impossible to distinguish between the following two accounts: Either the lexical candidates are individually assessed with respect to their goodness-of-fit within the sentence frame on the basis of their semantic features (a lexical-driven process), or initial assessment takes place on the basis of a field of semantic features that at that moment in time are not linked to specific lexical candidates in the set (feature-driven). The former account assumes that an increase of the N200 amplitude is seen when none of the lexical candidates fit the sentential context, whereas the latter assumes that a larger N200 is elicited when the semantic features that are required for congruity in the sentence frame are not (all) among the field of activated semantic features.

These two functional accounts of the selection process make different and testable predictions about the processing of words that vary in their contextual constraint in sentence contexts. The results of our previous study have shown that in relatively highly constraining sentences congruent words elicit both a small

N200 and a much reduced N400. In contrast, incongruent words elicit a larger N200 and an increased N400. There is evidence in the literature that the N400 is sensitive to contextual constraint. For example, taking into account that in semantically congruent sentences contextual constraint and cloze probability are tightly linked phenomena (cf. Kutas, Lindamood, & Hillyard, 1984), studies by Kutas and Hillyard (1984) and Van Petten, Coulson, Rubin, Plante, and Parks (1999) reveal a sensitivity of the N400 to variations of contextual constraint.[2] In these studies, when the contextual constraint of a sentence was low, congruent words (by definition of low cloze probability) elicited an N400 that was larger in amplitude than the N400 elicited to (high cloze) congruent words in highly constraining sentences. This indicates that although a word is congruent, the absence of highly constraining context makes the integration process to some extent more demanding. Suppose that, in accordance with the lexical-driven account of the N200, individual lexical candidates are assessed with respect to their possible fit within the preceding sentence. Analogous to the N400, a relatively large N200 should occur in response to congruent words in low constraint sentences: the absence of strong contextual constraints makes it more difficult to assess whether any candidate in the activated set fits the sentence frame very well. Note that this account also predicts a larger N200 in response to congruent words at earlier positions in the (high or low constraint) sentence, since contextual constraint is absent at the beginning of the sentence and increases as the sentence unfolds. However, if the modulation of the N200 amplitude reflects a process in which the presence of appropriate semantic features is assessed, a small N200 should occur, since most semantic features are compatible with low constraining sentences. Therefore, our design included semantically high as well as semantically low constraining sentences.

In this study the temporal relationship between lexical selection and semantic integration was also evaluated. We investigated whether there is some ’magical moment’ where lexical selection ends and semantic integration begins, or whether these two processes are of a cascading nature with the semantic integration process starting before lexical selection is completed. In the case of a semantically congruent word it is entirely conceivable that the presence of a candidate in the activated set that fits the context well, selection of the proper word is aided by this initial assessment process. However, what happens in the case of a semantically anomalous word, i.e. when the activated set does not contain a candidate that fits the context? Is semantic integration postponed until one candidate has been selected on the basis of acoustic input alone, or is integration attempted for more than one candidate? Van Petten and colleagues (1999)

2. Cloze probability of a word is defined as the percentage of subjects who use that word to end a particular sentence (see Bloom & Fischler, 1980).

addressed this very issue. In their study they examined the temporal relationship between the moment a word can be identified uniquely and the initiation of semantic integration by using the sensitivity of the N400. They made use of information about the isolation points (IP) of words, i.e., the minimum amount of acoustic signal necessary to identify a spoken word in the absence of contextual information (cf. Grosjean, 1980). It was hypothesized that depending on whether semantic integration begins only after a word has been uniquely identified or works with partial information resulting from perceptual analyses, responses to words that fit a sentence context should begin to differ from words that do not fit either shortly after IP, or even before IP, when the word becomes discrepant with, what they assumed were semantic expectations. Their experimental items consisted of high to low constraining sentences that ended either with (a) the highest cloze probability word, (b) a word that rhymed with the highest cloze probability word, (c) a semantically anomalous word that shared the same initial phonemes as the highest cloze probability word, or (d) an anomalous word of which the initial phonemes differed from those of the highest cloze probability word. For example: “It was a pleasant surprise to find that the car repair bill was only seventeen *dollars*/*scholars*/*dolphins*/*bureaus*”.

The results revealed that the sentence-final words in the three anomalous conditions all elicited a significantly larger N400 than the high-cloze probability endings. Moreover, the onset of the N400 effect differed between conditions. In the fully anomalous and rhyme conditions, the onset of the N400 effect preceded the IP of the sentence-final words. Relative to these two conditions, the onset of the N400 effect in the condition where the anomalous word shared its phonemic onset with the highest cloze probability word, was found to be delayed by some 200 ms and corresponded to the IP. It was concluded that the onset of the N400 effect was related to the moment at which the acoustic input first diverged from semantic expectation. Van Petten and colleagues concluded that the N400 effect reflects semantic processing of the perceived word and that this semantic processing begins on partial and incomplete information about the perceived word.

However, the results of their study did not show a distinguishable early effect preceding the N400 effect. It is possible that using the same kind of stimuli as in our previous study, with plosives as onset phonemes, the congruity effect obtained by Van Petten and colleagues (1999) can in fact be divided into an early N200 effect preceding the IP and an N400 effect after IP. We suggest that the use of plosives makes the onsets of sentence-final words more homogeneous and therefore, prevents a latency jitter in the averaged waveforms masking potential N200 effects, which may occur with use of different consonant types as word onsets. The option of two separate effects was also considered by Van Petten and colleagues on the basis of two studies by Connolly, Phillips, Stewart and Brake (1992) and Connolly and Phillips (1994), who argued for the existence of a separate component related to phonological processing, called the *Phonological Mismatch Negativity* (PMN). However, Van Petten and colleagues discarded this idea, based on the fact that they, themselves, had not obtained a separate component and that the PMN and N400 in Connolly and colleagues' studies not only appeared to have the same sensitivity to sentence context, but also had the same spatial distribution. Our previous work has shown, that using plosives as onset phonemes, we were able to obtain an N200 and N400 with different topographical distributions (Van den Brink et al., 2001). We, therefore, decided to test this alternative interpretation of the congruity effect obtained by Van Petten and colleagues (1999) being composed of an N200 effect preceding IP followed by an N400 effect after IP by presenting only an initial part of the sentence-final words.

If semantic integration into the prevailing context does not set in until the anomalous candidate has been selected on the basis of an initial phonological analysis (Sequential Hypothesis), we expected the partially presented sentence-final words to reveal an N200 effect in the absence of an N400 effect. However, if lexical selection and semantic integration are cascading processes, and semantic integration works with several candidates (Cascading Hypothesis), the ERPs of the partially presented completions would show an N200 effect followed by an N400 effect. In doing so, we tried to make sure that the initial part of the sentence-final word was long enough to, theoretically, initiate the lexical selection process (i.e. contained at least the first two phonemes, preferably including a full vowel), but did not exceed the IP of the word.

So, our design looked as follows: First, we wanted to replicate our previous finding of an N200 effect followed by an N400 effect. Therefore, we had subjects listen to Dutch sentences that ended with a word that was either (a) congruent, e.g. "Deze veertienjarige pianist heeft duidelijk veel *talent*" ("This fourteen year old pianist obviously has a lot of *talent*"), or (b) semantically anomalous beginning with phonemes that differed from the congruent completion, e.g. "Deze veertienjarige pianist heeft duidelijk veel *klimaat*" ("This fourteen year old pianist obviously has a lot of *climate*"). Second, to investigate the building blocks of the selection process we included (c) a low constraining carrier sentence that ended with the fully presented words from the congruent completions of the semantically constraining sentences, e.g. "Je gaat nu luisteren naar het woord *talent*" ("You now hear the word *talent*"). Finally, to test whether lexical selection and semantic integration are sequential or cascading processes, in three additional conditions the sentence-final words were cut off prior to the IP: (d) partially congruent, e.g. "Deze veertienjarige pianist heeft duidelijk veel *ta*." ("This fourteen year old pianist obviously has a lot of *ta*"), (e) partially incongruent, e.g. "Deze veertienjarige pianist heeft duidelijk veel *kli*" ("This fourteen year old pianist obviously has a lot of *cli*"), and (f) the partially presented low constraint, e.g. "Je gaat nu luisteren naar het woord *ta*" ("You now hear the word

Table 3-1. *Example of experimental materials translated into English*

Condition	*Sentence*	*Critical Word*	
WWC	This fourteen year old pianist obviously has a lot of	*talent*	/tælənt/
WWA	This fourteen year old pianist obviously has a lot of	*climate*	/klaɪmət/
WWLC	You now hear the word	*talent*	/tælənt/
PWC	This fourteen year old pianist obviously has a lot of	*ta*	/tæ/
PWA	This fourteen year old pianist obviously has a lot of	*cli*	/klaɪ/
PWLC	You now hear the word	*ta*	/tæ/

ta”). See Table 3-1 for examples and Appendix for full set of experimental materials.

For the fully presented words in the semantically high constraining sentences (Whole Word Congruent and Whole Word Anomalous) we expected to find an N200 component in both conditions, with a larger amplitude in the Whole Word Anomalous condition. In the anomalous condition this N200 component would be followed by a large N400 component, whereas in the congruent condition this N400 component would be very much reduced (replication of our previous study; Van den Brink et al., 2001). For the high versus low constraining contexts, in the fully presented words the Lexical-driven Hypothesis predicted an N200 effect, whereas the Feature-driven Hypothesis did not: If during lexical selection, lexical candidates are assessed with respect to their possible fit within the sentence, a relatively large N200 will occur in response to fully presented congruent words in semantically low constraint sentences (Whole Word Low Constraint); the absence of strong contextual constraints makes the selection process of a lexical candidate more demanding. However, if the modulation of the N200 amplitude reflects a process in which the presence of appropriate semantic features is assessed, we expect a relatively small N200 to occur, since most semantic features are compatible with low constraining sentences. In both cases the N200 component should be followed by an N400 component.

In order to obtain the partially presented words we first performed an extensive gating study of isolated words to identify the IP for each word. On the basis of the results we were able to pick a fragment for each word which was long enough to correctly identify the first phonemes of the word (preferably including the vowel), but was not long enough to identify the word with much confidence (i.e., preceded the IP). For the partially presented words we expected to find N200 components similar to those found in their fully presented counterparts; a small N200 in the congruent condition (Partial Word Congruent), an increased

N200 in the anomalous condition (Partial Word Anomalous), and depending on the hypothesis, a small or large N200 in the low constraint condition (Partial Word Low Constraint). Now, if semantic integration follows up on identification of the anomalous word and the cut-off point of the sentence-final words precedes the recognition point of that word, we did not expect to find an N400 in the Partial Word Anomalous condition, since the word would not have been recognized yet. In the anomalous completions the recognition point is equal to the IP of that word, due to the lack of the appropriate semantic contextual constraint for that word (the semantic context cannot help in identifying the word). However, in congruent completions the semantic context might move the recognition point forward, and therefore, precede the IP of that word. In any case, the sequential hypothesis does not predict an N400 effect between the partially presented congruent and anomalous completions; the anomalous word is not recognized, and therefore will not be integrated (no N400), and the congruent word is either recognized and easily integrated (much reduced N400) or also not recognized and not integrated (no N400). However, if semantic integration is initiated before the lexical selection process is completed, an N400 effect might still occur. This also holds for the partially presented words in low constraining context (Partial Word Low Constraint); whether or not an N400 effect would be elicited depends on the predictions made by the Sequential (no effect) or Cascading Hypothesis (an effect).

EXPERIMENT 1

Method

Subjects

The experiment was conducted with 24 native speakers of Dutch (21 female, mean age 22, range 19-26 years) from the subject pool of the Max Planck Institute for Psycholinguistics. All had normal to corrected-to-normal vision and were right-handed (nine subjects reported having a left-handed parent or sibling). None of the subjects had any neurological impairment or had experienced any neurological trauma. Nor had any of the subjects participated in the pretests (see below). Subjects were paid for their participation.

Materials

The experimental items consisted of a set of 260 quadruplets of semantically constraining sentences across four experimental conditions and a set of 130 carrier phrases followed by a sentence-final word from one of the 260 quadruplets spliced to the carrier phrase. For the constraining contexts, the sentences in each quadruplet were identical up to the final word. The sentence-final word was either congruent or anomalous and was presented as a whole or was partly cut off. In the Whole Word Congruent condition (WWC), sentences ended with a high cloze probability word, e.g., “Deze veertienjarige pianist heeft duidelijk veel *talent*” (“This fourteen year old pianist obviously has a lot of *talent*”). In the Whole Word Anomalous condition (WWA), sentences ended with a word that was semantically anomalous and also had initial phonemes that differed from the highest cloze probability word, e.g., “Deze veertienjarige pianist heeft duidelijk veel *klimaat*” (“This fourteen year old pianist obviously has a lot of *climate*”). In a third condition the sentences ended with the same highest cloze probability word as in the WWC condition, but only the initial part was presented, e.g., “Deze veertienjarige pianist heeft duidelijk veel *ta*” (“This fourteen year old pianist obviously has a lot of *ta*”). This condition is called the Partial Word Congruent condition (PWC). In a fourth condition, the Partial Word Anomalous condition (PWA), the anomalous sentence-final word was only partly presented, e.g., “Deze veertienjarige pianist heeft duidelijk veel *kli*” (“This fourteen year old pianist obviously has a lot of *cli*”).

The 260 quadruplets were derived from a set of sentence materials that had been used in a previous study and which were part of a larger set of sentences that had been submitted to a cloze test. Thirty subjects from the subject pool of the Max Planck Institute for Psycholinguistics were given a list of 350 sentences with the final word omitted. Subjects were asked to carefully read the sentences and to fill in the first word that came to mind at the position of the omitted sentence-final word. On the basis of the results, a set of 260 sentences with a cloze probability of .50 or higher formed the basis for the 260 quadruplets used in this experiment. Items for the WWA and PWA conditions were constructed by replacing the sentence-final word with a semantically anomalous word with word-initial phonemes that differed from the beginning phonemes of the high cloze probability word and other congruent words.

The cutoff point of the sentence-final words in the two partial conditions had to precede the IP of those words. IP of a word was defined as the gate at which at least 67% of the participants correctly identified the word, and accuracy remained above 60% at subsequent gates.[3] To obtain the IP for each sentence-final word in the WWC and WWA conditions, we had 24 subjects from the sub-

3. These criteria are similar, if not somewhat stricter than those used in a study by Van Petten and colleagues (1999), who defined IP as the gate at which 70% of the participants (seven out of ten) correctly identified the word, and accuracy remained above 60% at subsequent gates.

ject pool of the Max Planck Institute for Psycholinguistics perform an extensive gating task on the 520 isolated sentence-final words (260 sentences with each 2 completions; congruent and anomalous). On each trial, subjects were auditorily presented with increasingly longer fragments (in steps of 50 ms) of one particular word. Amplitude over the final 10 ms of the fragments was tapered to zero to avoid clicks in the signal that would result from a sharp cutoff. For each fragment, the subjects were asked to type in on a keyboard what they thought the word was going to be, and in addition to give a confidence rating. On the basis of the results we were able to pick a fragment for each word which was long enough to correctly identify the first phonemes of the word (preferably including the vowel), but was not long enough to identify the word with much confidence (i.e., preceded IP).

Because the sentences within each quadruplet were identical up to the final word, they had the same length (mean length of 10.8 words; range 5-15) and were equally constraining; the critical words in the WWC condition had a mean cloze probability of .84 (range: .50-1.0). All sentence-final words were reasonably well-known nouns selected from a Dutch word corpus called CELEX (Baayen, Piepenbrock & Van Rijn, 1993); all critical words in the two Whole Word conditions had a frequency of at least 30 counts per 42 million (this equals 1.48 log), with a mean duration of 516 ms and a mean log frequency of 2.87 in the WWC condition, and 515 ms and 2.49 in the WWA condition. The fragments in the two Partial Word conditions had a mean duration of 159 ms in the PWC condition, and 169 ms in the PWA condition. Each sentence-final word began with a plosive. This provided a clear physical marker that facilitated the alignment of the ERP-waveform to the onset of the sentence-final word.

Four lists were constructed to ensure that no subject heard the same sentence or critical word more than once. In addition to the set of 260 semantically constraining experimental items (65 per condition per list), a set of 65 filler sentences was constructed. These fillers were all semantically congruent and were fully presented, to increase the number of sentences that were correct (congruent and presented as a whole). In a separate block following these 325 (260 + 65) items a set of 130 low constraint items was presented. These low constraint items consisted of 4 different low constraining carrier phrases with a critical word taken from the WWC and the PWC conditions. The critical words were spliced to the carrier phrase to form the Whole Word Low Constraint condition (WWLC): e.g. “Je gaat nu luisteren naar het woord *talent*” (“You now hear the word *talent*”) and the Partial Word Low Constraint condition (PWLC): e.g. “Je gaat nu luisteren naar het woord *ta*” (“You now hear the word *ta*”). The critical words in the Low Constraint conditions were randomized across the four lists to ensure that none of the critical words were presented to the same subject twice (i.e., in the highly constraining Congruent conditions and in the Low Constraint conditions).

Finally, the experimental lists were preceded by a practice list of 16 items, which reflected the experimental materials. The practice list was used to familiarize the subjects with the experimental procedure.

The experimental sentences, carrier phrases, fillers and practice sentences were all spoken by a female speaker, with normal intonation at a normal speaking rate, and were recorded in one recording session. The sentences were originally recorded in triplets (see Van den Brink et al., 2001), to make sure that intonation and speaking rate were kept constant within each set. In the Low Constraint conditions the critical words were spliced to the carrier phrases. Sentences were spoken in a sound-attenuating booth and recorded on a digital audio tape. The DAT-recordings were sampled at 16 kHz mono and stored on computer disk. A speech waveform editing system was used to mark the onset of the sentence-final words and to splice the critical words to the carrier phrases in the Low Constraint conditions.

Procedure

Subjects were tested individually in a dimly illuminated sound-attenuating booth. They were seated in a comfortable reclining chair, instructed to move as little as possible, and told that they would hear a number of sentences. Their task was to attentively listen to these sentences and to try to understand them. In addition they were told that several sentences would be semantically anomalous and that some of the sentence-final words would only partially be presented. No additional task demands were imposed.

Each trial began with a 300 ms warning tone, followed after 1200 ms silence by the spoken sentence. The next trial began 4100 ms after sentence offset. To ensure that subjects would not blink during and shortly after presentation of the sentence, 1000 ms prior to the beginning of the sentence a fixation point (an asterisk) was displayed on the computer screen. The asterisk remained on the screen until 1600 ms after offset of the spoken sentence. Subjects were instructed to fixate on the asterisk during presentation of the sentences, but were free to blink and move their eyes when the asterisk was not displayed on the screen. Subjects listened to the stimuli via closed-ear headphones. After the practice session, the semantically constraining trials were presented in 4 blocks of approximately 12 minutes, followed by two blocks of 10 minutes containing the Low Constraint trials.

EEG-recording

The EEG was recorded from 29 Ag/AgCl-sintered electrodes mounted in an elastic cap, each referred to the left mastoid (see Figure 2–1 for the electrode distribution). Five electrodes were placed according to the 10-10 Standard System of the American Electroencephalographic Society over midline sites at Fz, FCz, Cz, Pz, and Oz locations, along with 9 lateral pairs of electrodes over standard sites on frontal (AF3, AF4, F3, F4, F7 and F8), fronto-central (FC3 and FC4), fronto-temporal (FT7 and FT8), central (C3 and C4), centro-parietal (CP3 and CP4), parietal (P3 and P4), and occipital (PO7 and PO8) positions. Three additional pairs were placed laterally over symmetrical positions: (a) a temporal pair (LT and RT) placed laterally to Cz, at 33% of the interaural distance, (b) a temporo-parietal pair (LTP and RTP) placed 30% of the interaural distance lateral and 13% of the nasion-inion distance posterior to Cz, and (c) a parietal pair midway between LTP/RTP and PO7/PO8 (LP and RP). Vertical eye movements were monitored via a supra- to sub-orbital bipolar montage. A right to left canthal bipolar montage was used to monitor for horizontal eye movements. Activity over the right mastoid bone was recorded on an additional channel to determine whether there were differential contributions of the experimental variables to the presumably neutral mastoid site. No such differential effects were observed.

The EEG and EOG recordings were amplified with a SynAmp Model 5083 EEG amplifier (NeuroScan Inc., Herndon, Va, USA), using a hi-cut of 30 Hz (notch filter 60 Hz) and a time constant of 8 s (0.02 Hz). Electrode impedances were kept below 3 kOhm for the EEG recording and below 5 kOhm for the EOG recording. The EEG and EOG signals were digitized on-line with a sampling frequency of 200 Hz.

Results

For 24 subjects, data from critical trials were analyzed according to the following procedure. Prior to off-line averaging, all single-trial waveforms were screened for eye movements, electrode drifting, amplifier blocking, and EMG artifacts in a critical window that ranged from 150 ms before onset of the sentence-final word, to 1900 ms after onset of the sentence-final word. Trials containing artifacts were rejected (average number of trials per condition 8.5%, range 7.9 to 9.5% per condition). For each subject, average waveforms were computed across all remaining trials per condition after baselining the waveforms of the individual trials on the basis of the averaged activity in a time window of 150 ms preceding onset of the sentence-final word.

Figure 3-1 displays the grand average waveforms of the fully presented words (Whole Words) in high constraining sentences by electrode site time-locked to the onset of the sentence-final word. There are several things to note. First, in both conditions, the sentence-final words elicited an N100 component. This component appears to be slightly larger (but is in fact not) in the WWA condition than in the WWC condition. This is most visible in the frontal to central

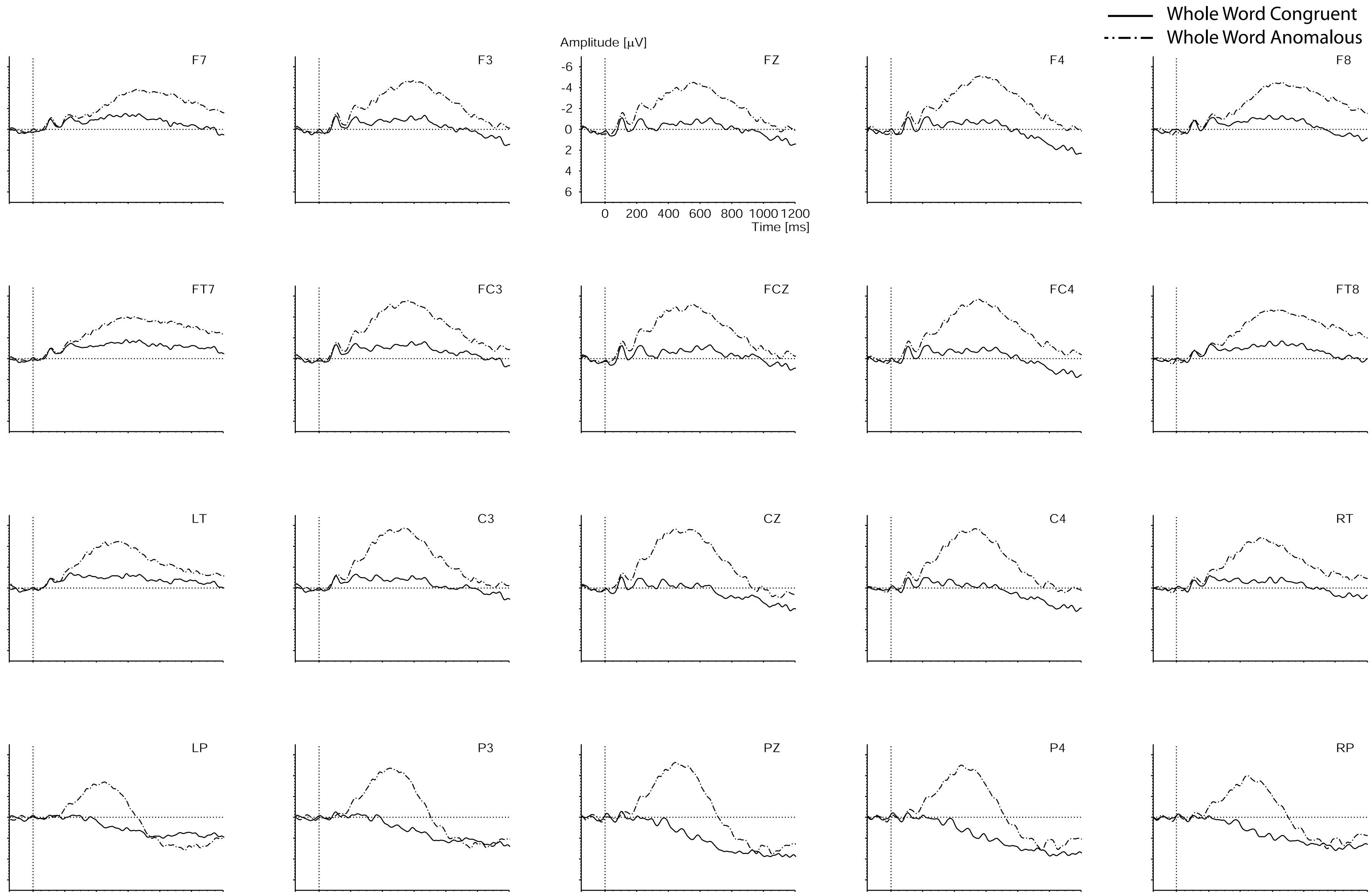

Figure 3-1. *Grand average ERPs to critical words in WWC and WWA. Time 0 is the onset of critical words. Negative polarity is plotted upwards.*

electrodes, including the temporal electrodes. It is not common to find a clear N100 component in a study using natural connected speech, given the continuous nature of the speech signal (Connolly, Stewart & Phillips, 1990; Connolly et al., 1992, 1994). However, as in our previous study (Van den Brink et al., 2001), all sentence-final words began with a plosive, which is a relatively clear onset marker in connected speech. In addition, the homogeneity of the sentence-final word onsets presumably added to the clear presence of the N100 component in the averaged waveforms. Second, a negativity at approximately 200 ms is visible in the waveforms. This negativity is apparent in both conditions, but is largest in the WWA condition and is most visible over the frontal sites. Third, the semantically anomalous sentence-final words in the WWA conditions elicit a broad negativity peaking at approximately 400 ms, which is more negative than the ERP elicited in the WWC condition. Its latency characteristics and morphology are similar to previously reported N400 effects.

Figure 3-2 displays the grand average waveforms of the Whole Words in high versus low constraint contexts by electrode site time-locked to the onset of the sentence-final word. The first thing to note is that the sentence-final words in the low constraint context did not elicit a clear N100 component. Second, a negativity at approximately 200 ms is visible in the waveforms. This negativity is apparent in both conditions, but is largest in the WWLC condition. Third, the sentence-final words in the WWLC conditions elicit a broad negativity peaking at approximately 400 ms, which is more negative than the ERP elicited in the WWC condition. Its latency characteristics and morphology are similar to previously reported N400 effects.

Figure 3-3 displays the grand average waveforms of the partially presented words (Partial Words) in high constraining sentences by electrode site time-locked to the onset of the sentence-final word. As in the Whole Word conditions, in both Partial Word conditions, the sentence-final words elicited an N100 component. This component is most visible in the frontal to central electrodes, including the temporal electrodes. Second, the most striking feature in the two conditions is an increased negativity peaking at approximately 300 ms, which is more negative in the anomalous condition than in the congruent condition. Its morphology is different from the waveforms in the Whole Word conditions and, therefore, might be related to the moment of acoustic offset of the sentence-final word. Especially in the partially presented conditions the sentence ends rather abruptly. Therefore, we decided to collapse the two partially presented conditions and time-lock the waveforms on a trial-by-trial basis to the acoustic offset of each individual word. Figure 3-4 displays the grand average waveform by electrode time-locked to the acoustic offset of the partially presented words. What can be seen in the figure is an increased negativity peaking at 150 ms, over poste-

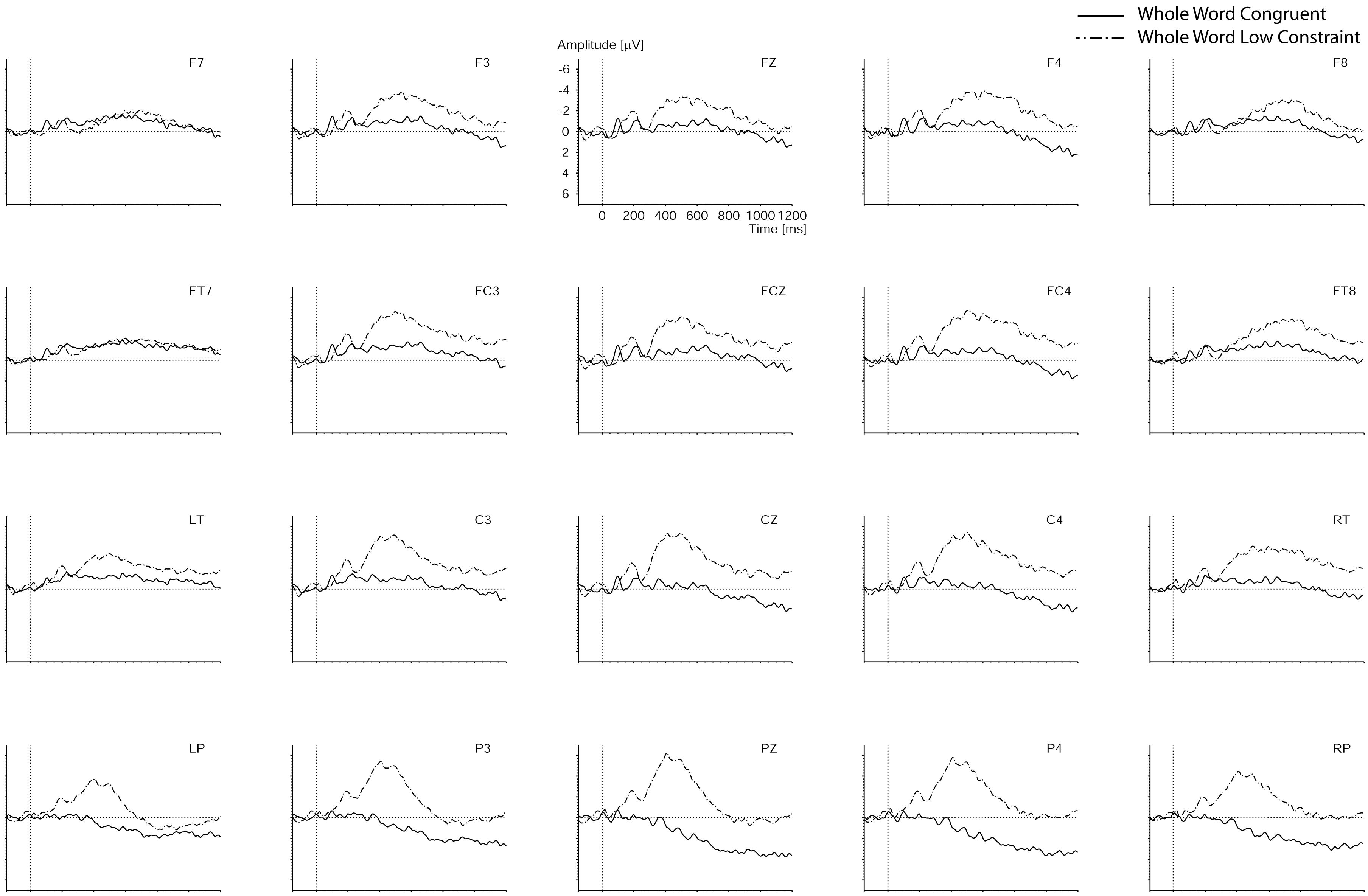

Figure 3-2. *Grand average ERPs to critical words in WWC and WWLC. Time 0 is the onset of critical words.*

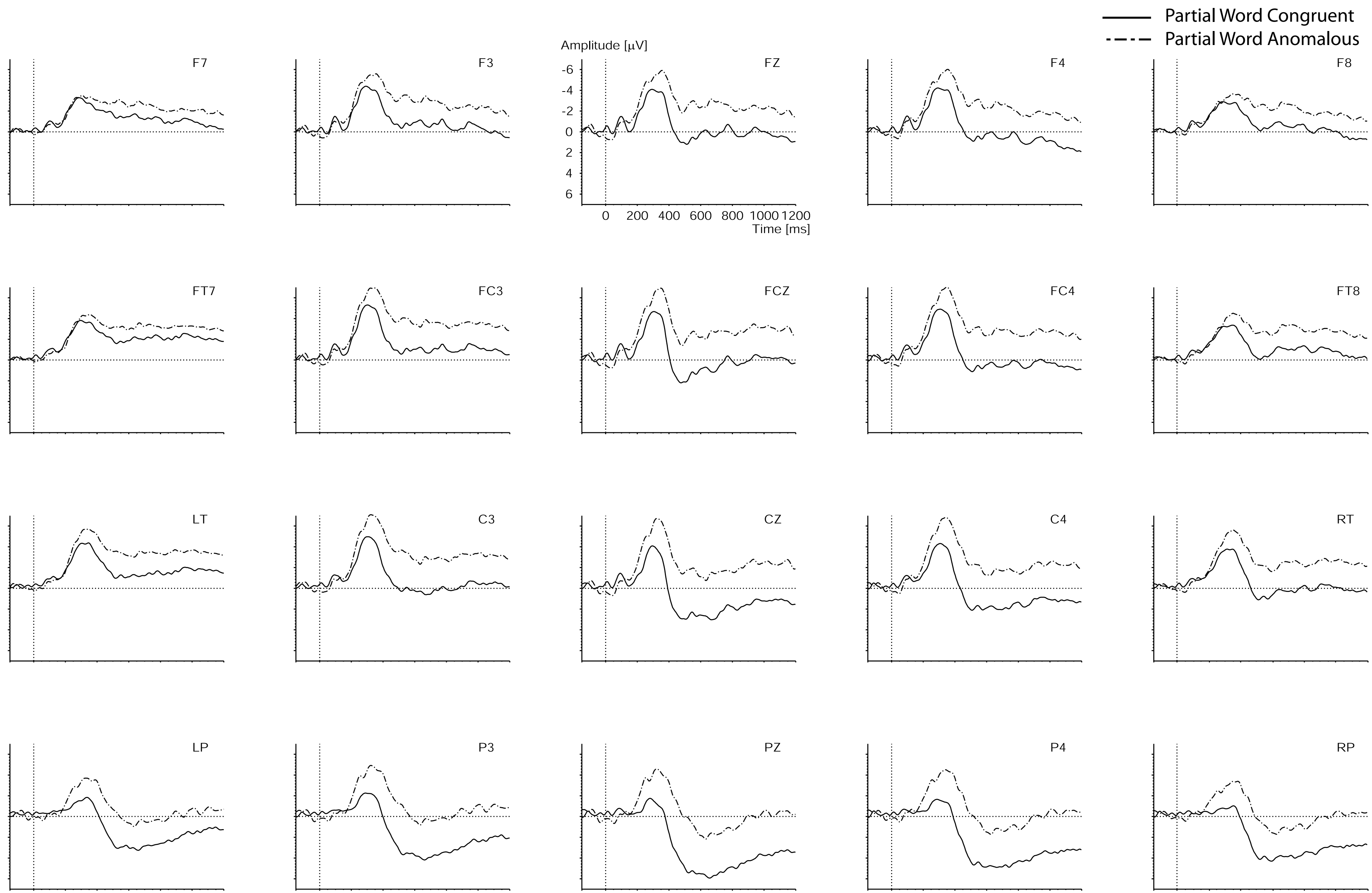

Figure 3-3. *Grand average ERPs to critical words in PWC and PWA. Time 0 is the onset of critical words.*

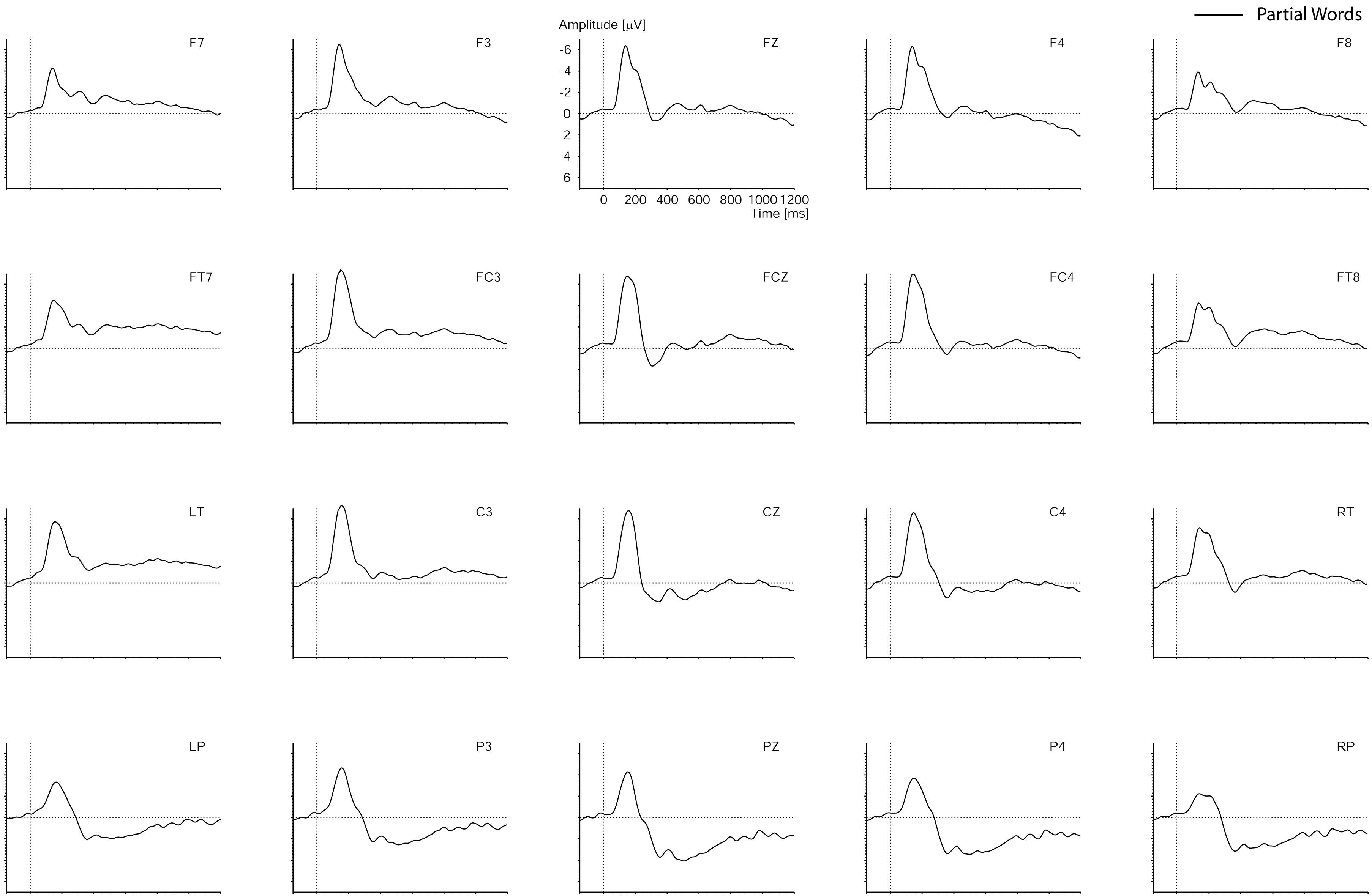

Figure 3-4. *Grand average ERPs to all partial critical words in semantically constraining sentences. Time 0 is the onset of critical words.*

rior sites followed by a positive shift over posterior electrodes. Since the partially presented words had a mean duration of 160 ms, this indicates that the increased negativity peaking at 300 ms in Figure 3-3 is indeed related to the acoustic offset of the partially presented word (and sentence). Due to the occurrence of this off potential, we cannot make any claims about underlying components in the waveforms between 150 and 500 ms. Finally, Figure 3-3 shows a late positivity between 600 and 1000 ms. This late positivity reaches maximal amplitude at around 700 ms and is maximal over posterior sites. In the literature there are indications that late positivities reflect wrap-up processes at the end of sentences (cf. Juottonen, Revonsuo, & Lang, 1996).

Figure 3-5 displays the grand average waveforms of the Partial Words in high versus low constraint contexts by electrode site time-locked to the onset of the sentence-final word. There are several things to note. The sentence-final words in both the high constraining and the low constraining context elicited an N100 component, however, the N100 component in the PW Low Constraint condition appears to peak somewhat later. Second, in both conditions there is an increased negativity peaking at approximately 300 ms, which at centro-parietal sites is more negative in the PWLC condition than in the PWC condition. Figure 3-3 reveals that the increased negativity is related to the moment of acoustic offset of the sentence-final word. Again, due to the occurrence of the off potential, based on inspection of the waveforms we cannot make any claims about underlying components in the 150 to 500 ms time interval. Finally, the sentence-final words in the PWLC conditions elicit a broad negativity, which at frontal to central sites is a sustained negativity, and at parietal sites peaks at approximately 400 ms.

Statistical analyses of the congruity effects consisted of a number of repeated measures analyses of variance (ANOVAs) with mean amplitude values computed for each subject and each electrode in different latency windows: for the Whole Word conditions, (a) 150-250 ms after critical-word onset for the early negativity (N200), and (b) 300-500 ms after final-word onset for the N400; for the Partial Word conditions, (a) 150-250 ms after critical-word onset for the early negativity (N200), (b) 250-350 ms after final-word onset for the off potential, and (c) 300-500 ms after final-word onset for the N400. For each latency window, the results were first analyzed in an omnibus ANOVA that crossed three levels of the congruity factor (Congruent, Anomalous, and Low Constraint) with the 29-level electrode factor.

In addition to the omnibus ANOVA, a priori pairwise comparisons between the congruity conditions were tested using ANOVAs with a 2-level congruity factor. For the Whole Word conditions, in the N200 latency window, we expected the ERP in the Congruent condition (baseline) to differ in amplitude from the ERP in the Anomalous condition (WWC vs. WWA). As for the Whole Words in

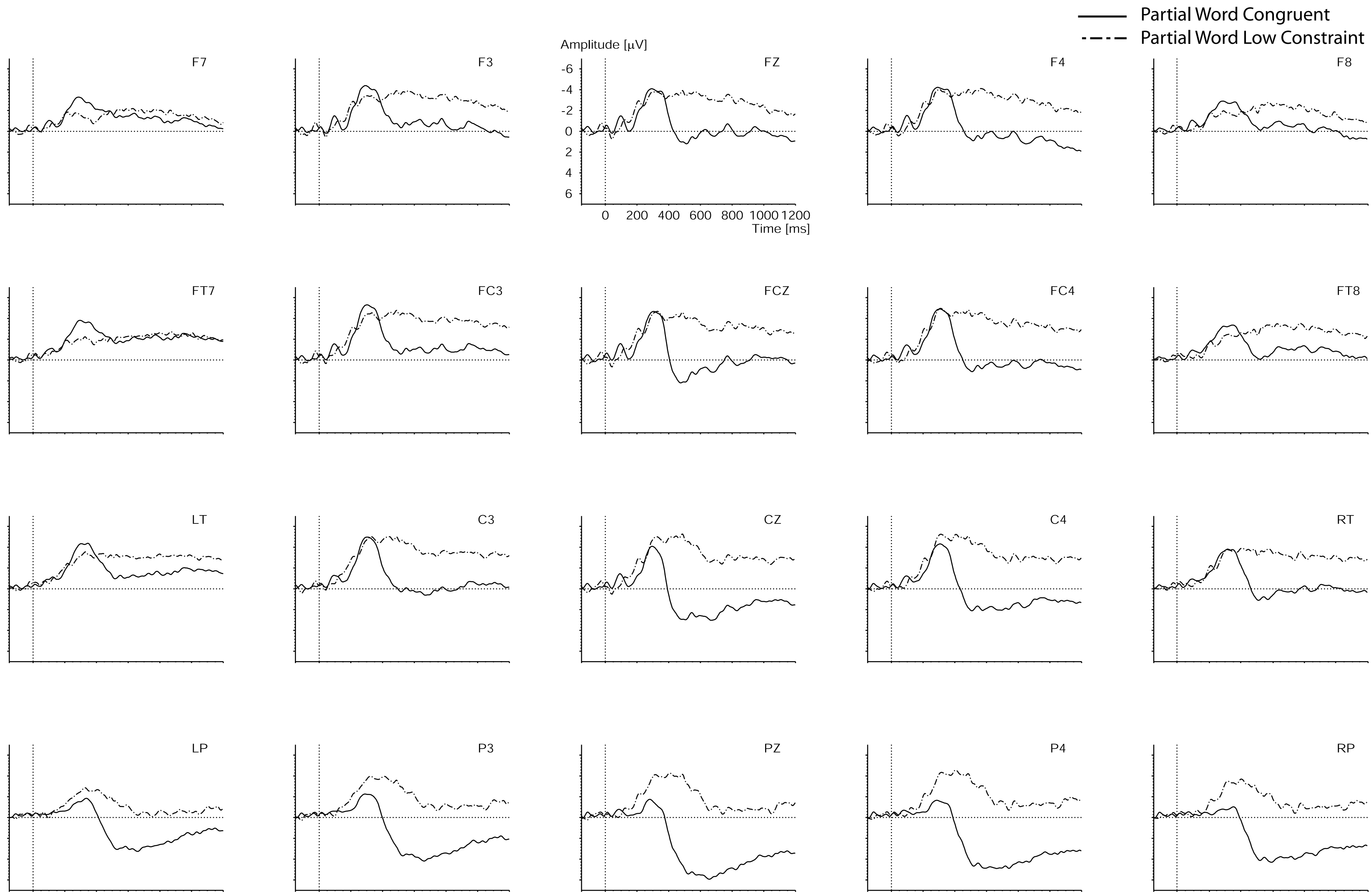

Figure 3-5. *Grand average ERPs to critical words in PWC and PWLC. Time 0 is the onset of critical words.*

the high versus low constraint contexts conditions, depending on the underlying process (lexical-driven vs. feature-driven) the ERP of the Congruent completion should either differ in amplitude from that of the Low Constraint completion or it should not (WWC vs. WWLC). In the N400 latency window we expected the ERP in the Congruent condition (baseline) to differ in amplitude from the ERPs in both the Anomalous condition (WWC vs. WWA) and the Low Constraint condition (WWC vs. WWLC). For the Partial Word conditions, in the N200 latency window, as in their fully presented counterparts, we expected the ERP in the Congruent condition (baseline) to differ in amplitude from the ERP in the Anomalous condition (PWC vs. PWA). Again as in the fully presented completions, for the Partial Words in high versus low constraint contexts one of two outcomes were expected: depending on the underlying process either the ERP of the Congruent condition differed in amplitude from that of the Low Constraint condition or it did not (PWC vs. PWLC). In the off potential latency window we expected the ERP in the Congruent condition (baseline) not to differ in amplitude from the ERPs in both the Anomalous condition (PWC vs. PWA) and the Low Constraint condition (PWC vs. PWLC). As for the N400 latency window, depending on whether lexical selection and integration are purely sequential or partially overlapping processes, the ERPs of both the PWA and PWLC completion either did not differ in amplitude from that of the PWC completion, or they both did.

Scalp distributions of the congruity effects were subsequently explored in three separate ANOVAs: an ANOVA on anterior versus posterior sites (Fz, FCz, AF3, AF4, F3, F4, F7, F8, FC3, FC4, FT7, FT8/Pz, Oz, CP3, CP4, LTP, RTP, P3, P4, LP, RP, PO7, PO8); anterior left hemisphere versus anterior right hemisphere (AF3, F3, F7, FC3, FT7/AF4, F4, F8, FC4, FT8); posterior left hemisphere versus posterior right hemisphere (CP3, LTP, P3, LP, PO7/CP4, RTP, P4, RP, PO8). Univariate *F* tests with more than one degree of freedom in the numerator were adjusted by means of the Greenhouse-Geisser/Box's epsilon hat correction (Maxwell & Delaney, 1990). The original degrees of freedom and adjusted *p* values will be reported.

Whole Word conditions

The Early Negativity/N200 latency window: 150-250 ms. Table 3-2 displays the results of the mean ERP amplitude ANOVAs in the 150-250 ms latency range for the Whole Word conditions. The omnibus ANOVA for the N200 latency window resulted in a significant main effect of congruity. The a priori pairwise comparisons revealed that both the WWA completions and the WWLC completions elicited a larger N200 than the WWC completions (corresponding to an effect of 0.83 μV and 1.13 μV, respectively). In these pairwise analyses, interactions of con-

Table 3-2. *ANOVA on mean ERP amplitude in the 150-250 ms latency range (N200) for Whole Word conditions*

	source	df	*F*	*MSE*	*p*
Omnibus ANOVA (29 electrodes)					
Overall	Con	2, 46	6.38	37.39	.005 **
	Con x El	56, 1288	4.45	0.61	.002 **
WWC vs. WWA	Con	1, 23	9.00	26.93	.006 **
	Con x El	28, 644	3.25	0.45	.020 *
WWC vs. WWLC	Con	1, 23	9.20	48.11	.006 **
	Con x El	28, 644	5.53	0.84	.002 **
Anterior vs. posterior (2 x 12 electrodes)					
WWC vs. WWA	Con x Site	1, 23	1.61	4.48	.217
WWC vs. WWLC	Con x Site	1, 23	10.46	8.85	.004 **
Anterior left vs. anterior right (2 x 5 electrodes)					
WWC vs. WWA	Con x Site	1, 23	0.11	1.39	.740
WWC vs. WWLC	Con x Site	1, 23	0.10	2.54	.755
Posterior left vs. posterior right (2 x 5 electrodes)					
WWC vs. WWA	Con x Site	1, 23	0.69	1.23	.413
WWC vs. WWLC	Con x Site	1, 23	0.06	2.41	.807

Note. Con = Congruity type; El = Electrode. * $p < .05$; ** $p < .01$;

gruity with electrodes reached significance in the WWC versus WWLC condition analysis. Topographical analyses of the WWC versus WWLC condition revealed a significant interaction of congruity with site in the anterior/posterior analysis, indicating that the N200 effect in WWLC had a more posterior distribution compared to the even distribution of WWC.

The N400 latency window: 300-500 ms. Table 3-3 displays the results of the mean ERP amplitude ANOVAs in the 300-500 ms latency range. The omnibus ANOVA indicated that the basic congruity effect in the N400 latency window was significant. Further analysis revealed that both the WWA and the WWLC completions elicited a larger N400 than the WWC completions (corresponding to an effect of

Table 3-3. *ANOVA on mean ERP amplitude in the 300-500 ms latency range (N400) for Whole Word conditions*

	source	df	*F*	*MSE*	*p*
		Omnibus ANOVA (29 electrodes)			
Overall	Con	2, 46	48.64	48.29	.000 ***
	Con x El	56, 1288	22.62	0.88	.000 ***
WWC vs. WWA	Con	1, 23	71.84	55.50	.000 ***
	Con x El	28, 644	22.30	0.73	.000 ***
WWC vs. WWLC	Con	1, 23	46.32	64.49	.000 ***
	Con x El	28, 644	32.04	1.14	.000 ***
		Anterior vs. posterior (2 x 12 electrodes)			
WWC vs. WWA	Con x Site	1, 23	32.01	7.25	.000 ***
WWC vs. WWLC	Con x Site	1, 23	61.06	12.20	.000 ***
		Anterior left vs. anterior right (2 x 5 electrodes)			
WWC vs. WWA	Con x Site	1, 23	2.65	1.73	.117
WWC vs. WWLC	Con x Site	1, 23	2.10	2.41	.161
		Posterior left vs. posterior right (2 x 5 electrodes)			
WWC vs. WWA	Con x Site	1, 23	1.14	2.56	.297
WWC vs. WWLC	Con x Site	1, 23	2.71	3.86	.113

Note. Con = Congruity type; El = Electrode. *** $p < .001$

3.38 µV and 2.93 µV, respectively). Interactions with electrodes were also obtained in the pairwise comparisons. Topographical analyses showed that the congruity effects in relation to the WWC condition were significantly larger over posterior than anterior regions of the scalp. No differences between hemispheres were found.

Onset latencies. To establish the onset of the congruity effect for the fully presented words in high constraining context, additional analyses were performed. Onset latencies were estimated by first separately computing the mean amplitude values for all 29 electrodes in 20 ms latency ranges (bins) that shifted in steps of 10 ms from critical word onset until 500 ms after critical word onset (e.g., 0-20,

Table 3-4. *ANOVA on mean ERP amplitude in the 150-250 ms latency range (N200) for Partial Word conditions*

	source	df	*F*	*MSE*	*p*
	Omnibus ANOVA (29 electrodes)				
Overall	Con	2, 46	2.79	41.03	.078
	Con x El	56, 1288	2.26	0.65	.063
PWC vs. PWA	Con	1, 23	5.96	30.66	.023 *
	Con x El	28, 644	3.09	0.57	.040 *
PWC vs. PWLC	Con	1, 23	2.98	53.78	.098
	Con x El	28, 644	2.70	0.85	.065
	Anterior vs. posterior (2 x 12 electrodes)				
PWC vs. PWA	Con x Site	1, 23	0.59	7.93	.449
	Anterior left vs. anterior right (2 x 5 electrodes)				
PWC vs. PWA	Con x Site	1, 23	037	1.32	.550
	Posterior left vs. posterior right (2 x 5 electrodes)				
PWC vs. PWA	Con x Site	1, 23	1.77	0.86	.196

Note. Con = Congruity type; El = Electrode. * $p < .05$

10-30, etc.). The values for the latency bins were submitted to ANOVAs that tested against the null-hypothesis of zero difference between the a priori selected conditions WWC versus WWA. To compensate for multiple comparisons, we considered a congruity effect significant when at least 5 consecutive bins reached a statistical significance level of $p < .05$. The onset latency analyses for WWC versus WWA comparison on the amplitudes of the two waveforms revealed a significant congruity effect in the 190-210 ms bin and in all consecutive bins.

Partial Word conditions

The Early Negativity/N200 latency window: 150-250 ms. Table 3-4 displays the results of the mean ERP amplitude ANOVAs in the 150-250 ms latency range for the Partial Word conditions. The omnibus ANOVA for the N200 latency window did not result in a significant main effect of congruity ($p = .08$). The a priori pair-

Table 3-5. *ANOVA on mean ERP amplitude in the 250-350 ms latency range (off potential) for Partial Word conditions*

	source	df	*F*	*MSE*	*p*
		Omnibus ANOVA (29 electrodes)			
Overall	Con	2, 46	7.11	62.68	.004 **
	Con x El	56, 1288	10.95	0.95	.000 ***
PWC vs. PWA	Con	1, 23	14.38	56.50	.001 **
	Con x El	28, 644	6.06	0.83	.002 **
PWC vs. PWLC	Con	1, 23	0.48	88.75	.494
	Con x El	28, 644	15.00	1.27	.000 ***
		Anterior vs. posterior (2 x 12 electrodes)			
PWC vs. PWA	Con x Site	1, 23	8.25	11.25	.009 **
		Anterior left vs. anterior right (2 x 5 electrodes)			
PWC vs. PWA	Con x Site	1, 23	0.77	1.37	.389
		Posterior left vs. posterior right (2 x 5 electrodes)			
PWC vs. PWA	Con x Site	1, 23	0.37	1.82	.551

Note. Con = Congruity type; El = Electrode. ** $p < .01$; *** $p < .001$

wise comparisons revealed that the PWA completions elicited a larger N200 than the PWC completions (corresponding to an effect of 0.73 μV). The ERPs in the PWC and PWLC conditions did not significantly differ in amplitude ($p = .10$, corresponding to a difference of 0.68 μV). Only in the PWC versus PWA analysis, did the interaction of congruity with electrodes reach significance. Topographical analyses for this comparison revealed no significant interactions of condition by site, indicating that the effect has an even distribution across the scalp.

The off potential latency window: 250-350 ms. Table 3-5 displays the results of the mean ERP amplitude ANOVAs in the 250-350 ms latency range for the Partial Word conditions. The omnibus ANOVA for the off potential latency window resulted in a significant main effect of congruity. Further analysis revealed that the PWA completions elicited a larger ERP than the PWC completions (corresponding to an effect of 1.53 μV), whereas the PWLC condition did not differ

Table 3-6. *ANOVA on mean ERP amplitude in the 300-500 ms latency range (N400) for Partial Word conditions*

	source	df	*F*	*MSE*	*p*
		Omnibus ANOVA (29 electrodes)			
Overall	Con	2, 46	21.50	68.89	.000 ***
	Con x El	56, 1288	17.54	1.14	.000 ***
PWC vs. PWA	Con	1, 23	40.24	61.23	.000 ***
	Con x El	28, 644	14.72	0.70	.000 ***
PWC vs. PWLC	Con	1, 23	20.07	97.16	.000 ***
	Con x El	28, 644	23.46	1.63	.000 ***
		Anterior vs. posterior (2 x 12 electrodes)			
PWC vs. PWA	Con x Site	1, 23	13.38	8.08	.001 **
PWC vs. PWLC	Con x Site	1, 23	24.37	23.64	.000 ***
		Anterior left vs. anterior right (2 x 5 electrodes)			
PWC vs. PWA	Con x Site	1, 23	7.23	1.33	.013 *
PWC vs. PWLC	Con x Site	1, 23	9.84	2.62	.005 *
		Posterior left vs. posterior right (2 x 5 electrodes)			
PWC vs. PWA	Con x Site	1, 23	1.94	1.65	.177
PWC vs. PWLC	Con x Site	1, 23	15.44	3.32	.001 **

Note. Con = Congruity type; El = Electrode. * $p < .05$; ** $p < .01$; *** $p < .001$

significantly from the PWC condition in the off potential latency window. Interactions with electrodes were also obtained in the pairwise comparisons. Topographical analyses showed that the congruity effect involving the PWA condition was significantly larger over posterior than anterior regions of the scalp. No differences between hemispheres were found.

The N400 latency window: 300-500 ms. Table 3-6 displays the results of the mean ERP amplitude ANOVAs in the 300-500 ms latency range for the partially presented words. The omnibus ANOVA indicated that the basic congruity effect in the N400 latency window was significant. Further analysis revealed that both the

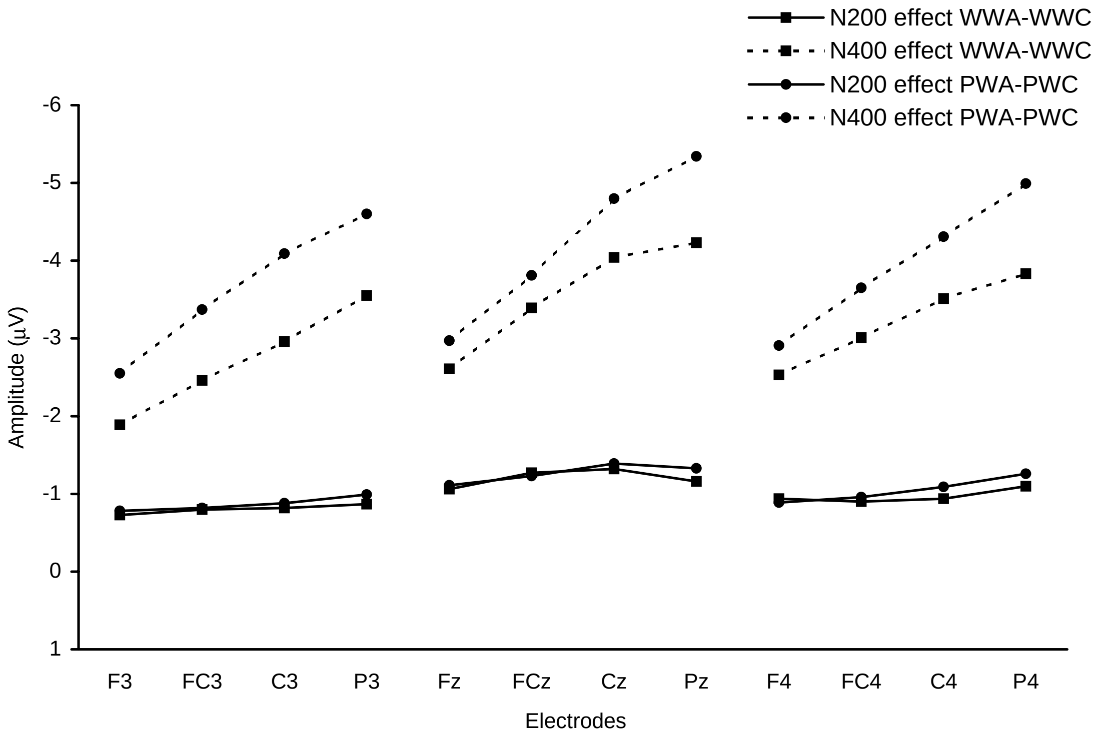

Figure 3-6. *Distribution of the N200 and N400 effects for fully and partially presented sentence-final words in semantically high-constraint sentences, for twelve sites. The N200 effect was determined by subtracting the mean amplitude in the 150-250 ms latency window of the grand average ERP for the semantically congruent sentence-final words from the mean amplitudes of the grand average ERP for the semantically anomalous sentence-final words. The N400 effect was determined in the same manner on the basis of the mean amplitudes in the 300-500 ms latency window.*

PWA and the PWLC completions elicited a larger ERP than the PWC completions (corresponding to an effect of 2.64 µV and 2.37 µV, respectively). Interactions with electrodes were also obtained in the pairwise comparisons. Topographical analyses showed that the congruity effects in relation to the PWC condition were significantly larger over posterior than anterior regions of the scalp and were larger over right frontal than left frontal regions.

Topographical distributions of the congruity effects

N200 vs. N400. Figure 3-6 shows the topography of mean amplitude effects between the Congruent and Anomalous conditions in high constraining contexts in the N200 and the N400 latency windows. The figure reveals that both the N200 effect in the Whole Word conditions and the N200 effect in the Partial

Word conditions are equally distributed across the scalp, whereas both N400 effects are largest over posterior sites. To establish whether the N200 and N400 congruity effects in both the Whole Word and the Partial Word conditions have statistically distinct scalp distributions, we performed topographical analyses. First, for every subject difference scores between the Congruent and Anomalous conditions were computed for every electrode in the N200 latency window and the N400 latency window for the Whole Word and Partial Word conditions separately. Second, a scaling procedure was performed to avoid that differential amplitude effects between the two latency windows would be incorrectly interpreted as distribution effects. In this procedure, the electrode-specific difference scores were *z*-transformed for each latency window separately (Rösler, Heil, & Glowolla, 1993; see also McCarthy & Wood, 1985). The *z*-transformed values were entered into an ANOVA that crossed the 2-level latency window factor (N200 and N400) with the 29-level electrode factor. For the Whole Word conditions, a significant interaction of latency window by electrodes ($F(28, 644) = 8.42$, $MSE = 0.35$, $p < .001$) revealed that the congruity effects found in the two latency windows indeed have different spatial distributions across the scalp. This difference in scalp distributions was subsequently explored in three additional topographical ANOVAs (using the same electrode configurations as previously described). In the anterior/posterior analysis a significant interaction of window by site was obtained ($F(1, 23) = 15.40$, $MSE = 2.56$, $p = .001$). In the anterior left/right and the posterior left/right analyses no significant interaction of window by site was obtained (both Fs < 1). For the Partial Word conditions we obtained identical results: A significant interaction of latency window by electrodes ($F(28, 644) = 5.51$, $MSE = 0.28$, $p < .001$) and a significant interaction of window by site ($F(1, 23) = 16.56$, $MSE = 1.35$, $p < .001$) in the anterior/posterior analysis. In the anterior left/right and the posterior left/right analyses no significant interaction of window by site was obtained ($p = .19$ and $p = .60$, respectively). The significant interactions of window by site in the anterior/posterior analysis for both Whole Words and Partial Words underscores that the N200 and N400 effects have different spatial distributions, with the N400 effect having a more posterior distribution and the N200 effect being equally distributed across the scalp.

Figure 3-7 shows the topography of mean amplitude effects between the highly constraining and Low Constraint conditions in the N200 and the N400 windows. Again we see that the N200 effect in the Partial Word conditions has an equal distribution across the scalp. However, the N200 effect in the Whole Word conditions now has a slightly more posterior distribution. Both N400 effects are largest over posterior sites. For the Whole Word conditions a significant interaction of latency window by electrodes ($F(28, 644) = 8.54$, $MSE = 0.23$, $p < .001$) revealed that the congruity effects found in the two latency windows do have dif-

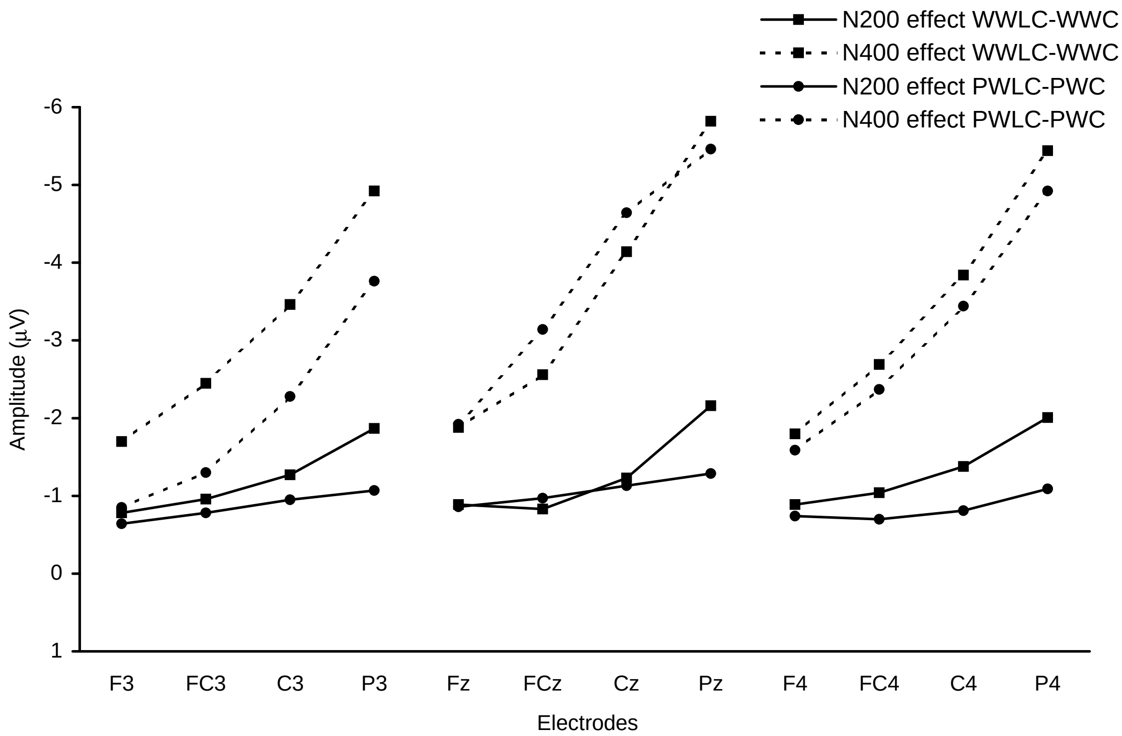

Figure 3-7. *Distribution of the N200 and N400 effects for fully and partially presented sentence-final words in semantically high-constraint versus low-constraint sentences, for twelve sites. The N200 effect was determined by subtracting the mean amplitude in the 150-250 ms latency window of the grand average ERP for the semantically congruent sentence-final words from the mean amplitudes of the grand average ERP for the semantically anomalous sentence-final words. The N400 effect was determined in the same manner on the basis of the mean amplitudes in the 300-500 ms latency window.*

ferent spatial distributions across the scalp. This difference in scalp distributions was subsequently explored in three additional topographical ANOVAs (using the same electrode configurations as previously described). In the anterior/posterior analysis a significant interaction of window by site was obtained ($F(1, 23) = 21.48$, $MSE = 1.11$, $p < .001$). Also the posterior left/right analysis revealed a significant interaction of window by site ($F(1,23) = 5.69$, $MSE = 0.47$, $p < .05$). In the anterior left/right analysis no significant interaction of window by site was obtained ($F < 1$). The significant interaction of window by site in the anterior/posterior and posterior left/right analyses shows that the N200 and N400 effects have different spatial distributions with the N400 effect being largest over posterior sites in the right hemisphere. As the difference in amplitude in the N200 window for the PWC versus PWCL completions did not reach significance, a topographical analysis between the N200 effect and N400 effect in this comparison is not warranted.

Discussion

The grand average waveforms of the Whole Word conditions in Figure 3-1 reveal that an N200 component was visible in both conditions, which was larger in the anomalous than in the congruent completions. Onset analyses revealed that the onset of the congruity effect between WWC and WWA occurred early on in the signal, namely at 190 ms. The N200 effect had an even distribution and was followed by an N400 effect with a centro-parietal distribution (see Figure 3-6). The topographical anterior versus posterior analysis after scaling of the absolute size of the effects revealed that the spatial distributions of the N200 and N400 effect were significantly different. These findings constitute a replication of our previous study.

In another comparison related to the matter of the exact nature of the selection process, the grand average waveforms in Figure 3-2 reveal a larger N200 component in the low constraint condition in relation to the high constraint completions, clearly distinct in timing from the following N400 effect. No clear N100 component is visible in the low constraint conditions. This may be due to the fact that the completions in this condition were spliced to the carrier phrases. According to the participants, this sometimes resulted in the subjective feeling that the completions followed the carrier phrases too quickly. Figure 3-7 shows that both the N200 effect and the N400 effect have posterior distributions. However, the topographical analysis revealed that these spatial distributions are still statistically different. The presence of an N200 effect in the high versus low constraint comparison supports the hypothesis that the N200 effect reflects a selection process where lexical candidates are individually assessed with respect to their goodness-of-fit within the sentence frame on the basis of their semantic features (a lexical-driven process).

Turning to the comparisons involving the partial words, Figure 3-3 reveals an unanticipated large ERP component in the grand average waveforms, which, as shown in Figure 3-4, seems to be related to the offset of the partially presented words. This off potential obscures potential underlying N200 and N400 components. Figure 3-6 shows that we did find an effect in the N200 latency window. The occurrence of the off potential cannot account for this effect, as both the congruent and anomalous completions ended in the same, abrupt manner. We conclude that any effect must be due to an underlying N200 effect. We also observed an effect in the off-potential window. Again, as both conditions contained partial completions, we suspect this observed off-potential effect is due to the preceding N200 effect being carried over to the off-potential window. In addition to these effects we also obtained a significant N400 effect. As in their fully presented counterparts, Figure 3-6 shows that the N200 effect had an even distribution, whereas the N400 effect had a centro-parietal distribution, and topographical analyses revealed that these scalp distributions are statistically distinct. These results indicate that apparently, the N400 effect sets in before recognition of the actual word takes place.

Finally, the PWLC condition served as an additional control condition. We obtained an N200 effect between WWC and WWLC. Unfortunately, statistical analysis revealed that the difference in amplitude in the N200 window did not reach significance in the PWC versus PWLC comparison (p = .098). When we look at Figures 3-6 and 3-7, however, we see that the difference in N200 amplitude between PWLC and PWC is in the same ball park as the other N200 effects. We, therefore, suspect that lack of power is the reason that the difference in amplitude did not reach statistical significance. Consistent with the anomalous Partial Words, here too we obtained a significant N400 effect.

On the basis of these results we can conclude the following: First, the selection process is lexical-driven rather that feature-driven. This means that selection takes place on the basis of the meaning of an activated word rather than compatibility of several features with the preceding context. Second, although the semantic congruity effect clearly can be divided into two effects (with different spatial distributions), namely the N200 effect related to lexical selection and the N400 effect reflecting semantic integration, elicitation of an N400 in the Partial Words disconfirmed our hypothesis of the congruity effect consisting of an N200 before IP and an N400 after IP. This suggests that integration is not postponed until the anomalous candidate has been selected on the basis of phonological analysis alone, but is initiated before the selection process is completed, and works with several remaining candidates instead. In order to investigate this last finding somewhat further we decided to do an additional experiment.

EXPERIMENT 2

Figure 3-6 revealed that both the N200 effects and the N400 effects in the Partial Word conditions are similar to those in their fully presented counterparts. Apparently, the N400 effect sets in before recognition of the actual (anomalous) word takes place. This means that integration processes start before selection of the one appropriate candidate has taken place, and that (the onset of) the N400 effect is not related to the earliest moment at which a word is recognized (i.e., at IP).

To investigate this hypothesis somewhat further we decided to do a second experiment. This time we wanted to use the information we obtained from the gating study to align the EEG waveforms of the individual completions to the isolation point (IP) for each word. Furthermore, we divided the critical words into two groups with early or late IPs. If the N400 is related to the IP (i.e., the earliest moment at which a word can be identified) as suggested by the Sequential Hypothesis, then the N400 effect should set in at or soon after IP, and should therefore differ between the early and late IP words. If, however, semantic integration starts before the word is recognized, as suggested by the Cascading Hypothesis and supported by the results of our first experiment, then onset of the N400 could occur prior to the IP and would not have to differ as a function of IP latency. We decided to run another experiment in which we presented subjects with more trials in the congruent and anomalous conditions than in the first experiment. This would ensure that the data had a better signal-to-noise ratio after dividing the critical words into equally large groups with early and late IPs.

Method

Subjects

The experiment was conducted with 12 native speakers of Dutch (11 female, mean age 21.5, range 19-23 years) from the subject pool of the Max Planck Institute for Psycholinguistics. All had normal to corrected-to-normal vision and were right-handed (3 subjects reported having a left-handed parent or sibling). None of the subjects had any neurological impairment or had experienced any neurological trauma. Nor had any of the subjects participated in the pretests (see below). Subjects were paid for their participation.

Materials, procedure and EEG-recording

The experimental items consisted of the items from the WWC and WWA conditions in the first experiment. For purposes not relevant to this study we added a third condition. This resulted in a set of 260 triplets of semantically constraining sentences across three experimental conditions. The sentences in each triplet were identical up to the final word. In the Whole Word Congruent condition (WWC), sentences ended with a high cloze probability word, e.g., “Deze veertienjarige pianist heeft duidelijk veel *talent*” (“This fourteen year old pianist obviously has a lot of *talent*”). In the Whole Word Anomalous condition (WWA), sentences ended with a word that was semantically anomalous and also had initial phonemes that differed from the highest cloze probability word, e.g., “Deze veertienjarige pianist heeft duidelijk veel *klimaat*” (“This fourteen year old pianist obviously has a lot of *climate*”).

Sentences had a mean length of 10.8 words (range 5-15) and were equally constraining; the critical words in the congruent condition had a mean cloze probability of .84 (range: .50-1.0). All sentence-final words were reasonably well-known nouns selected from a Dutch word corpus called CELEX (Baayen et al., 1993); all critical words had a frequency of at least 30 counts per 42 million (this equals 1.48 log), with a mean duration of 516 ms and a mean log frequency of 2.87 in the WWC condition, and 515 ms and 2.49 in the WWA condition. Each sentence-final word began with a plosive. This provided a clear physical marker that facilitated the alignment of the ERP-waveform to the onset of the sentence-final word.

Three lists were constructed to ensure that no subject heard the same sentence or critical word more than once. In addition to the set of 260 experimental items, a set of fillers was constructed to balance the number of sentences that ended anomalously and congruously. Finally, the experimental lists were preceded by a practice list of 20 items, which reflected the experimental materials. The practice list was used to familiarize the subjects with the experimental procedure. Recording of the materials, procedure and EEG-recording were all similar to the first experiment.

Results

Data from critical trials were analyzed according to the following procedure. Prior to off-line averaging, all single-trial waveforms were screened for eye movements, electrode drifting, amplifier blocking, and EMG artifacts in a critical window that ranged from 150 ms before onset of the sentence-final word, to 1900 ms after onset of the sentence-final word. Trials containing artifacts were rejected (average number of trials per condition 6.5%, range 4.1 to 8.1%). For each subject, average waveforms were computed across all remaining trials per condition after baselining the waveforms of the individual trials on the basis of the averaged activity in a time window of 150 ms preceding onset of the sentence-final word.

We divided the critical words into equally large groups with early and late IPs. For the congruent completions the 50^{th} percentile corresponded to an IP at 283 ms and for the anomalous completions at 285 ms. This leads to the following four conditions, with 130 items per condition: congruent completions with early IPs (mean 223 ms), anomalous completions with early IPs (mean 235 ms), congruent completions with late IPs (mean 341 ms), and anomalous completions with late IPs (mean 344 ms).

Figure 3-8 displays the grand average waveforms of all four conditions by electrode site time-locked to the onset of the sentence-final word. What can be seen from the figure is that irrespective of whether a critical word belongs to the group with early or late IPs the waveforms of the congruent and anomalous completions across these groups are practically identical. We performed statistical analyses of the congruity effects, that consisted of a repeated measures analysis of variance (ANOVAs) with mean amplitude values computed for each subject and each electrode in two different latency windows: (a) 150-250 ms after crit-

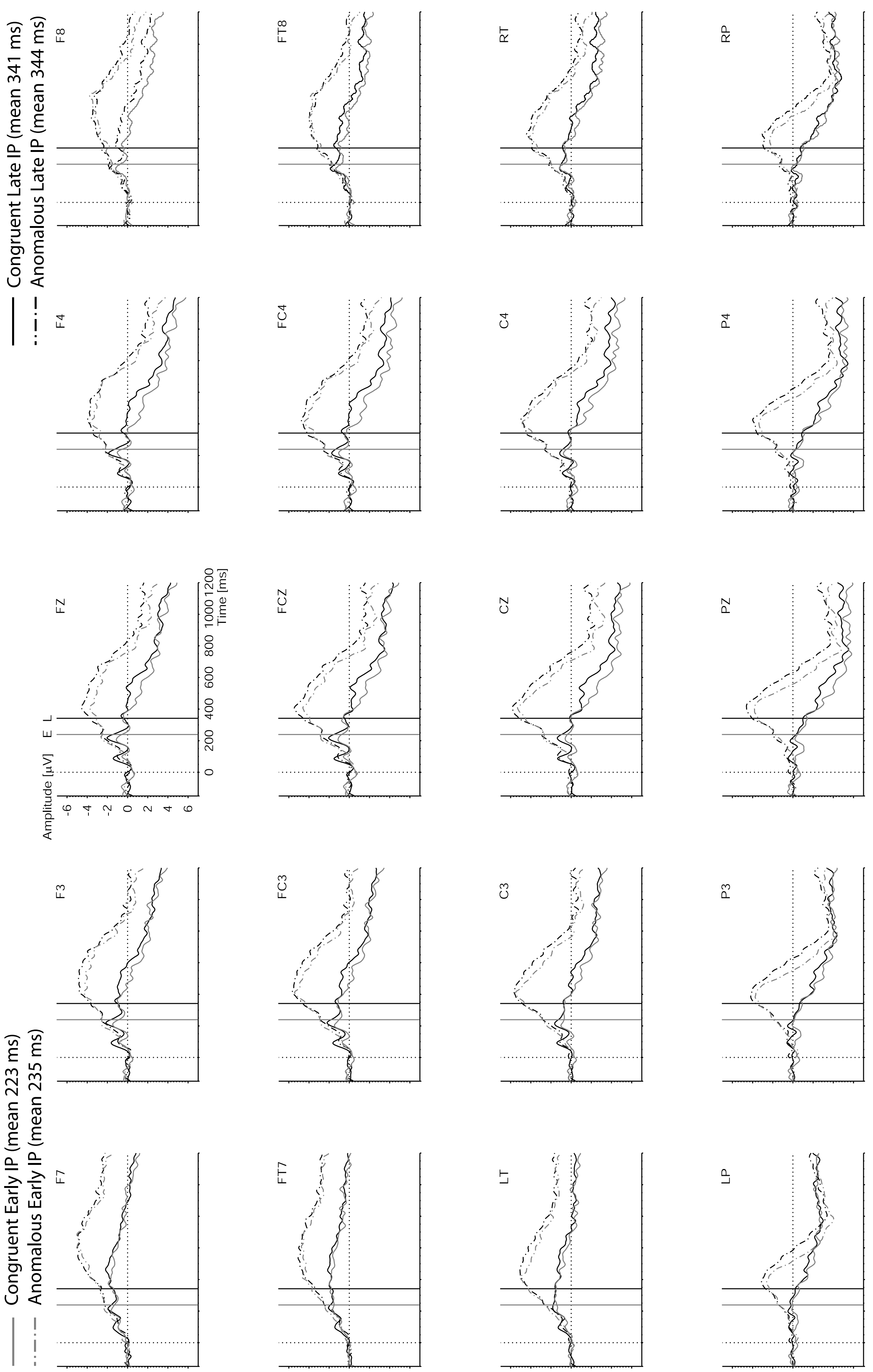

Figure 3-8. *Grand average ERPs to critical words in four conditions. Time 0 is the onset of critical words. Lines E and L mark the mean IPs for the early and late comparisons.*

ical-word onset for the N200, and (b) 300-500 ms after final-word onset for the N400. For each latency window, the results were analyzed in an omnibus ANOVA with two levels of the IP factor (Early, Late), two levels of the congruity factor (Congruent, Anomalous) and the 29-level electrode factor. For the N200 window, the analysis revealed no main effect of IP ($F < 1$), a significant main effect of Congruity ($F(1,11) = 8.33$, $MSE = 39.94$, $p < .05$), and no interaction between these two factors. For the N400 window, similar results were found; no main effect of IP ($F(1,11) = 1.57$, $MSE = 32.46$, $p = .236$), a significant main effect of Congruity ($F(1,11) = 57.62$, $MSE = 88.97$, $p < .001$), and again no interaction between these two factors.

Time-locking the waveforms to the IP should give us more information about the relation between the onset of the N400 and IP. Figure 3-9 displays the difference waveforms of both early and late comparisons by electrode site time-locked to IP. Again, what we see is that irrespective of which group words belong to, the waveforms are remarkably similar and a congruity effect is initiated before IP. Onset analysis were performed to establish the onset of the congruity effects. Onset latencies were estimated by first separately computing the mean amplitude values for all 29 electrodes in 20 ms latency ranges (bins) that shifted in steps of 10 ms from 200 ms prior to IP until 100 ms after IP (e.g., –200 until –180 ms, –190 until –170 ms, etc.). The values for the latency bins were submitted to ANOVAs that tested against the null-hypothesis of zero difference between the a priori selected conditions WWC versus WWA for words with early and late IPs separately.

The onset latency analyses for the WWC versus WWA with early IP comparison on the amplitudes of the two waveforms revealed a significant congruity effect in the –50 until –30 ms bin and in all consecutive bins. The onset latency analyses for the WWC versus WWA with late IP comparison on the amplitudes of the two waveforms revealed a significant congruity effect in the –140 until –120 ms bin and in all consecutive bins. So, in the case of the words with early IPs, the mean IP is 230 ms and the congruity effect sets in approximately 50 ms prior to IP. In the case of the words with late IPs, the mean IP is 340 ms and the congruity effect sets in approximately 140 ms prior to IP.

GENERAL DISCUSSION

In this study we were interested in two theoretically important questions: a) what are the building blocks of the lexical selection process, and b) are lexical selection and semantic integration sequential or cascading in nature? In order to be able to address these questions using ERPs, we first had to replicate the findings of our previous study (cf. Van den Brink et al., 2001). This previous study

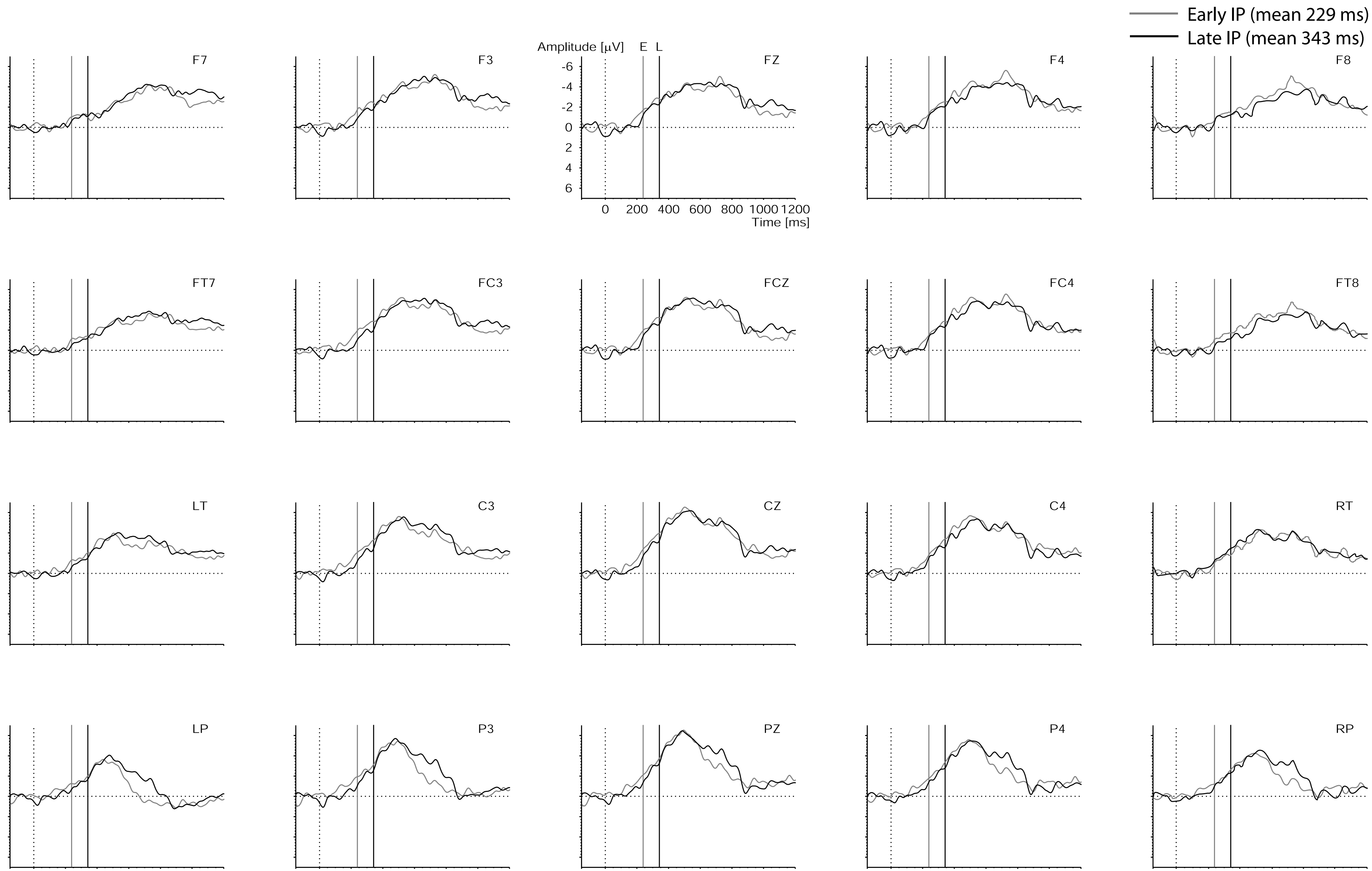

Figure 3-9. *Difference waveforms to critical words with early IPs (solid gray line) and late IPs (solid black line), time-locked to IP. Time 0 is the onset of critical words. Lines E and L mark the mean IPs for the early and late comparisons.*

revealed the presence of a separate effect preceding the well-documented N400 effect. We proposed that whereas the N400 effect reflects semantic integration, the preceding N200 effect is related to the lexical selection process. Replication of our previous results would demand that the ERP of the anomalous completions for the fully presented sentence-final words diverges from the congruent completions early on in the signal. Furthermore, in both conditions an early negative shift peaking at 200 ms should be visible. In the anomalous condition, this early negative shift should be larger than in the congruent condition and should be followed by a large N400 component which would be very much reduced in the congruent sentence-final words. As hypothesized, onset analyses confirmed that the onset of the congruity effect between the Whole Word Congruent (WWC) and Whole Word Anomalous (WWA) conditions occurred early on in the signal, namely at 190 ms. Furthermore, Figure 3-1 shows that an N200 component was visible in the grand average waveforms of both conditions, which was larger in the anomalous than in the congruent completions. As revealed by Figure 3-6, this N200 effect had an even distribution and was followed by an N400 effect with a classical centro-parietal distribution. The topographical anterior versus posterior analysis after scaling of the absolute size of the effects revealed that the spatial distributions of the N200 and N400 effect were significantly different. These findings constitute a replication of our previous study.

Having replicated our previous finding of a congruity effect consisting of an N200 followed by an N400, we were now interested in the exact nature of the lexical selection process as reflected by the N200. We tested this by looking at the difference in N200 amplitude between congruent words presented in semantically constraining sentences and in sentences with low contextual constraint. It was hypothesized that if during lexical selection, lexical candidates are assessed with respect to their possible fit within the sentence, a relatively large N200 would occur in response to congruent words in semantically low constraint sentences; the absence of strong contextual constraints makes the selection process of a lexical candidate more demanding. However, if the modulation of the N200 amplitude reflects a process in which, instead of lexical candidates, the presence of appropriate semantic features is assessed, a relatively small N200 was expected to occur, since most semantic features are compatible with low constraining sentences. In both cases the N200 component would be followed by an N400 component. The grand average waveforms in Figure 3-2 reveal a larger N200 component in the low constraint condition in relation to the high constraint completions, clearly distinct in timing from the following N400 effect. Topographical analyses revealed that whereas both the N200 effect and the N400 effect have posterior distributions (see Figure 3-7), these spatial distributions are statistically different.

The clear presence of an N200 effect in the high versus low constraint comparison indicates that the N200 effect reflects a selection process where lexical candidates are individually assessed with respect to their goodness-of-fit within the sentence frame on the basis of their semantic features (a lexical-driven process). The lexical-driven account of the N200 assumes that when individual lexical candidates are assessed with respect to their possible fit within the preceding sentence, analogous to the N400, a relatively large N200 occurs in response to congruent words in low constraint sentences: the absence of strong contextual constraints makes it more difficult to assess whether any candidate in the activated set fits the sentence frame very well.

To address the second question of whether semantic integration follows up on lexical selection of one appropriate candidate or proceeds with a number of candidates, we introduced partially presented completions to semantically high constraining sentences. If, according to the Sequential Hypothesis, semantic integration into the prevailing context does not set in until one appropriate candidate has been selected on the basis of an initial phonological analysis, the partial completions were expected to reveal an N200 effect in the absence of an N400 effect. However, if lexical selection and semantic integration are cascading processes, and the semantic integration process works with several candidates, according to the Cascading Hypothesis, the ERPs of the partial completions would show an N200 effect followed by an N400 effect. Figure 3-3 reveals an unanticipated large ERP component in the grand average waveforms of the partially presented critical words, which, as shown in Figure 3-4, appears to be related to the offset of the partially presented words. This off potential obscures potential underlying N200 and N400 components. However, as shown in Figure 3-6, an effect was obtained in the N200 latency window. As both the congruent and anomalous completions ended in the same abrupt manner, this effect cannot be accounted for by the off potential itself. We, therefore, conclude that any effect must be due to an underlying N200 effect. An effect was also observed in the off-potential window. Again, as both conditions contained partial completions, the observed off-potential effect is suspected to be due to the preceding N200 effect being carried over to the off-potential window. In addition to these effects a significant N400 effect was obtained. As in their fully presented counterparts, Figure 3-6 shows that the N200 effect had an even distribution, whereas the N400 effect had a centro-parietal distribution, and topographical analyses revealed that these scalp distributions are statistically distinct. These results indicate that apparently, the N400 effect sets in before recognition of the actual word takes place. It seems that semantic integration processes start before selection of the one appropriate (but anomalous) candidate has taken place, and that (the onset of) the N400 effect is not related to the earliest moment at which a word is recognized (i.e., at IP).

To investigate this hypothesis further we performed a second experiment. We used information we obtained from the gating study about the earliest moment at which a word can be identified, the isolation point (IP), to further investigate the (onset of) the N400 effect. The critical words were divided into two groups with early or late IPs (with means of 230 and 340 ms, respectively). We hypothesized that if the N400 is related to the IP, then the N400 effect should set in at or soon after IP, and should therefore differ between the early and late IP words. If, however, semantic integration starts before the word is uniquely recognized, as indicated by the results of our first experiment, then onset of the N400 could occur prior to the IP and should not have to differ between the two groups of items. As seen in Figure 3-8, irrespective of whether a word has an early or late IP, the waveforms of the congruent as well as the anomalous completions are practically identical. Statistical analysis confirmed a significant main effect of Congruity in the absence of an interaction between the factors IP and Congruity. Also, when we time-locked the waveforms to IP, the difference waveforms of the early and late comparisons were practically identical (see Figure 3-9). Onset analyses revealed that in the case of words with early IPs, with a mean of 230 ms, the congruity effect sets in approximately 50 ms prior to IP. In the case of words with late IPs, with a mean of 340 ms, the congruity effect sets in approximately 140 ms prior to IP.

In the case of words with early IPs the congruity effect preceding IP is possibly only the N200 effect. Since the N200 reflects the lexical selection process, we would expect to find this congruity effect to occur prior to IP. However, in the case of words with late IPs, it seems that in addition to the N200 effect, the N400 effect already has set in well before the IP. Onset of the N400 effect is not postponed until after IP, as was predicted by the Sequential Hypothesis, but instead sets in at the same time as in the group of words with early IPs. So, despite a mean difference in IP of at least 110 ms between the two groups, the factor early or late IP does not seem to affect the onset nor the peak of the N400. These results support our finding of an N400 effect in the Partial Words in our first experiment and can only be accounted for by the Cascading Hypothesis. It seems that the semantic integration process does not wait until one appropriate candidate has been selected on the basis of a phonological analysis. Instead, integration is attempted for a selected number of candidates that still match the acoustic input.

Relating these findings to the findings by Van Petten and colleagues (1999), we can say that the results of this study suggest that the congruity effect, either between semantically congruous and anomalous words, or between congruous words in semantically high and low constraining sentences, can, in fact, be divided into an N200 and an N400 effect, and that these effects reflect qualitatively distinct processes, namely the lexical selection and the semantic integration processes. This distinction enables us to be somewhat more precise than Van Petten and colleagues. They concluded that “The latency results are more compatible with a continuous mapping from acoustic input onto semantic representations, rather than a single selection point at which an item is classified as congruous or incongruous and semantic processing must be restarted if the wrong choice is made” (p. 415). However, our results show that two distinct effects reflecting two functionally different processes can be distinguished; the N200 effect and the N400 effect. With the N200 effect reflecting lexical selection, there is a certain time frame in which lexical selection can take place, and presumably does in the case of congruous words in highly constraining sentences. If, however, selection of one appropriate candidate is difficult on the basis of the acoustic analysis of the first phonemes of a word and context-based specifications, as would be the case for anomalous words, as well as congruous words in low constraint sentences, integration as reflected by the N400 is still attempted for those candidates that match the acoustic input. Since speech is such a rapid phenomenon, one can imagine that the comprehension system cannot always wait for a word to be fully perceived. In these cases, integration is attempted for a selected number of candidates that still match the acoustic input, and thus, begins before word identification is complete.

Overall, our findings seem most compatible with word-identification models such as Shortlist and the Cohort model that allow a bottom-up priority for acoustic processing of initial phonemes of the perceived word, causing multiple lexical candidates that share word onset to be accessed (Marslen-Wilson, 1987; Marslen-Wilson & Welsh, 1978; Norris, 1994). After activation of a set of candidates top-down context information from the preceding sentence (or discourse) frame is used to narrow down the number of candidates to the one that is most compatible with both form and content constraints. In the case of a candidate that fits the specifications well, selection then is a by-product of integration. If however, none of the candidates from the set seem to fit the contextual constraints, with congruent words in semantically low constraining contexts at one end of the continuum and anomalous words in high constraining contexts at the other, integration is attempted for a number of candidates that still match the acoustic input. Here, the semantic integration process is instigated before word identification is complete. Common sense experience tells us that after unsuccessful integration of several candidates, the actual word eventually is perceived on the basis of acoustic analysis alone, in which case identification of an anomalous word is usually closely followed by a “What did you say?” from the listener.

The Influence of Semantic and Syntactic Context Constraints on Lexical Selection and Integration in Spoken-Word Comprehension as Revealed by ERPs.

CHAPTER 4

Daniëlle van den Brink and Peter Hagoort[1]

ABSTRACT

An event-related brain potential experiment was carried out to investigate the influence of semantic and syntactic context constraints on lexical selection and integration in spoken-word comprehension. Subjects were presented with constraining spoken sentences that contained a critical word that was either (a) congruent, (b) semantically and syntactically incongruent, but beginning with the same initial phonemes as the congruent critical word, or (c) semantically and syntactically incongruent, beginning with phonemes that differed from the congruent critical word. Relative to the congruent condition an N200 effect reflecting difficulty in the lexical selection process was obtained in the semantically and syntactically incongruent condition where word onset differed from that of the congruent critical word. Both incongruent conditions elicited a large N400 followed by a Left Anterior Negativity (LAN) time-locked to the moment of word category violation and a P600 effect. These results would best fit within a cascaded model of spoken-word processing, proclaiming an optimal use of contextual information during spoken-word identification by allowing for semantic and syntactic processing to take place in parallel after bottom-up activation of a set of candidates, and lexical integration to proceed with a limited number of candidates that still match the acoustic input.

1. This chapter has been submitted for publication.

INTRODUCTION

During a conversation, we are able to analyze the acoustic information we receive incrementally, select the proper words by mapping the sensory input onto stored lexical knowledge containing phonological, semantic and syntactic information, extract the meaning of those words and integrate them into the ongoing sentential or discourse context to come to an overall interpretation of the utterance. The question of how these processes interact remains a matter of debate. In general, the spoken-word recognition process, which lies at the heart of spoken language processing, is assumed to consist of three basic subprocesses: lexical access, lexical selection and lexical integration. The functional architectures of many spoken-word recognition models describing these subprocesses differ, but both Marslen-Wilsons's Cohort model and Norris' Shortlist model, for instance, pose that during lexical access multiple lexical candidates that share word onset are activated in parallel on the basis of an analysis of the initial phoneme(s) of a word (Marslen-Wilson, 1987; Marslen-Wilson & Welsh, 1978; Norris, 1994). This is a purely autonomous or bottom-up process. As pronunciation of a word progresses over time, lexical candidates are dropped or become less activated as soon as they no longer correspond to the incoming acoustic signal. Selection of the proper candidate is said to take place when only one candidate is left that matches the acoustic signal best. Word recognition in sentences or discourse additionally requires that the selected word is integrated into a higher-order meaning representation of the preceding context.

The key issues relate to how bottom-up activation interacts with contextual information to establish an interpretation of the utterance. At some point during auditory language comprehension semantic and syntactic properties of a word are evaluated with respect to constraints provided by the preceding context. An important question that needs to be answered pertains to the time-course of the use of different sources of higher-level context information in relation to lexical information during sentence processing; does semantic and syntactic processing occur in parallel or are they serial in nature? At the level of auditory sentence comprehension, this dichotomy is represented by two kinds of model. "Syntax-first" models, for instance, claim that syntactic processing (i.e. syntactic structure building) takes place before semantic information from the context is used (Frazier, 1987; Friederici, 1995; 2002). These "syntax-first" or serial models can be contrasted with constraint-based or interactive models that claim that all sources of information exert their influence directly and in parallel on auditory sentence processing and that none of them have priority over another (cf. Trueswell & Tanenhaus, 1994). A parallel can be drawn at the level of lexical processing; is semantic and syntactic information from the context used in parallel during spoken-word processing or does specific syntactic information have priority over semantic information?

Electrophysiology of language processing

The present study was designed to investigate the influence of semantic and syntactic context constraints on lexical selection and integration processes. A technique that seems especially suitable for studying brain processes in real time is the recording of event-related potentials (ERPs). ERPs reflect the sum of simultaneous postsynaptic activity of a large population of neurons recorded at the scalp as small voltage fluctuations in the electroencephalogram. Because of its high temporal (millisecond) resolution this technique has proven to be a sensitive measure of real-time language processing. Furthermore, previous studies have shown that ERPs provide qualitatively distinct correlates of semantic and syntactic processes.

The most salient electrophysiological correlate of semantic processing is the well-documented N400 (Kutas & Hillyard, 1980). The N400 is a negative-polarity potential that starts at about 200 to 250 ms, peaks at 400 ms after stimulus onset, and usually has a posterior distribution across the scalp. In sentence or discourse contexts, the N400 amplitude indexes the relative ease with which the meaning of a word is integrated in the preceding context. The better the semantic fit of a word within the sentence frame or larger discourse, the more reduced the amplitude of the N400 (Brown & Hagoort, 1993; Hagoort & Brown, 2000; Holcomb, 1993; Van Berkum, Zwitserlood, Hagoort & Brown, 2003). The most prominent effect related to syntactic processing is a positive shift occurring in the latency window of 500 to 800 ms after stimulus onset, the P600. Several syntactic violations, such as violations in agreement of number, gender and case, phrase-structure violations and subjacency violations, but also violation of structural preference elicit a P600 (cf. Hagoort, Brown & Osterhout, 1999; Friederici, 2002). In addition, problems in syntactic processing have been found to elicit a negative shift that occurs in a relatively early latency window of 100 to 500 ms after stimulus onset, and usually has a left-lateralized anterior distribution across the scalp. The exact functional interpretation and domain-specificity of previously mentioned ERPs in general, and the left anterior negativity (LAN) in particular, is under debate. For example, some researchers contribute the LAN to processes of verbal working memory, rather than claiming it to be specifically syntactic in nature (Coulson, King, & Kutas, 1998; Kluender & Kutas, 1993; cf. Hagoort et al., 1999). Nonetheless, in the context of language comprehension the LAN has been observed to be elicited in situations involving several types of syntactic violations, such as morpho-syntactic and word category violations (cf. Hahne & Friederici, 1999; Hagoort et al., 1999). Recently, a further subdivision has been proposed between two negativities within this early time window, because of a difference in latency and possible functional roles: An early left anterior negativity (ELAN) between 100 and 200 ms after stimulus onset, related to the processing of word category violations and a somewhat later left anterior negativity (LAN) between 300 and 500 ms after stimulus onset, related to the processing of morpho-syntactic violations (Friederici, 2002; Hahne & Jescheniak, 2001).

Serial versus interactive lexical processing

A number of ERP studies that investigated the interaction of syntax and semantics during lexical processing obtained results that point to their time course being serial in nature rather than parallel. A key finding was that words containing a word category violation as well as a semantic violation elicited an anterior negative effect in the range of 100 to 300 ms followed by a P600, but did not elicit an N400 (Friederici, Pfeifer & Hahne, 1993; Friederici, Steinhauer & Frisch, 1999; Hahne & Jescheniak, 2001, but see Ainsworth-Darnell, Shulman & Boland, 1998). The absence of an N400 in these results were interpreted as providing evidence for the claim that certain syntactic aspects can influence semantic lexical integration processes: Word category violation as reflected by the ELAN appeared to block attempts to integrate a lexical candidate into the preceding context.

A recent serial model that incorporates these findings is a neurocognitive model of sentence processing proposed by Friederici (Friederici, 2002; Friederici et al., 1999). Although presented as a serial or "syntax-first" model of auditory sentence processing, it makes specific claims at the level of spoken-word processing. An attractive feature of this model is that it specifies the temporal structure of lexical processing in terms of three phases. During the first phase, from 100 to 300 ms, the initial syntactic structure is said to be formed on the basis of word category information. In the second phase, from 300 to 500 ms, thematic role assignment takes place on the basis of lexical-semantic and morphosyntactic processes. In the third phase, from 500 to 1000 ms, integration of the different types of information occurs. The claims are that syntactic-phrase structure building (on the basis of word category information only) is entirely autonomous and precedes semantic processing, and that these processes interact only in the third phase.

However, the temporal characteristics of Friederici's model are primarily based on studies where ELANs were obtained in critical words that were presented auditorily and that contained clear morpho-syntactic markers at the beginning of the critical word indicating the word category. For instance, Hahne and Jescheniak (2001) and Friederici, Pfeifer and Hahne (1993) used auditorily presented sentences like “Die Birne wurde im *gepflückt*” (“The pear was being in-the *plucked*”) or “Die Freund wurde im *besucht*” (“The friend was being in-the *visited*”) were the morpho-syntactic markers "*ge*-" and "*be*-" in combination with the preceding auxiliary "wurde" are far more likely to lead to a past participle than a noun. One can question the validity of the temporal parameters of Friederici’s model, and possibly even of the claim that word category information is processed earlier than semantic information (Phase I vs. Phase II) if the specifications of the model are primarily based on studies in which word category information was always encoded in the prefix, and thus became available sooner than lexical-semantic information, encoded in the stem.

In most languages information about the word category often is encapsulated in the suffix of a word or in some cases even remains ambiguous. Contrary to many studies giving evidence to the claim that semantic processing acts on a small part of the perceived word, "syntax-first" models in general, would in these cases predict that semantic processing is postponed until after the word has been heard completely and information about the word category has become available. However, due to its specification of temporal characteristics of lexical processing, Friederici’s three-phase neurocognitive model appears to have more difficulty predicting the time course of lexical processing in these cases: Here, word category information embedded in the suffix does not become available during Phase I with temporal parameters of 100 to 300 ms, and according to the model, Phase II cannot be initiated if information about the word category has not been processed.

Now, consider the following account of an interactive model of spoken-word recognition (cf. Marslen-Wilson, 1987; Zwitserlood, 1989): After bottom-up activation of a number of lexical candidates on the basis of an analysis of the initial phoneme(s) of the spoken word (100 to 150 ms of acoustic signal) top-down context information starts to exert its influence. At this moment any information available, (i.e., phonological, semantic and syntactic) is used to assess which candidate is most compatible with both form and content constraints. This candidate is then integrated in the sentence context. If, however, in case of an anomalous word none of the lexical candidates fit the context well, selection of the proper candidate is difficult and can only be done on the basis of the acoustic information. Both this interactive model of spoken word processing and "syntax-first" models in general, predict that auditorily presented words that violate word category constraints, but lack clear morpho-syntactic markers as initial phonemes, would elicit a LAN following the late moment of violation detection. This also holds for the "syntax-first" model proposed by Friederici, provided violation detection can take place during the first 300 ms after word onset. However, contrary to "syntax-first" models, interactive models such as the one described earlier would predict that in the case of a word that violates semantic as well as syntactic constraints set by the preceding sentence context, prior to the LAN, an N400 would possibly be elicited due to semantic information already being available and processed before information about the word category has become available.

The present study

In the present study the time course of phonological, semantic and syntactic processing in spoken-word recognition was evaluated with ERPs. We used semantically constraining Dutch sentences with critical words that differed across three conditions. In the Fully Congruent condition (FC), the critical word was a non-sentence-final, highest-cloze probability word.[2] In a second condition called the Fully Incongruent (FI) condition, the critical word was replaced by a verb in past tense that apart from syntactic constraints also violated semantic constraints and had initial phonemes that differed from the highest-cloze probability word. In addition to these two conditions we were also interested in the ERP waveform to a condition where the onset of the word category violation resembles that of a semantically and syntactically congruent word. This third condition, therefore, contained a verb in past tense that began with the same initial phonemes as the highest-cloze probability word in the FC condition. This condition was called the Initially Congruent (IC) condition. An example of the experimental materials is given in Table 4-1. For the full set of experimental materials see Appendix. In both examples of target words in FI and IC conditions, the earliest moment at which the listener is able to detect that the word is actually a verb instead of a noun, from here on referred to as the category violation point (CVP), lies at the onset of the word-final syllable "*de*". For instance, at the onset of the word-final syllable "*de*" in *kliederde*, in Dutch the word *kliederboel* (*mess*) is still a possible noun continuation.

Two previous studies using experimental materials that manipulated semantic processing have shown that presenting semantically incongruent words with onsets that, given a semantically constraining preceding sentence frame, differ from those of the highest cloze probability words, elicit a negative effect between 150 to 250 ms after stimulus onset, related to phonological processing. This N200 effect is assumed to reflect the lexical selection process, where word-form information resulting from an initial phonological analysis and content information derived from the context interact (Van den Brink, Brown & Hagoort, 2001; Van den Brink, Brown & Hagoort, submitted). Note that in these previous studies all critical words elicited an N200, irrespective of whether the initial pho-

2. Cloze probability of a word is defined as the percentage of subjects who use that word to continue a particular sentence (see Bloom & Fischler, 1980).

Table 4-1. *Examples of the stimulus materials*

Condition	Sentence
Fully Congruent	Het vrouwtje veegde de vloer met een oude **bezem** gemaakt van twijgen (The woman wiped the floor with an old **broom** made of twigs)
Initially Congruent	Het vrouwtje veegde de vloer met een oude **bedelde** gemaakt van twijgen (The woman wiped the floor with an old **begged** made of twigs)
Fully Incongruent	Het vrouwtje veegde de vloer met een oude **kliederde** gemaakt van twijgen (The woman wiped the floor with an old **messed** made of twigs)

Note. The critical words are typed in bold face.

nemes were identical to those of a congruent word or not. Analogous to the functional interpretation of the N400, the amplitude of the N200 is believed to be indicative of whether the initial assessment of form-based activated lexical candidates reveals the presence of a lexical candidate that on the basis of its semantic and syntactic characteristics fits the contextual specifications. A small N200 is elicited when the set contains a candidate that fits the sentence context, a large N200 indicates that the set does not contain a lexical candidate that fits the preceding sentence frame well. Adding the third condition would enable us to investigate the influence of compatible initial phonemes of semantically and syntactically incongruent words on spoken-word recognition.

Following the interactive account of spoken-word processing we hypothesized that all three conditions should elicit an N200 component, with an amplitude that is largest in the FI condition and does not differ between the FC and IC conditions. In the two semantically and syntactically anomalous conditions this N200 component would be followed by an N400, a LAN, and a P600. The waveforms in the N400, the LAN, and P600 intervals would not be expected to differ between the IC and FI conditions, since both are equally anomalous, both in the semantic as well as in the syntactic sense.

METHOD

Subjects

The experiment was conducted with 21 native speakers of Dutch (20 female, mean age 21, range 18-27 years) from the subject pool of the Max Planck Institute for Psycholinguistics. All had normal to corrected-to-normal vision and were right-handed (four subjects reported having a left-handed parent or sibling). None of the subjects had any neurological impairment or had experienced any neurological trauma. Nor had any of the subjects participated in the pretest (see below). The data of five additional subjects were not analyzed due to too much contamination of artifacts such as blinks, muscle tension and excessive alpha activity. Subjects were paid for their participation.

Materials

The experimental items consisted of a set of 222 triplets of semantically constraining sentences across three experimental conditions. The sentences in each triplet were identical except for the critical word. In the Fully Congruent condition (FC), the critical word was a non-sentence-final, but high cloze probability word, e.g., “Het vrouwtje veegde de vloer met een oude *bezem* gemaakt van twijgen” (“The woman swept the floor with an old *broom* made of twigs”). In the Initially Congruent condition (IC), the critical word was a verb in past tense that had the same initial phonemes (and lexical stress) as the highest cloze probability word, e.g., “Het vrouwtje veegde de vloer met een oude *bedelde* gemaakt van twijgen” (“The woman swept the floor with an old *begged* made of twigs”). In the third condition the critical word was a verb in past tense that had initial phonemes that were totally unexpected given the sentential context, e.g., “Het vrouwtje veegde de vloer met een oude *kliederde* gemaakt van twijgen” (“The woman swept the floor with an old *messed* made of twigs”). This condition is called the Fully Incongruent condition (FI).

The 222 triplets were derived from a set of sentence materials that had been used in a previous study and which were part of a larger set of sentences that had been submitted to a cloze test. Thirty subjects from the subject pool of the Max Planck Institute for Psycholinguistics were given a list of 350 sentences with the final word omitted. Subjects were asked to carefully read the sentences and to fill in the first word that came to mind at the position of the omitted sentence-final word. On the basis of the results, a set of 222 sentences with a cloze probability of .50 or higher formed the basis for the 222 triplets used in this experiment. To avoid possible sentence-wrap-up effects we added a few words to each sentence (meanwhile making sure that the sentences remained meaningful), so that the critical words were non-sentence-final. Items for the IC condition were constructed by replacing the critical word by a verb in the past tense, but began with the same phonemes (mean length of overlap was 2.5 phonemes, range 2 to 5, always including a full vowel) and had the same lexical stress as the high cloze probability word, which was used in the FC condition. The items for the FI condition were constructed by replacing the critical word with a verb in past tense with word-initial phonemes that differed from the beginning phonemes of the high cloze probability word and other congruent words.

Because the sentences within each triplet were identical except for the critical word, they had the same length (mean length of 13.9 words; range 8-21) and were equally constraining; the critical words in the FC condition had a mean cloze probability of .84 (range: .50-1.0). All critical words were reasonably well-known nouns and verbs selected from a Dutch word corpus called CELEX (Baayen, Piepenbrock & Van Rijn, 1993) and had a mean duration of 386 ms and a frequency of 43.7 counts per million in the FC condition, 495 ms and 16.2 counts in the IC condition, and 485 ms and 13.6 counts in the FI condition. Each critical word began with a plosive. This provided a clear physical marker that facilitated the alignment of the ERP-waveform to the onset of the critical word.

Three lists were constructed to ensure that no subject heard the same sentence or critical word more than once. In addition to the set of 222 experimental items (74 per condition per list), a set of 74 fillers was constructed. These fillers were all semantically congruent, to balance the number of sentences that were anomalous and congruent. Finally, the experimental lists were preceded by a practice list of 20 items, which reflected the experimental materials. The practice list was used to familiarize the subjects with the experimental procedure.

The experimental sentences, fillers and practice sentences were all spoken by a female speaker, with normal intonation at a normal speaking rate, and were recorded in one recording session. The sentences were recorded in triplets, making sure intonation and speaking rate were kept constant within each triplet. Sentences were spoken in a sound-attenuating booth and recorded on a digital audio tape. The DAT-recordings were sampled at 16 kHz mono and stored on computer disk. A speech waveform editing system was used to mark the onset of the critical words. Also, the moment of word category violation, was marked for each critical word in IC and FI conditions individually using the CELEX database for reference. Based on phonetic transcriptions we identified the moment at which the verb in past tense and a possible noun continuation started to diverge from one another. For instance, the critical FI-word *kliederde* (*messed*) has a relatively well-known noun counterpart of *kliederboel* (*mess*). Here, the word category violation occurs at the onset of the word-final syllable "*de*", marking for a verb in past tense, and a marker was placed for alignment purposes. Using this procedure, the word category violation point (CVP) in IC was on average 336 ms (*SD* = 76 ms) and in FI 324 ms (*SD* = 70 ms).

Procedure

Subjects were tested individually in a dimly illuminated sound-attenuating booth. They were seated in a comfortable reclining chair, instructed to move as little as possible, and told that they would hear a number of sentences. Their task was to attentively listen to these sentences and to try to understand them. In addition they were told that several sentences would be anomalous. No additional task demands were imposed.

Each trial began with a 300 ms warning tone, followed after 1200 ms silence by the spoken sentence. The next trial began 3500 ms after sentence offset. To ensure that subjects would not blink during and shortly after presentation of the sentence, 1000 ms prior to the beginning of the sentence a fixation point (an asterisk) was displayed on the computer screen. The asterisk remained on the screen until 1000 ms after offset of the spoken sentence. Subjects were instructed to fixate on the asterisk during presentation of the sentences, but were free to blink and move their eyes when the asterisk was not displayed on the screen. Subjects listened to the stimuli via closed-ear headphones. After the practice session, the trials were presented in 5 blocks of approximately 10 minutes.

EEG-recording

The EEG was recorded from 29 Ag/AgCl-sintered electrodes mounted in an elastic cap, each referred to the left mastoid (see Figure 2–1 for the electrode distribution). Five electrodes were placed according to the 10-10 Standard System of the American Electroencephalographic Society over midline sites at Fz, FCz, Cz, Pz, and Oz locations, along with 9 lateral pairs of electrodes over standard sites on frontal (AF3, AF4, F3, F4, F7 and F8), fronto-central (FC3 and FC4), fronto-temporal (FT7 and FT8), central (C3 and C4), centro-parietal (CP3 and CP4), parietal (P3 and P4), and occipital (PO7 and PO8) positions. Three additional pairs were placed laterally over symmetrical positions: (a) a temporal pair (LT and RT) placed laterally to Cz, at 33% of the interaural distance, (b) a temporo-parietal pair (LTP and RTP) placed 30% of the interaural distance lateral and 13% of the nasion-inion distance posterior to Cz, and (c) a parietal pair midway between LTP/RTP and PO7/PO8 (LP and RP). Vertical eye movements were monitored via a supra- to sub-orbital bipolar montage. A right to left canthal bipolar montage was used to monitor for horizontal eye movements. Activity over the right mastoid bone was recorded on an additional channel to determine if there were differential contributions of the experimental variables to the presumably neutral mastoid site. No such differential effects were observed. The EEG and EOG recordings were amplified with a SynAmp Model 5083 EEG amplifier (NeuroScan Inc., Herndon, Va, USA), using a hi-cut of 30 Hz (notch filter 60 Hz) and a time constant of 8 s (0.02 Hz). Electrode impedances were kept below 3 kOhm for the EEG recording and below 5 kOhm for the EOG recording. The EEG and EOG signals were digitized on-line with a sampling frequency of 200 Hz.

Data analysis

Data from critical trials were analyzed according to the following procedure. Prior to off-line averaging, all single-trial waveforms were screened for eye movements, electrode drifting, and EMG artifacts in a critical window that ranged from 150 ms before onset of the sentence-final word, to 2000 ms after onset of the sentence-final word. Trials containing artifacts were rejected (11.7% in FC, 13.6% in IC, and 12.5% in FI). For each subject, average waveforms were computed across all remaining trials per condition after baseline correction of the individual trials on the basis of the averaged activity of 150 ms before onset of the critical word.

Statistical analyses of the congruity effects consisted of a number of repeated measures analyses of variance (ANOVAs) with mean amplitude values computed for each subject and each electrode in different latency windows: (a) 150-250 ms after critical-word onset for the early negativity (N200), (b) 300-500 ms after critical-word onset for the N400, and (c) 700-1000 ms after critical-word onset for the P600. The latency windows were determined after careful visual inspection of the grand average waveforms and corresponded with latency windows used in our previous studies (Van den Brink et al, 2001; Van den Brink et al., submitted). The latency window for the early negativity corresponds to the onset of the ascending flank and the offset of the descending flank. The N400 latency window corresponds to the onset of the ascending flank and 100 ms after its maximal amplitude. This 300-500 ms interval is a standard time window for measuring N400 effects. The latency window for the P600 corresponds to a window of 300 ms surrounding its maximal amplitude. For each latency window, the results were first analyzed in an omnibus ANOVA that crossed all three levels of the congruity factor (FC, IC, and FI) with the 29-level electrode factor. In addition to the omnibus ANOVA, a priori pairwise comparisons between the congruity conditions were tested using ANOVAs with a 2-level congruity factor.

Scalp distributions of the congruity effects were subsequently explored in three separate ANOVAs: an ANOVA on anterior versus posterior sites (Fz, FCz, AF3, AF4, F3, F4, F7, F8, FC3, FC4, FT7, FT8/Pz, Oz, CP3, CP4, LTP, RTP, P3, P4, LP, RP, PO7, PO8); anterior left hemisphere versus anterior right hemisphere (AF3, F3, F7, FC3, FT7/AF4, F4, F8, FC4, FT8); posterior left hemisphere versus posterior right hemisphere (CP3, LTP, P3, LP, PO7/CP4, RTP, P4, RP, PO8). Univariate *F* tests with more than one degree of freedom in the numerator were adjusted by means of the Greenhouse-Geisser/Box's epsilon hat correction (Maxwell & Delaney, 1990). The original degrees of freedom and adjusted *p* values will be reported.

RESULTS

Time-locking to word onset

Figure 4-1 displays the grand average waveforms by electrode site time-locked to the onset of the critical word. There are several things to note. First, as found in previous studies of ours and a recent study by Sanders and Neville using connected speech, the critical words elicited an N100 component in all three conditions (Sanders & Neville, 2003; Van den Brink et al., 2001; Van den Brink et al., submitted). Second, a negativity at approximately 200 ms is visible in the waveforms. This negativity is apparent in all three conditions, but is largest in the FI condition and is most visible over the frontal to central sites (see also enlarged FC4 in Figure 4-2). Third, the syntactically and semantically anomalous critical words in the IC and FI conditions elicit a broad negativity peaking at approximately 400 ms, which is more negative than the ERP elicited in the FC condition. In turn, this broad negativity is larger in the FI condition than in the IC condition. Its latency characteristics and morphology are similar to previously reported N400 effects. Finally, Figure 4-1 shows a late positivity between 700 and 1000 ms over parietal sites in the anomalous conditions. This positivity reaches maximal amplitude at around 800 to 900 ms and is present in both the IC and the FI conditions, but is largest in the IC condition (see also enlarged P4 in Figure 4-2). Its morphology is similar to previously reported P600 effects, related to difficulty in syntactic processing, but its latency characteristics differ. However, it is possible that since information about word category does not become available until at a relatively late moment in time (on average 330 ms after word onset), the P600 component may have been delayed.

The N200 latency window: 150-250 ms. Table 4-2 displays the results of the mean ERP amplitude ANOVAs in the 150-250 ms latency range. The omnibus ANOVA for the N200 latency window resulted in a significant main effect of congruity. The a priori pairwise comparisons revealed that the FI completions elicited a larger N200 than both the FC and the IC completions (corresponding to effects of 0.95 μV and 0.74 μV, respectively). In both of these comparisons the interaction of congruity with electrodes reached significance. Further topographical analyses revealed that the effects of the FI condition in relation to the FC and the IC conditions were larger over posterior than over anterior sites. The ERPs in the FC and IC conditions did not significantly differ in amplitude (a difference of 0.21 μV). No hemispheric differences were observed.

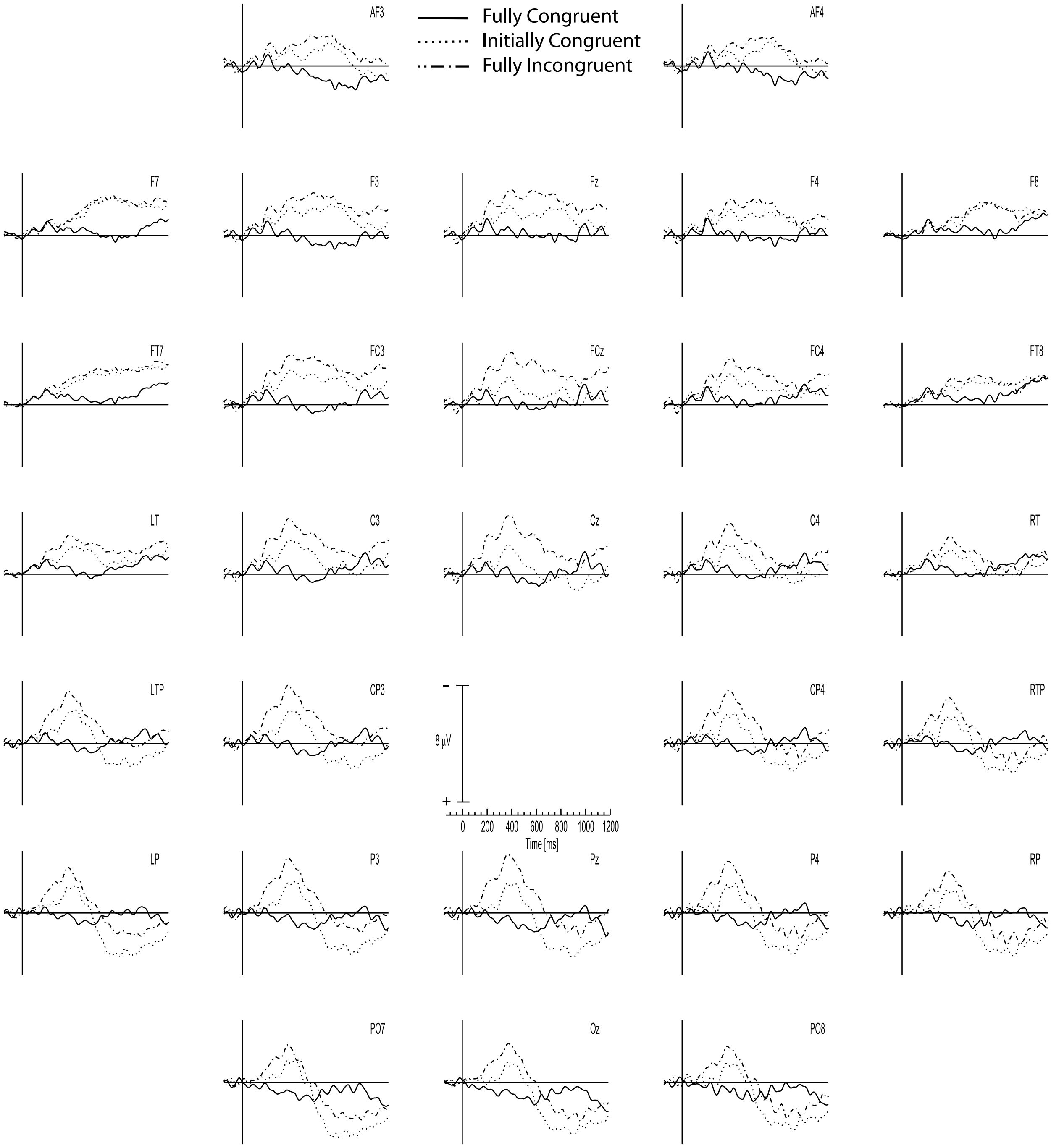

Figure 4-1. *Connected speech. Grand average ERPs from 29 scalp sites, to critical words that were congruent (solid line), semantically and syntactically incongruent but shared initial phonemes with congruent completions (dotted line), and semantically and syntactically incongruent and did not share initial phonemes with congruent completions (alternating dash/dot line), after baseline correction in the 150 ms prestimulus interval. Time 0 is the onset of critical words. The time axis is in milliseconds. Note that negative polarity is plotted upwards in this and subsequent figures.*

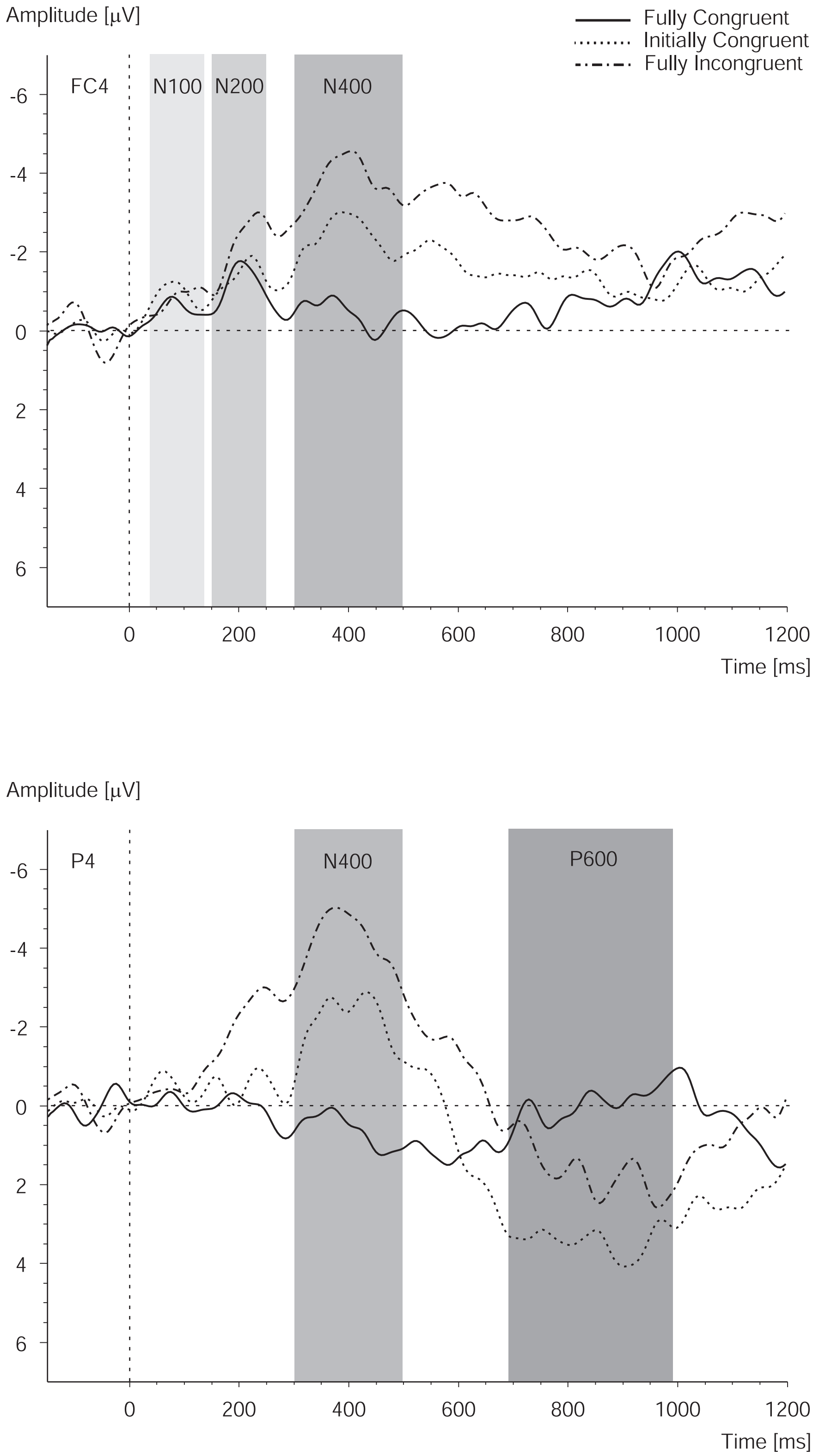

Figure 4-2. *Grand average ERPs from FC4 and P4, to critical words in three conditions. Time 0 is the onset of critical words.*

Table 4-2. *ANOVA on Mean ERP Amplitude in the 150-250 ms Latency Range (N200)*

	source	df	*F*	*MSE*	*p*
		Omnibus ANOVA (29 electrodes)			
Overall	Con	2, 40	13.54	11.20	.000 ***
	Con x El	56, 1120	4.36	0.44	.001 **
FC vs. FI	Con	1, 20	17.85	15.44	.000 ***
	Con x El	28, 560	8.96	0.38	.000 ***
FC vs. IC	Con	1, 20	1.42	9.91	.248
	Con x El	28, 560	0.63	0.50	.591
IC vs. FI	Con	1, 20	20.04	8.24	.000 ***
	Con x El	28, 560	4.64	0.44	.004 **
		Anterior vs. posterior (2 x 12 electrodes)			
FC vs. FI	Con x Site	1, 20	13.39	3.37	.002 **
IC vs. FI	Con x Site	1, 20	4.72	4.66	.042 *
		Anterior left vs. anterior right (2 x 5 electrodes)			
FC vs. FI	Con x Site	1, 20	3.22	1.03	.088
IC vs. FI	Con x Site	1, 20	1.49	1.03	.236
		Posterior left vs. posterior right (2 x 5 electrodes)			
FC vs. FI	Con x Site	1, 20	0.40	1.63	.533
IC vs. FI	Con x Site	1, 20	0.06	1.83	.806

Note. Con = Congruity type; El = Electrode. * $p < .05$; ** $p < .01$; *** $p < .001$

The N400 latency window: 300-500 ms. Table 4-3 displays the results of the mean ERP amplitude ANOVAs in the 300-500 ms latency range. The omnibus ANOVA indicated that the basic congruity effect in the N400 latency window was significant. Further analysis revealed that both the FI and the IC completions elicited a larger N400 than the FC completions (corresponding to effects of 2.51 µV and 1.49 µV, respectively). In both of these comparisons interactions of congruity with electrodes reached significance. In addition, the FI and the IC conditions differed significantly from each other in the N400 latency window (corresponding to an effect of 1.02 µV), and an interaction with electrodes was found as well. Topographical analyses showed that all three congruity effects were significantly larger over posterior than anterior regions of the scalp. No hemispheric differences were observed.

Table 4-3. *ANOVA on Mean ERP Amplitude in the 300-500 ms Latency Range (N400)*

	source	df	*F*	*MSE*	*p*
		Omnibus ANOVA (29 electrodes)			
Overall	Con	2, 40	27.17	35.67	.000 ***
	Con x El	56, 1120	7.74	0.58	.000 ***
FC vs. FI	Con	1, 20	48.88	39.22	.000 ***
	Con x El	28, 560	12.69	0.67	.000 ***
FC vs. IC	Con	1, 20	13.80	48.68	.001 **
	Con x El	28, 560	4.04	0.65	.006 *
IC vs. FI	Con	1, 20	16.69	19.12	.001 **
	Con x El	28, 560	5.49	0.40	.001 **
		Anterior vs. posterior (2 x 12 electrodes)			
FC vs. FI	Con x Site	1, 20	17.47	6.83	.000 ***
FC vs. IC	Con x Site	1, 20	6.61	6.33	.018 *
IC vs. FI	Con x Site	1, 20	4.73	4.19	.042 *
		Anterior left vs. anterior right (2 x 5 electrodes)			
FC vs. FI	Con x Site	1, 20	0.71	2.38	.410
FC vs. IC	Con x Site	1, 20	1.30	1.80	.267
IC vs. FI	Con x Site	1, 20	0.05	1.00	.819
		Posterior left vs. posterior right (2 x 5 electrodes)			
FC vs. FI	Con x Site	1, 20	1.32	1.49	.264
FC vs. IC	Con x Site	1, 20	1.56	1.44	.225
IC vs. FI	Con x Site	1, 20	0.01	0.81	.915

Note. Con = Congruity type; El = Electrode. * $p < .05$; ** $p < .01$; *** $p < .001$

To establish whether the difference in ERP amplitude between the FI and IC conditions might be due to an early differential effect in the N200 latency window, we performed additional analyses in the N400 latency window after applying baseline correction in the 250-300 ms interval (see also Van den Brink et al., 2001). This time interval corresponds to a period just after the N200 component latency window. Figure 4-3 shows the grand average waveforms after this alternative baseline correction procedure. The omnibus ANOVA indicated that the basic congruity effect in the N400 latency window was still significant: $F(2, 40)$

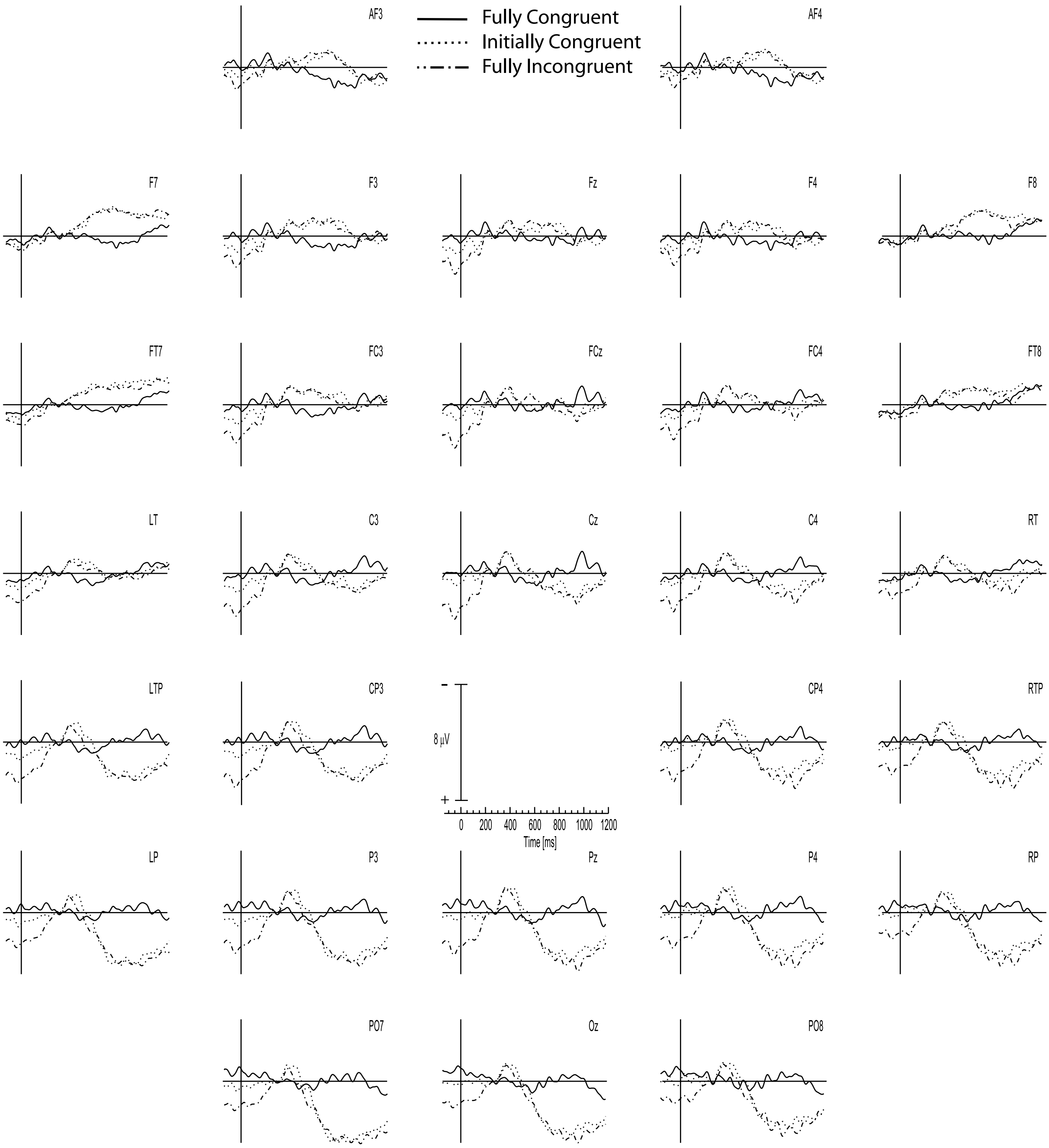

Figure 4-3. *Grand average ERPs from 29 scalp sites, to critical words in three conditions, after baseline correction in the 250-300 ms interval. Time 0 is the onset of critical words.*

Table 4-4. *ANOVA on Mean ERP Amplitude in the 700-1000 ms Latency Range (P600)*

	source	df	*F*	*MSE*	*p*
		Omnibus ANOVA (29 electrodes)			
Overall	Con	2, 40	2.46	48.86	.110
	Con x El	56, 1120	26.20	0.78	.000 ***
FC vs. FI	Con	1, 20	0.89	62.09	.357
	Con x El	28, 560	24.43	0.95	.000 ***
FC vs. IC	Con	1, 20	1.11	58.78	.304
	Con x El	28, 560	39.10	0.90	.000 ***
IC vs. FI	Con	1, 20	9.36	25.73	.006 **
	Con x El	28, 560	6.15	0.50	.000 ***

Note. Con = Congruity type; El = Electrode. ** $p < .01$; *** $p < .001$

= 5.88, *MSE* = 23.00, $p < .006$. The pairwise comparisons revealed that both the FI and the IC completions elicited a larger N400 than the FC completions (corresponding to effects of 0.72 µV with $F(1,20) = 7.83$, *MSE* = 19.92, $p = .01$ and 0.89 µV with $F(1,20) = 10.96$, *MSE* = 21.94, $p < .01$, respectively). However, the FC and the IC conditions did not significantly differ from each other: $F(1, 20) < 1$.

The P600 latency window: 700-1000 ms. Table 4-4 displays the results of the mean ERP amplitude omnibus ANOVAs in the 700-1000 ms latency range. The omnibus ANOVA on mean amplitudes did not result in a significant main effect of congruity. Pairwise analyses revealed that only the ERP amplitude in the FI condition differed significantly from the ERP amplitude in the IC condition. Again, because of the possibility that amplitude effects in this latency window were affected by earlier differential effects in the N200 latency window, we performed further analyses after baseline correction in the 250-300 ms interval.

Table 4-5 displays the results of the mean ERP amplitude omnibus ANOVAs in the 700-1000 ms latency range after baseline correction in the 250-300 ms interval (Figure 4-3). The omnibus ANOVA on mean amplitudes now did result in a significant main effect of congruity. Further analysis revealed that both the FI and the IC completions elicited a larger P600 than the FC completions (corresponding to effects of 1.37 µV and 1.06 µV, respectively). In both of these comparisons interactions of congruity with electrodes reached signifi-

Table 4-5. *ANOVA on Mean ERP Amplitude in the 700-1000 ms Latency Range (P600) after Averaging in the 250-300 ms Interval*

	source	df	*F*	*MSE*	*p*
		Omnibus ANOVA (29 electrodes)			
Overall	Con	2, 40	5.24	59.78	.015 *
	Con x El	56, 1120	29.94	0.94	.000 ***
FC vs. FI	Con	1, 20	7.44	76.46	.013 *
	Con x El	28, 560	37.10	1.16	.000 ***
FC vs. IC	Con	1, 20	4.74	72.16	.042 *
	Con x El	28, 560	41.82	0.99	.000 ***
IC vs. FI	Con	1, 20	0.94	30.71	.345
	Con x El	28, 560	0.39	0.68	.728
		Anterior vs. posterior (2 x 12 electrodes)			
FC vs. FI	Con x Site	1, 20	86.36	12.47	.000 ***
FC vs. IC	Con x Site	1, 20	122.55	8.52	.000 ***
IC vs. FI	Con x Site	1, 20	0.03	7.49	.856
		Anterior left vs. anterior right (2 x 5 electrodes)			
FC vs. FI	Con x Site	1, 20	2.99	3.51	.099
FC vs. IC	Con x Site	1, 20	2.54	2.55	.126
IC vs. FI	Con x Site	1, 20	0.22	2.26	.648
		Posterior left vs. posterior right (2 x 5 electrodes)			
FC vs. FI	Con x Site	1, 20	0.07	2.72	.800
FC vs. IC	Con x Site	1, 20	2.60	2.04	.123
IC vs. FI	Con x Site	1, 20	1.88	1.88	.186

Note. Con = Congruity type; El = Electrode. * $p < .05$; *** $p < .001$

cance. Topographical analyses revealed that the effects in relation to the FC condition (baseline) had a posterior distribution: In the anterior/posterior analyses, the interaction of the factors Congruity by Site reached significance both in the FC vs. FI comparison and the FC vs. IC comparison. The ERPs in the FI and the IC conditions did not significantly differ from each other. Again, no hemispheric differences were observed.

Onset latencies relative to word onset. To investigate the exact onset of the congruity effects we performed additional analyses. Onset latencies were estimated by first separately computing the mean amplitude values for all 29 electrodes in 20 ms latency ranges (bins) that shifted in steps of 10 ms from target onset until 500 ms after target onset (e.g., 0-20, 10-30, etc.). The values for the latency bins were submitted to ANOVAs that tested against the null-hypothesis of zero difference between the a priori selected conditions FC vs. FI and FC vs. IC. To compensate for multiple comparisons, we considered a congruity effect significant when at least 5 consecutive bins reached a statistical significance level of $p < .05$.

The onset latency analyses for the FC vs. FI comparison on the amplitudes of the two waveforms first revealed a significant congruity effect in the 170-190 ms latency bin ($p < .01$) and this effect remained significant over the entire test region (500 ms). In the FC vs. IC comparison the congruity effect did not start until the 310-330 ms latency bin. So, the FI waveform deviated from the FC waveform approximately 140 ms earlier than the waveform of the IC words (i.e., 170 vs. 310 ms after word onset).

Time-locking to the word category violation point

Figure 4-1 did not reveal the clear presence of a LAN in our data. Consider, however, that a LAN is believed to be elicited upon detection of a word category violation. Since the moment of detection differs between the critical words within a condition, the LAN might be smeared when the waveforms are time-locked to word onset. When time-locked to the moment of detection of a word category violation, the LAN, if present, should become visible. Figure 4-4 displays the grand average waveforms for electrode sites F7, F8, Pz, P3, and P4 time-locked on a trial-by-trial basis to the moment at which the critical words in the IC and FI conditions could be identified as verbs only and a word category violation was detected. This word category violation point (CVP) was assessed on the basis of phonetic transcriptions of the critical words. More specifically, on the basis of a Dutch word corpus it was assessed at what moment the critical word was no longer a possible noun. The time period preceding the CVP corresponds to the mean time period preceding CVP between the two conditions, which was 330 ms (336 ms in IC and 324 ms in FI, respectively). Therefore, in the alignment in Figure 4-4, the zero points of IC and FI correspond to word onset only approximately. Since information about the exact onset of each critical word is lost in this time-locking procedure, baseline correction cannot take place on the basis of information related to word onset. Therefore, baseline correction was applied on the basis of the averaged activity of 150 ms preceding CVP. Remember that the critical words in the FC condition, plotted in gray in Figure 4-4, do not contain word category violation points. In time-locking the FC waveform to word onset,

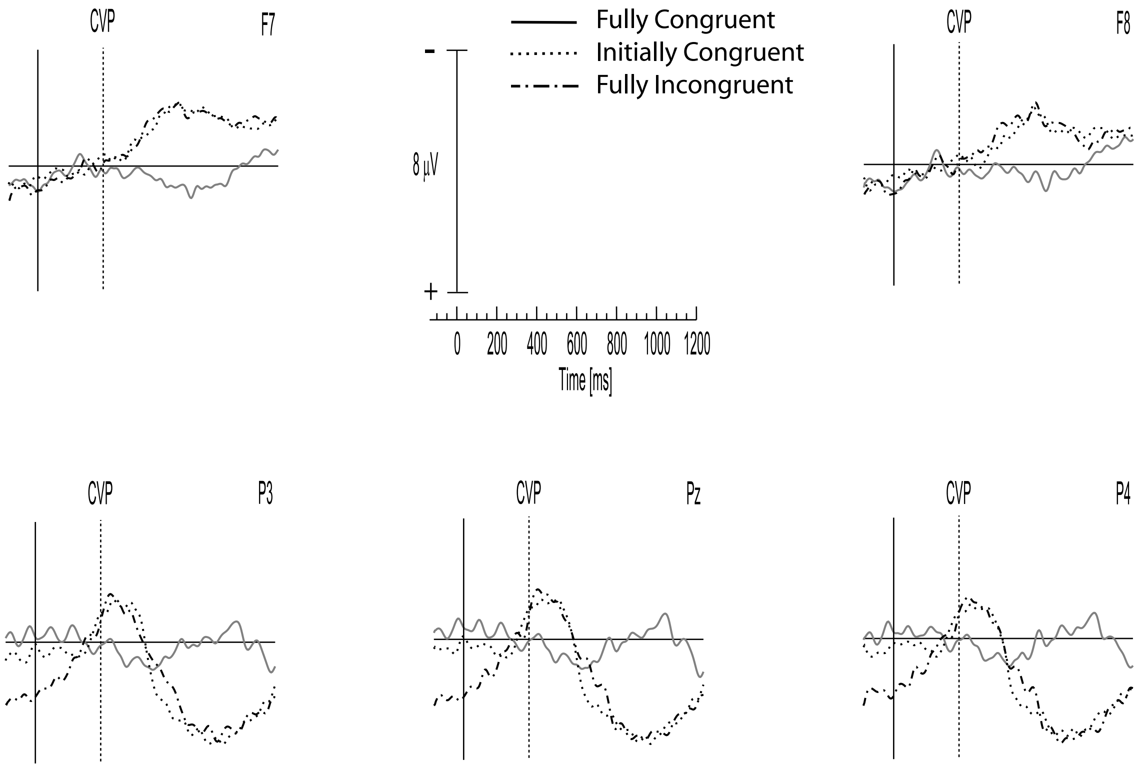

Figure 4-4. *Grand average ERPs from F7, F8, Pz, P3, and P4 sites, to critical words that were semantically and syntactically incongruent but shared initial phonemes with congruent completions (dotted line) and semantically and syntactically incongruent and did not share initial phonemes with congruent completions (alternating dash/dot line), after time locking on a trial-by-trial basis to the moment of word category violation (CVP), and grand average waveforms to congruent critical words (solid line) time-locked to word onset. Baseline correction was applied in the 150 ms interval preceding CVP for FI and IC.*

and adding a time period of 330 ms before the time-locking point in the incongruent conditions IC and FI (and applying baseline correction in the 180-330 ms interval for all three conditions), the time line of information processing between the three conditions is kept more or less constant. When we inspect the centro-parietal to occipital electrodes, what can be seen is that in both IC and FI the N400 has set in prior to CVP and is followed by a broad positive shift, peaking at around 600 ms after CVP. However, when we look at the frontal electrodes, again for both IC and FI a broad negativity peaking at around 370 ms after CVP is clearly visible. The anterior negative effect is most prominent at F7 and to a somewhat lesser extent at F8. To investigate the latter anterior negative shift we decided to perform a repeated measures ANOVA on the anterior electrode sites (Fz, FCz, AF3, AF4, F3, F4, F7, F8, FC3, FC4, FT7, and FT8) in the latency window of 600 to 800 ms (corresponding to 270 to 470 ms after CVP for FI and IC).

Table 4-6. *ANOVA on Mean ERP Amplitude in the 270-470 ms Latency Range after CVP (LAN)*

	source	df	*F*	*MSE*	*p*
	Omnibus ANOVA (12 electrodes)				
Overall	Con	2, 40	13.29	18.48	.000 ***
	Con x El	22, 440	5.05	0.47	.001 **
FC vs. FI	Con	1, 20	26.23	15.33	.000 ***
	Con x El	11, 220	5.92	0.47	.001 **
FC vs. IC	Con	1, 20	11.90	27.84	.003 **
	Con x El	11, 220	6.48	0.65	.001 **
IC vs. FI	Con	1, 20	0.28	12.27	.602
	Con x El	11, 220	0.71	0.31	.549
	Anterior left vs. anterior right (2 x 5 electrodes)				
FC vs. FI	Con x Site	1, 20	7.64	0.98	.012 *
FC vs. IC	Con x Site	1, 20	7.65	1.67	.012 *

Note. Con = Congruity type; El = Electrode. * $p < .05$; ** $p < .01$; *** $p < .001$

The LAN latency window: 270-470 ms after CVP. Table 4-6 displays the results of the mean ERP amplitude omnibus ANOVA in the 270-470 ms latency range after CVP. Baseline correction was based on the averaged activity of 150 ms immediately preceding CVP. The omnibus ANOVA on mean amplitudes resulted in a significant main effect of congruity. Further analysis revealed that both the FI and the IC completions elicited a larger LAN than the FC completions (corresponding to effects of 1.79 μV and 1.62 μV, respectively), and in both of these comparisons an interaction with electrodes was found as well. The FC and the IC conditions did not significantly differ from each other. Topographical analyses revealed that the effects in relation to the FC condition (baseline) were larger over the left hemisphere: In the anterior left/anterior right analyses, the interaction of the factors Congruity by Site reached significance both in the FC vs. FI comparison and the FC vs. IC comparison.

Inspection of the waveforms in this latency interval at posterior sites reveals a possible short-lived congruity effect between IC and FI. However, statistical analyses of the parietal and occipital band electrodes (Pz, Oz, P3, P4, LP, RP, PO7, and PO8) revealed no main congruity effect for this comparison ($F(1,20) = 2.71$, $MSE = 9.78$, $p = .115$).

Onset latencies relative to the word category violation point. We also performed onset analyses for the LAN at F7 and for the N400 at Pz where the effects are largest. Onset latencies were estimated by first separately computing the mean amplitude values for the F7 in 20 ms latency ranges (bins) that shifted in steps of 10 ms from 100 ms prior to CVP until 500 ms after CVP (e.g., 0-20, 10-30, etc. after CVP). The values for the latency bins were submitted to ANOVAs that tested against the null-hypothesis of zero difference between the a priori selected conditions FC vs. FI and FC vs. IC.

At F7, the onset latency analyses for the FC vs. FI comparison on the amplitudes of the two waveforms first revealed a significant congruity effect in the 90-110 ms latency bin after CVP ($p < .01$) and this effect remained significant over the entire test region. In the FC vs. IC comparison the congruity effect started between 120-140 ms after CVP and also remained significant over the entire test region. So, both the FI and the IC waveforms deviated from the FC waveform at approximately 100 ms after CVP.

At Pz, the onset latency analyses for the FC vs. FI comparison on the amplitudes of the two waveforms first revealed a significant congruity effect in the latency bin that starts 10 ms before CVP ($p < .01$) and this effect remained significant until the 190-210 ms latency bin after CVP. In the FC vs. IC comparison the congruity effect started between 30 and 50 ms before CVP and remained significant until the 180-200 ms latency bin after CVP. So, even though we applied a baseline correction procedure in the 150 ms interval prior to CVP, both the FI and the IC waveforms already deviated from the FC waveform at or even before CVP.

Scalp distribution of effects

Figure 4-5 shows the isopotential voltage maps of mean amplitude effects between the FC and FI conditions in the N200, the N400, and the P600 latency window after time-locking to word onset, and in the LAN window after time-locking to CVP. The figure reveals that both the N200 effect and the N400 effect are largest over centro-parietal sites. The LAN effect is largest over left frontal sites, and the P600 effect has a parietal maximum. To establish whether the congruity effects in the N200 and N400 latency windows still have statistically distinct scalp distributions, we performed an additional analyses. First, for every subject difference scores between the FC and FI conditions were computed for every electrode in the N200 latency window and the N400 latency window. Second, a scaling procedure was performed to avoid that differential amplitude effects between the two latency windows would be incorrectly interpreted as distribution effects. In this procedure, the electrode-specific difference scores were z-transformed for each latency window separately (Rösler, Heil, & Glowolla, 1993; see also McCarthy & Wood, 1985). The z-transformed values were entered

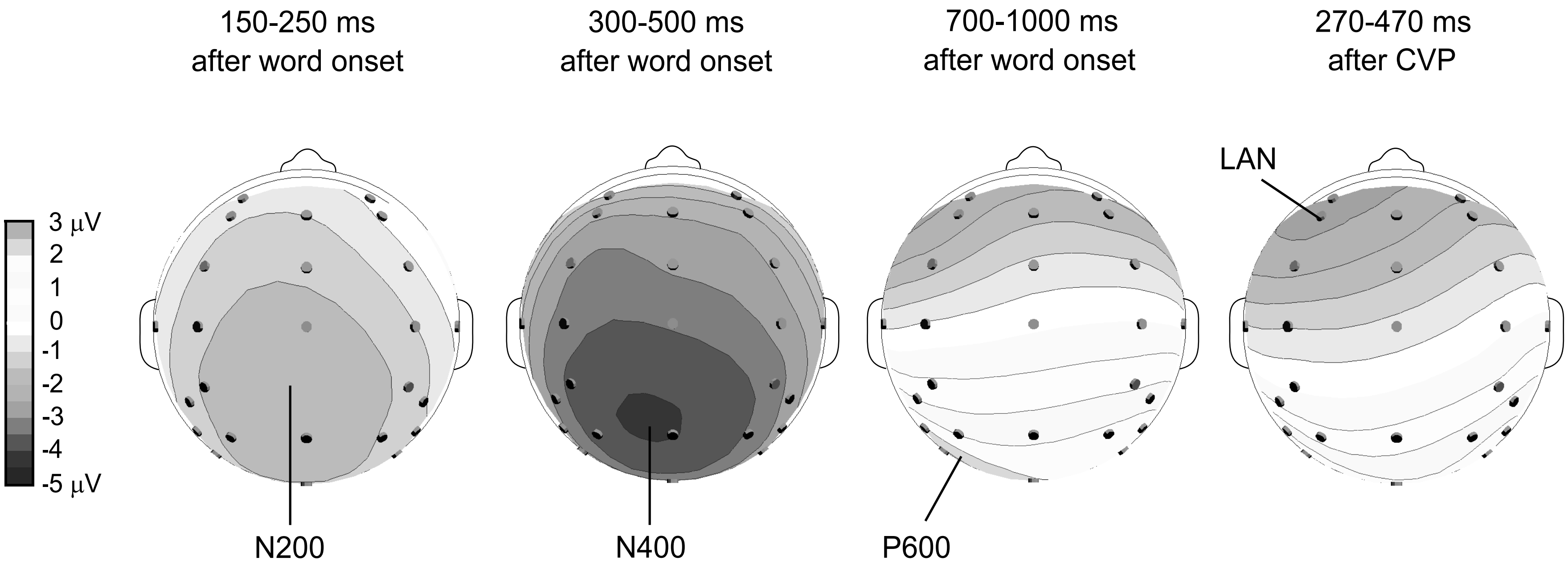

Figure 4-5. *Isopotential voltage maps of the N200, N400, LAN, and P600 effects. Maps are based on difference waveforms that resulted from subtracting the mean amplitude in the latency windows of the grand average ERP for FC from the mean amplitude of the grand average ERP for FI.*

into an ANOVA that crossed the 2-level latency window factor (N200 and N400) with the 29-level electrode factor. The topographical analysis revealed that the congruity effects found in the 150-250 ms and 300-500 ms latency windows do not have different spatial distributions across the scalp: no significant interaction of latency window by electrodes was obtained ($F(28,560) = 1.69$, $MSE = 0.29$, $p = .146$). Although not significant the N400 does seem to have a slightly more posterior distribution than the N200. In previous studies this difference was found to be significant (Van den Brink et al., 2001; submitted).

DISCUSSION

The present study investigated the influence of semantic and syntactic context constraints on lexical selection and integration processes. More specifically, we used ERPs to investigate the time-course of processing of different sources of information such as phonological, semantic and syntactic, and their impact on lexical selection and integration processes in a situation where all sources of information about the perceived word become incrementally available, namely in spoken-word comprehension. We used semantically constraining Dutch sentences that contained critical words that were either the highest cloze probability noun for that sentence (fully congruent or FC), a verb in past tense that apart from syntactic constraints also violated semantic constraints and had initial phonemes that differed from the highest-cloze probability noun (fully incongruent or FI), or a verb in past tense that apart from syntactic constraints also violated semantic constraints but began with the same initial phonemes as the highest-cloze probability noun (initially congruent or IC). For the conditions containing the syntactically and semantically incongruent critical words, the moment of word category violation was assessed for each verb and labeled the category violation point (CVP). The study revealed that, in the domain of language comprehension, four different ERP effects can be distinguished that appear to be relatedfour different ERP effects related to three types of sources of information: a) A phonological effect as reflected by the N200, b) a semantic effect reflected by the N400, and c) syntactic effects reflected by the LAN and P600.

Phonological processing

This study shows that semantically and syntactically incongruent words with initial phonemes that differed from their congruent counterparts elicited a larger negativity in the 150-250 ms range after stimulus onset than both the congruent critical words and the semantically and syntactically incongruent words that began with the same phonemes as the congruent counterparts. The onset analysis reveals that the congruity effect between the FC and the FI critical words sets in at 170 ms. These results are in line with a number of studies using connected speech, which revealed that semantically incongruent words with onsets that, given a semantically constraining preceding sentence frame, differ from those of the highest cloze probability words, elicit an early negative shift, related to phonological processing (Connolly & Phillips, 1994; Hagoort & Brown; 2000; Van den Brink et al., 2001; Van den Brink et al., submitted). In these studies, it was assumed that this early negative effect reflects the lexical selection process, where word-form information resulting from an initial phonological analysis and content information derived from the context interact.

In their 1994 study, Connolly and Phillips obtained an early negativity in sentence-final words that were semantically anomalous and had initial phonemes that differed from those of the highest cloze probability word (e.g., “The dog chased the cat up the *queen*”), comparable to the FC condition in the present study. However, they did not find an early negativity in a condition similar to our IC condition, where sentence-final words were semantically anomalous but had the same initial phonemes the highest cloze probability word (e.g., “The gambler had a streak of *luggage*”). Connolly and Phillips, therefore, attributed this early negativity to a mismatch of the initial phonemes of the presented word with contextually determined expected phonemes, and labelled it the *Phonological Mismatch Negativity* (PMN). They proposed that during sentence processing, on the basis of the context, a terminal word is predicted. But only after an initial phonological analysis of the perceived word the top-down context process is claimed to begin to exert its influence. A PMN is elicited if the expectancy of the terminal word on the basis of the context and the phonological analysis of the initial phonemes of the perceived word are not in agreement.

In the present study, as well as our previous studies (Van den Brink et al., 2001; Van den Brink et al., submitted), all critical words elicited an N200, irrespective of whether the initial phonemes were identical to those of a congruent word or not. Therefore, in our previous studies, the process underlying the early negative effect was interpreted somewhat differently from the interpretation laid out by Connolly and Phillips. We proposed that the amplitude of the N200 is indicative of whether the initial assessment of form-based activated lexical candidates reveals the presence of a candidate that fits the semantic and syntactic constraints of the preceding sentence. A small N200 would be elicited when the set contains a candidate that fits the contextual specifications. In the present study, this is the case for the FC and IC conditions, since on the basis of the first phonemes, the highest cloze probability word is activated. A large N200 would indicate that the set does not contain a candidate that fits the preceding sentence frame well, as is the case for the FI condition in the present study.

In the studies mentioned a psychophysiological distinction could be made between the early negative effect and the N400 effect. Failure to do so could be construed as weakening the claim that the two effects are genuinely distinct from one another. Connolly and Phillips (1994) were able to doubly dissociate the PMN and the N400 on the basis of experimental manipulations, finding a PMN in the absence of a N400 in one condition and vice versa in another (e.g., "The gambler had a streak of luggage" versus "Don caught the ball with his glove", where hand was the highest cloze probability word). In our previous studies a distinction could be made between the N200 effect and the N400 effect on the basis of their spatial distributions across the scalp (Van den Brink et al., 2001; Van den Brink et al., submitted). Whereas the N200 effect had an equal distribution across the scalp, the N400 effect had a clearly posterior distribution. In neurocognitive research, these statistically different distributions are usually interpreted as reflecting the activity of at least partly distinct neuronal populations, and thus, warrant the claim that the N200 and N400 effects could reflect distinct aspects of the spoken language comprehension process. The present study did not explicitly test the distinction between the N200 and N400 effects. So, even though most aspects of the N200 component in this study are consistent with our previous findings, namely that it can be obtained in all critical words, is largest in semantically incongruent words with initial phonemes that differ from their congruent counterparts, and its morphology is most prominent over frontal to fronto-central sites, on the basis of the results in the present study, we cannot exclude the possibility that the N200 effect is in fact not distinct from the N400 effect, reflecting overall semantic processing (Van Petten, Coulson, Rubin, Plante, & Parks, 1999).

Semantic processing

The semantically and syntactically incongruent words elicited an N400, indexing difficulty in lexical integration, irrespective of whether their initial phonemes were similar to those of the congruent word or not. The apparent difference in amplitude between the N400 elicited in the IC and FI conditions can be explained by the differential amplitude in the N200 latency window preceding the effect in the N400 time interval. Figure 4-3 shows that when we control for the differential effect in the early latency window, the N400 (and P600) differences obtained in the following time intervals vanish. The onset analysis of the congruity effect between the FC and IC critical words is not confounded by this early effect and reveals that the congruity effect sets in at 310 ms after word onset. Important to the current issue, in the present study the N400 has set in before information about the word category has become available. These results are in line with two studies that investigated the temporal relationship between the lexical selection and integration of a word's meaning into the preceding context (Van den Brink et al., submitted; Van Petten et al., 1999). In these studies information about the moment a word can uniquely be identified on the basis of acoustic information alone, known as the Isolation Point (IP) of a word, was related to the timing of (the onset of) the N400, to assess whether semantic integration processing begins only after word identification is completed. It was found that in sentences ending with semantically anomalous words (e.g., "This fourteen year old pianist obviously has a lot of *climate*"), onset of the N400 occurred prior to IP, indicating that semantic integration processing is initiated before a (semantically anomalous) word candidate is selected on the basis of the acoustic signal. In the present study, the N400 sets in even before listeners realize the critical word is actually a verb instead of a noun (i.e. before CVP). Taken together, we conclude that semantic integration processing can start before the acoustic information allows the selection of a unique candidate, and thus, seems to be attempted in parallel for multiple candidates that are still compatible with the bottom-up acoustic input.

Syntactic processing

When time-locked to word onset the waveforms of the semantically and syntactically incongruent critical words revealed a syntactic effect in the form of what appeared to be a somewhat delayed P600, which followed the N400. However, we hypothesized that any syntactic effect would be elicited only after detection of the word category violation encapsulated in the critical words. Therefore, we decided to time-lock the waveforms to the earliest moment at which a word category violation can be detected, assessed for each critical word and labeled the category violation point (CVP). Figure 3-4 shows that time-locking the waveforms on a trial-by-trial basis to CVP, reveals the presence of an anterior negative shift preceding the P600 (reaching maximal amplitude at 600 ms after CVP) in the semantically and syntactically anomalous conditions IC and FI. This anterior negativity is present at the anterior frontal, frontal and fronto-central electrodes, and is most prominent at F7. The Left Anterior Negativity (LAN) reaches its maximal amplitude approximately 370 ms after CVP, and has an onset at approximately 100 ms after CVP for both anomalous conditions.

It is not entirely clear what the relation is between the Left Anterior Negativity obtained in this study and earlier reported ELANs, LANs or bilateral Anterior Negativities. In some ways our Left Anterior Negativity is reminiscent of the other anterior negativities, with respect to its polarity, its (left) frontal distribution and the fact that it is elicited to syntactic violations. However, with respect to timing it seems to be different from these other anterior negativities. Of course, we must keep in mind that our study differs in some respects from the other studies obtaining an anterior negativity. First, whereas many studies that obtained anterior negativities were conducted in the visual modality with syntactic and semantic information becoming almost immediately available, this study was conducted in the auditory domain, where this information becomes incrementally available. Second, in most of the studies using auditorily presented sentences, the critical words contained clear morpho-syntactic markers at the beginning of the word indicating the word category and were in sentence-final position (Friederici, et al., 1993; 1999; Hahne & Friederici, 1999; 2002; Hahne & Jescheniak, 2001). In the present study, word category information was contained in the suffix of the critical word, and the word category violation point was on average 330 ms after onset. Moreover, our critical words were presented in non-sentence-final position, thereby preventing possible pollution of the data from sentence-wrap up processes (cf. Hagoort, in press; Osterhout, 1997). In conclusion, the LAN obtained in our study possibly belongs to a class of anterior negativities reflecting syntactic processing. More specifically, this LAN probably reflects the detection of a mismatch between the required word category (in this case a noun) and the word category actually presented (a verb). The latency of this LAN, compared to other anterior negativities that are believed to reflect a syntactic mismatch of word category, is delayed as information about the word category becomes available at a later moment during word processing than was the case in most other studies.

Conclusion

Although our study, unlike any other, not only reveals the presence of both an N400 and a LAN in the same waveform, but also reveals that the LAN has a later onset (and peak) than the N400, we do not presume that during spoken-word processing the processing of lexical-semantic information in general precedes that of syntactic (word category) information. Instead, these results are interpreted as providing strong evidence for the claim of continuous use of any sources of information the moment they become available. These results clearly provide evidence against the claim that building of syntactic-phrase structure, based on word category information, is autonomous and precedes semantic integration processes, and that these syntactic and semantic processes interact only in a later time interval (Friederici, 2002). This claim was partly based on results from recent auditory studies using critical words that, as in our study, violated both the syntactic and semantic constraints of the preceding sentence context. In these studies an Early LAN and a P600 in the absence of an N400 were obtained (Friederici et al., 1993; Hahne & Jescheniak, 2001). However, contrary to the critical words used in the present study, theirs allowed for a rapid detection of a word category violation (due to the morpho-syntactic markers "*ge*-" and "*be*-").

The present study testifies to the incremental and cascaded nature of on-line language processing. It shows that the moment a violation of any kind occurs, it is detected by the system. In the case of the FI critical words, the moment the system detected a mismatch between the lexical candidates that were activated on the basis of bottom-up information and the semantic and syntactic constraints imposed by the preceding sentence frame, an N200 effect occurred. For the IC critical words, an N400 was instigated at the moment a semantic violation was detected. It was not until later in the word that a syntactic error became manifest, which resulted in a LAN and a P600.

These data clearly show that, contrary to predictions of a serial model, the system does not specifically need syntactic information about word category in order to begin to semantically integrate a perceived word. In other words, semantic processing is not dependent on the result of syntactic processing or vice versa. Instead, the system works with the information it receives and uses it immediately. The results of this study fit with a cascaded model of spoken-word processing that allows for an early influence of contextual information after bottom-up activation of a set of lexical candidates, such as incorporated in the Cohort model or Shortlist (Marslen-Wilson, 1987; Marslen-Wilson & Welsh, 1978; Norris, 1994). Although not explicitly specified in these models, our data point to an optimal use of contextual information during spoken-word identification by allowing for semantic and syntactic processing to take place in parallel, and integration to proceed with a limited number of candidates.

Summary and Conclusions

CHAPTER 5

Understanding spoken language requires an interplay of a number of complex processes. Since the primary aim of spoken language processing is to comprehend the message of the speaker by combining the meanings of individual words in the utterance, processes related to the recognition of spoken words play a central role in language comprehension. In general, spoken-word recognition is assumed to involve three lexical processes: *access* to the mental lexicon where words are stored, *selection* of a word from a number of candidates, and *integration* of a word's meaning into an overall interpretation of the preceding context. The aim of the present study was to gain more insight into spoken-word comprehension and the influence of sentence-contextual information on these processes using ERPs. Chapter 2 was concerned with the moment at which context information is used in the recognition of spoken-words. Chapter 3 dealt with the temporal relationship between lexical selection and semantic integration into the preceding sentence frame during spoken-word comprehension. Chapter 4 investigated the time-course of the processing of different sources of linguistic information obtained from the context, such as phonological, semantic and syntactic information, during spoken-word comprehension.

SUMMARY OF RESULTS

Most of the current models of spoken-word comprehension assume that contextual influences play a role in the spoken-word recognition process. However, the moment at which contextual influences start to exert an influence is a matter of debate. The first experiment (Chapter 2) was designed to investigate this issue. The participants in this experiment listened to sentences that ended with a word that was either (a) congruent, (b) semantically anomalous, but began with the same phonemes as the congruent completion, or (c) semantically anomalous, and began with phonemes that differed from the congruent completion (e.g., “Het vrouwtje veegde de vloer met een oude *bezem/beker/krater*”). The results were as follows. The onset of the congruity effect between the fully congruent and fully incongruent conditions at 220 ms after sentence-final word onset provided an upper estimate of the moment at which context starts to exert an influence on spoken-word recognition. This congruity effect preceded the congruity effect between the fully congruent and the initially congruent conditions by 50 ms. The ERP waveform morphology of these congruity effects differed. Whereas the congruity effect between the fully congruent and initially congruent conditions consisted of a monophasic N400 effect, the congruity effect between the fully congruent and fully incongruent conditions consisted of a biphasic effect. This biphasic effect consisted of an N400 effect, that was preceded by an early negative shift peaking at 200 ms, the N200 effect. The scalp distributions of the N200 and N400 effects differed, reflecting the activity of at least partly distinct neuronal populations, and thus providing evidence for the claim that these two effects reflect different processes.

It was concluded that whereas the N400 reflects difficulty in semantic integration processing, the N200 effect is related to the lexical selection process where word-form information resulting from an initial phonological analysis and content information derived from the context interact. The amplitude of the N200 is believed to be indicative of whether the initial assessment of the form-based activated set of lexical candidates reveals the presence of a candidate with semantic characteristics that fit the contextual specifications. A small N200 is elicited if the set contains an appropriate candidate, a large N200 is elicited if that is not the case.

Now that an electrophysiological marker for the lexical selection process seemed to have been found, it was our intention to use this marker to gain more insight into the selection process. The experiment described in Chapter 3 addressed three issues: replication of the biphasic congruity effect obtained in the first experiment, taking a closer look at the building blocks used in the lexical selection process, and investigation of the temporal relationship between lexical selection and semantic integration. Using spoken sentences that ended with either a congruent or a semantically anomalous word with onset phonemes that differed from those of the congruent completion (e.g., “Het vrouwtje veegde de vloer met een oude *bezem/krater*”), we were able to replicate the major findings of our first experiment. The congruity effect had an onset at 190 ms and consisted of an N200 effect followed by an N400 effect, with different spatial distributions.

To test the second issue, participants were presented with spoken sentences that were either semantically highly constraining and where the sentence-final word was a high cloze probability word (e.g., “Het vrouwtje veegde de vloer met een oude *bezem*”) or were not semantically constraining at all and, consequently, the sentence-final word was of low cloze probability (e.g., “Het volgende woord is *bezem*”). The resulting waveforms to the sentence-final words revealed an N200 effect, clearly distinct in timing from an N400 effect. Both deflections were larger in the latter condition than in the former. This suggests that during the lexical selection process assessment takes place on the basis of semantic features associated with individual candidates and not merely on the basis of a field of semantic features detached from the lexical candidates. The absence of strong contextual constraints makes it difficult to assess whether a candidate in the activated set fits the preceding sentence frame well, resulting in a large N200. In contrast, most semantic features are compatible with low constraining sentences, and assessment on the basis of semantic features would have resulted in a small N200.

The third issue in Chapter 3 concerns the question of whether semantic integration follows up on lexical selection of one candidate or whether these processes are of a cascaded nature (i.e. semantic integration is attempted before selection of one candidate is completed). To test this issue, participants were also presented with semantically constraining sentences that ended with words that were only partially presented. In principle, the completions were either congruent words, or semantically anomalous words with onset phonemes that differed from those of the congruent completions, but only the initial part of the words were presented (e.g., “Het vrouwtje veegde de vloer met een oude *be/kra*”). An extensive gating task was used to ensure that the cut-off point of each word preceded the word’s isolation point (IP). In other words, words were cut off before identification of the word could be established. The results showed an N200 effect followed by an N400 effect, suggesting that lexical selection and semantic integration are cascading processes. Semantic integration is initiated before selection of one (anomalous) candidate is completed. An additional experiment that split the fully presented sentence-final words into a group with early IPs and a group with late IPs confirmed these results. The factor early or late IP did not affect the onset nor the peak of the N400. In words with early IPs, with a mean of 230 ms, the congruity effect sets in 50 ms prior to IP. In words with late IPs, with a mean of 340 ms, the congruity effect sets in 140 ms prior to IP. This indicates that the semantic integration process does not wait until one lexical candidate has been selected on the basis of a phonological analysis. Instead, integration is attempted for a selected number of candidates that still match the acoustic input.

The experiments described in Chapters 2 and 3 clearly showed that sentential context can exert an influence early on in spoken-word comprehension. Chapter 4 deals with the relative timing of the use of different aspects of contextual information during spoken-word comprehension, such as semantic and syntactic information. Does the processing of information follow the incremental manner in which different types of information become available in the speech signal, or does specific syntactic information about the word category have to be processed before semantic integration can take place? In the literature, the latter account has recently received some support (Friederici, 2002, Friederici; Steinhauer & Frisch, 1999; Hahne & Jescheniak, 2001). To investigate this issue, the participants in the final experiment were presented with constraining sentences that contained a critical word that was either (a) congruent, (b) semantically and syntactically incongruent, but began with the same initial phonemes as the congruent critical word, or (c) semantically and syntactically incongruent, and began with phonemes that differed from those of the congruent critical word (e.g., “Het vrouwtje veegde de vloer met een oude *bezem/bedelde/kliederde* gemaakt van twijgen”). For both conditions containing the semantically and syntactically incongruent words, the moment of word category violation was assessed for each verb. This category violation point (CVP) on average was located at 336 ms after word onset for the initially congruent condition and 324 ms for the fully incongruent condition.

The results revealed that relative to the congruent critical words, an N200 effect was obtained in the fully incongruent critical words, with an onset of 170 ms. Both incongruent conditions elicited a large N400 followed by a Left Anterior Negativity (LAN) time-locked to CVP and a P600 effect. Whereas the N400 effect indexes difficulty in semantic integration, both the LAN and the P600 have been shown to be related to syntactic processing (cf. Hagoort, Brown & Osterhout, 1999). Important to the issue at hand, the N400 in both incongruent conditions set in before information about the word category had become available. Considering that the incongruent critical word cannot have been recognized by then, this finding is in line with the results from the two experiments described in Chapter 3, revealing that semantic integration processes can start before the acoustic information allows the selection of a unique (anomalous) candidate. These results clearly indicated that knowledge of the syntactic category of a word is not needed before semantic integration can take place. These findings, therefore, were interpreted as providing evidence for an account of cascaded spoken-word processing that proclaims an optimal use of contextual information during spoken-word identification. Optimal use is accomplished by allowing for semantic and syntactic processing to take place in parallel after bottom-up activation of a set of candidates, and lexical integration to proceed with a limited number of candidates that still match the acoustic input.

A COMPARISON OF RESULTS ACROSS EXPERIMENTS

Before I discuss the implications of the findings in this thesis with respect to theories of spoken-word processing, I will first take a look at the similarities and differences between the results obtained from the experiment in Chapter 2 (Experiment 1), the first experiment in Chapter 3 (Experiment 2a) and the experiment in Chapter 4 (Experiment 3). First, all three experiments revealed the clear presence of a negative shift preceding the N400. This negativity peaks at 200 ms after critical-word onset and was visible in all critical words. Modulation of this N200 was achieved by a phonological manipulation. Whenever the onset phonemes of a presented word did not match those of a word that fits the semantic (and syntactic) constraints of the preceding sentence frame well, a larger N200 was elicited than the N200 of a word that does fit the constraints well. These results indicate that context already exerts an influence in this time frame.

It was hypothesized that the onset of a congruity effect would provide us with an upper estimate of the moment context started to exert an influence on spoken-word processing. Across the three experiments, the onset of the congruity effect was found to differ slightly in latency: at 220 ms after critical word onset in Experiment 1, at 190 ms in Experiment 2a, and at 170 ms in Experiment 3. Part of this variation must be accounted for by variation between individuals since the congruity effects in Experiments 1 and 2a were elicited by the same stimuli, but tested on different participants. Another part of the variation might be explained by variable speech rate. Since the congruent words were identical across experiments it can be established that the speech rate of the (same) female speaker was higher for Experiment 3 than the Experiments 1 and 2a (with a mean word duration of 386 ms vs. 516 ms). Although the possibility that context already exerted an influence prior to these moments cannot be excluded on the basis of these results, the latest moment at which context is illustrated to start to exert an influence in all three experiments lies in the N200 latency domain.

Semantically incongruent critical words in all three experiments elicited a large negativity that peaked at 400 ms after word onset, the N400. In relation to the congruent critical words this resulted in robust N400 effects. Although N400 effects have sometimes been related to lexical access (Kutas & Federmeier, 2000), the most widely held view today, is that in sentence contexts, the N400 amplitude indexes the ease of semantic integration into the overall meaning representation of the preceding context (Brown & Hagoort, 1993; Hagoort & Brown, 2000; Holcomb, 1993). Based on the onset of the congruity effects between the fully congruent and initially congruent critical words in Experiments 1 and 3, onset of the N400 effect lies at about 290 ms after word onset (270 ms vs. 310 ms). Based on visual inspection of the waveforms across all three experiments, the onset of the N400 effect seems to be stable (despite a variation in speech rate). The additional experiment in Chapter 3 (Experiment 2b) provides proof for this assumption. The results showed that neither the onset nor the peak of the N400 were related to the theoretically interesting, and intuitively most promising time point, the IP. The IP is defined as the minimum amount of acoustic signal necessary to identify a spoken word in the absence of contextual information (cf. Grosjean, 1980). Irrespective of whether words belonged to a group with an early or a late IP, onset and peak of the N400 were identical. Furthermore, onset of the N400 effect occurred before the IP, revealing that even though the lexical selection process could not have been completed on the basis of the acoustic input, the N400 effect set in.

In relation to the congruent critical words the syntactically and semantically incongruent critical words in Experiment 3 elicited a LAN effect that became visible after time-locking the waveforms to the word category violation point, followed by a P600 effect. Both of these effects have been shown to be related to syntactic processing, and were absent in Experiments 1 and 2a.

Finally, I need to make some remarks about the scalp distributions of the N200 and N400 effects. As stated in the introduction of this thesis, although information about the spatial distribution of effects across the scalp says very little about the underlying cortical generators of cognitive functions, it can be very useful in making inferences about the likelihood that these effects reflect the activity of distinct neuronal populations subserving qualitatively different cognitive processes. Based on the waveforms one could question a functional distinction between the two effects and state that the N200 effect is merely the onset of the N400 effect, reflecting overall semantic processing without fractionation into subprocesses (Van Petten, Coulson, Rubin, Plante, & Parks, 1999).

Figure 5-1 shows the spatial distributions across the scalp of the N200 and N400 effects across Experiments 1, 2a, and 3. To test whether the scalp distributions of the N200 and N400 effects across experiments are different from each other, extra analyses were performed. First, for every subject difference scores between the fully congruent and fully incongruent conditions were computed for every electrode in the N200 and N400 latency windows for each experiment. Second, a scaling procedure was performed to avoid that differential amplitude effects between the three experiments would be incorrectly interpreted as distribution effects. In this procedure, the electrode-specific difference scores were *z*-transformed for each latency window separately (Rösler, Heil, & Glowolla, 1993;

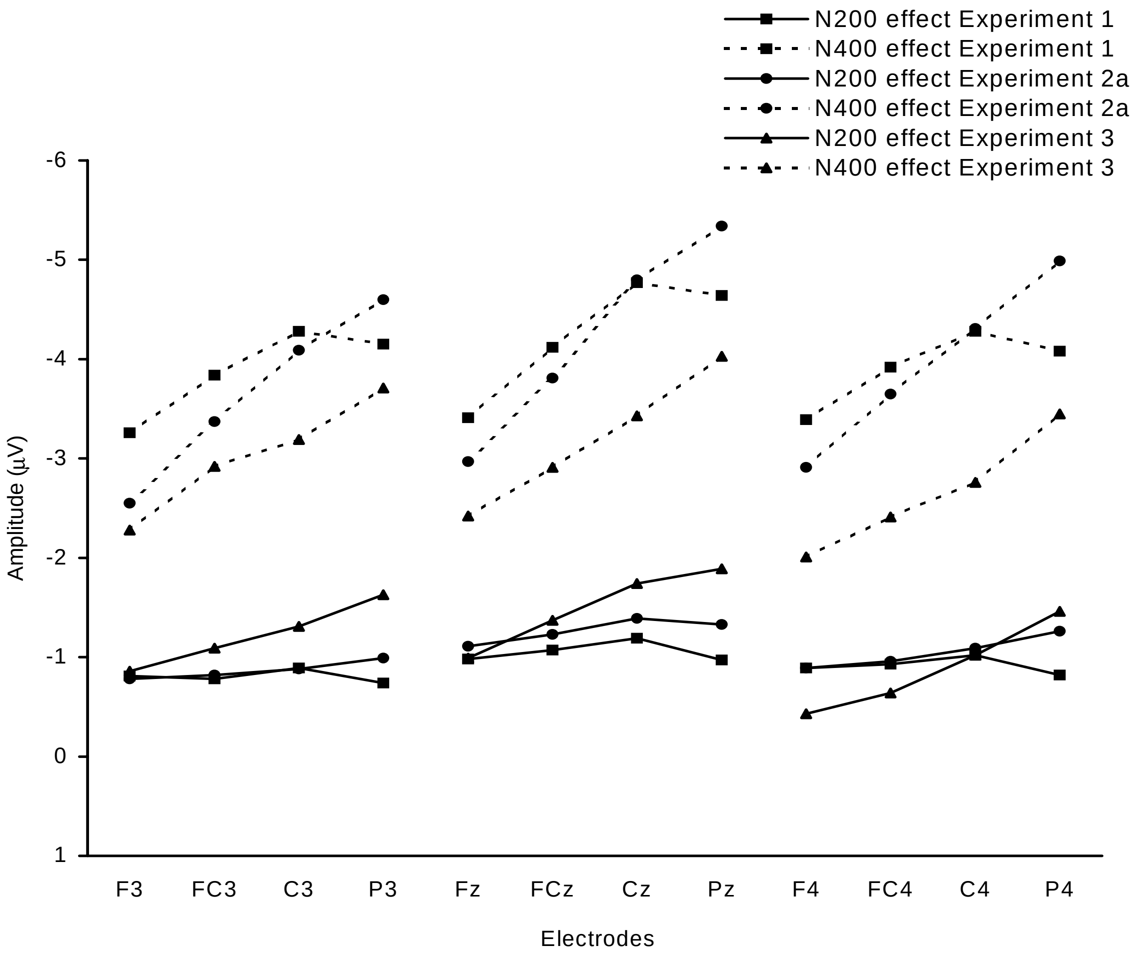

Figure 5-1. *Distribution of the N200 and N400 effects for four left hemisphere sites (F3, FC3, C3, P3), four midline sites (Fz, FCz, Cz, Pz), and four right hemisphere sites (F4, FC4, C4, P4) for three experiments. The N200 effect was determined by subtracting the mean amplitude in the 150-250 ms latency window of the grand average ERP for the semantically congruent sentence-final words from the mean amplitudes of the grand average ERP for the semantically anomalous sentence-final words. The N400 effect was determined in the same manner on the basis of the mean amplitudes in the 300-500 ms latency window.*

see also McCarthy & Wood, 1985). The *z*-transformed values were entered into a repeated measures ANOVA with a 3-level experiment factor, a 2-level window factor, and a 29-level electrode factor. A significant interaction of window by electrodes was obtained ($F(28,1764) = 13.78$, $MSE = 0.34$, $p < .001$) in the absence of a three-way interaction of window by electrodes by experiment ($F(56,1764) = 1.24$, $MSE = 0.34$, $p = .261$). This indicates that the N200 effect and the N400 effect have different spatial distributions, and that these distributions do not differ across the experiments.

However, the results in Chapter 4 indicated that the N200 and N400 effect did not have significantly different spatial distributions. The overall analysis may not have been sensitive to this difference. Therefore, I decided to do additional analyses for the N200 and N400 effects separately, by comparing two experiments at a time. To start with the scalp distributions of the N400 effects; Chapters 2, 3 and 4 revealed that they did not vary across experiments and had a posterior maximum. The additional topographical analyses revealed that the congruity effects found across the three experiments do not have different spatial distributions across the scalp. No significant interaction of experiment by electrodes was obtained for any of the three comparisons. In the comparison for Experiment 1 versus Experiment 2a: $F(28,1204) = 1.77$, $MSE = 0.54$, $p = .135$; Experiment 1 versus 3: $F(28,1120) = 2.04$, $MSE = 0.61$, $p = .083$; and Experiment 2a versus 3: $F(28,1204) < 1$. The results revealed no interaction of experiment by electrodes, indicating that the scalp distributions of the N400 effects indeed do not differ between experiments.

Although Figure 5-1 shows similar N200 effects, based on the findings in Chapters 2, 3, and 4 the spatial distributions of the N200 effects were found to differ across the three experiments. Whereas Experiment 1 revealed that the N200 effect had a flat distribution across the scalp, Experiments 2a and 3 showed a more posterior maximum. When the distribution of the N200 effect in relation to the N400 effect was tested after absolute scaling of the effects, Experiments 1 and 2a revealed statistically significant different spatial distributions, but Experiment 3 did not. I decided to test the spatial distributions of the N200 effects in pairwise comparisons across experiments. The results revealed that although the scalp distributions of the N200 effects did not differ between Experiments 1 and 2a ($F(28,1204) < 1$), and 2a and 3 ($F(28,1204) = 1.18$, $MSE = 0.86$, $p = 321$), they did differ between Experiments 1 and 3 ($F(28, 1204) = 2.84$, $MSE = 0.84$, $p < .05$). In the latter comparison an extra anterior versus posterior analysis (for details about exact configuration see Chapter 4) revealed a significant experiment by site interaction ($F(1,40) = 43.66$, $MSE = 6.07$, $p < .05$), indicating that the N200 effect in Experiment 3 is more posteriorly distributed than in Experiment 1.

Finding robustly different spatial distributions of the N200 and N400 effects in and across all experiments would have been most convincing in showing that the two effects are the result of the firing of at least partially distinct neuronal populations. This, in turn would have provided solid proof for the assumption that different cognitive processes underlie these two effects. In this respect the results of Experiment 3 deviate from those in Experiments 1 and 2a which revealed different scalp distributions for the N200 and the N400 effects. I can only speculate about the reason for not obtaining different spatial distributions between the two effects in Experiment 3. From a statistical point of view only the N200 effect in Experiment 3 seems to behave differently. Apart from the syntactic manipulation, which is not obvious to the listener during the N200 latency interval (as CVP on average was located at 330 ms after critical word onset), the only difference between this experiment and Experiments 1 and 2a is the position of the critical word. Whereas in the first two experiments they were in sentence-final position, the critical words in Experiment 3 had a sentence-medial position. This factor may influence the ERP-waveform to such an extent that they, in general, have a more negative maximum over posterior sites, possibly due to other cognitive processes involved in building up a meaning representation of the sentence-frame.

Figure 5-2 can substantiate this hypothesis. The figure displays the waveforms to congruent words in sentence-medial and sentence-final positions. The solid line represents the fully presented sentence-final congruent words from Experiment 2a. The alternating slash-dot line is the product of 42 nouns in sentence-medial position. Forty-two sentences containing three or more nouns were selected and the waveforms were aligned at the second noun of those sentences (e.g., “Het vrouwtje veegde de *vloer* met een oude *bezem*”). Although I cannot make any inferences about amplitude effects between these critical words, since different nouns are compared and the number of averages differs considerably, Figure 2 reveals a general trend of the sentence-medial words having a posterior negative maximum relative to the sentence-final words.

However, apart from a deviant spatial distribution across the scalp, which was obtained for Experiments 1 and 2a, there still are a number of valid reasons for assuming that the N200 is indeed a separate negativity, and that the N200 effect reflects a cognitive process different from that of the N400 effect. First of all, the morphology of the N200 was identical in all critical words across the experiments. It is a negativity peaking at 200 ms after word onset, which is most clearly seen at frontal to central electrodes and is clearly distinct from the N400 which is largest at posterior sites. Also, the N200 could be manipulated independently from the N400 (although unfortunately not vice versa). Moreover, previously mentioned findings were replicable. Finally, there is ample evidence in the literature that spoken-word comprehension should be fractionated into several subprocesses such as lexical access, lexical selection, and lexical integration. The explanation that the N200 effect is part of the N400 effect, and that this biphasic effect reflects an undifferentiated semantic process related to context, would appear too strict in light of the obtained ERP profiles. The interpretation of the data as two differential effects reflecting different cognitive processes, fits well

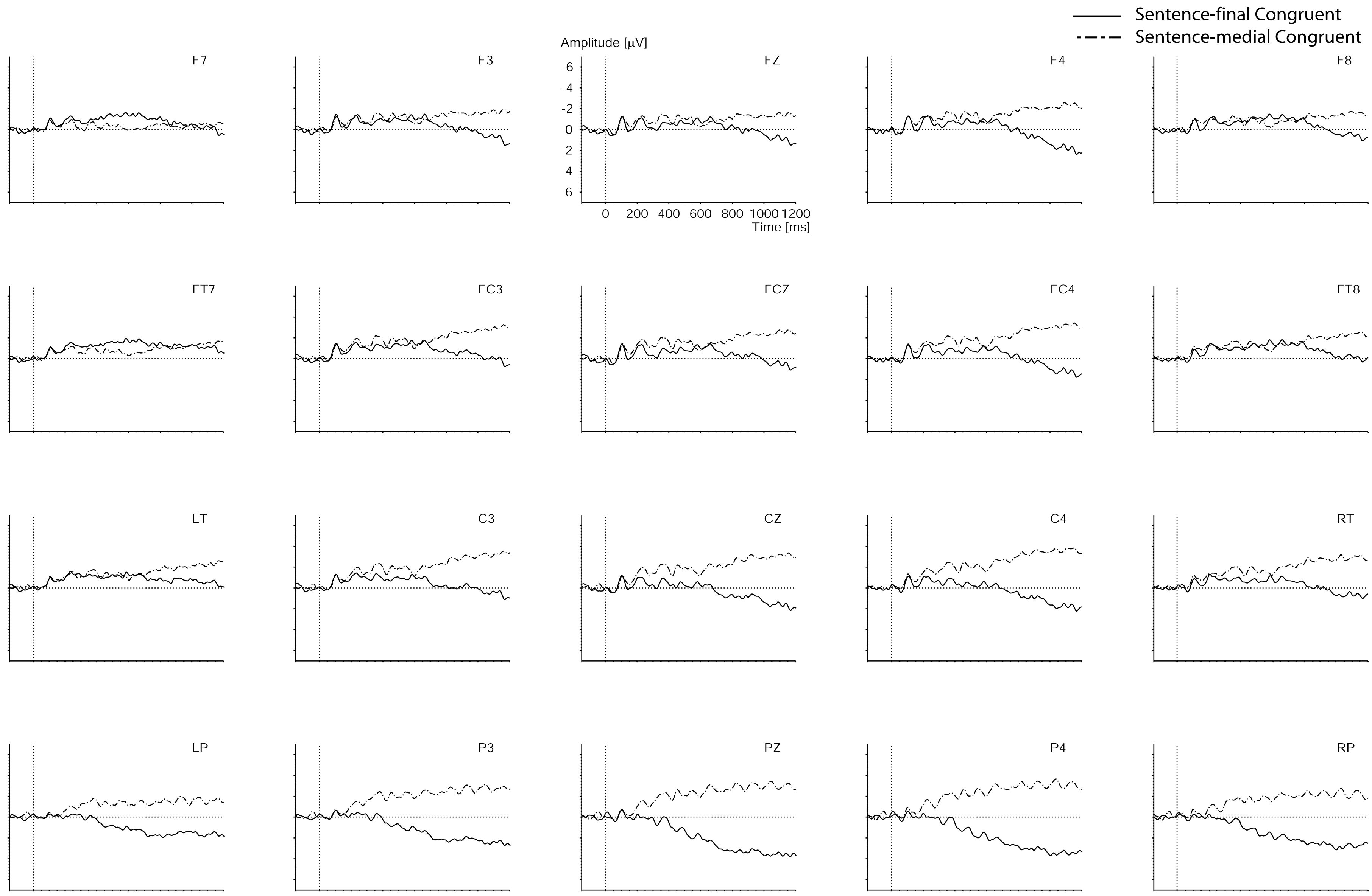

Figure 5-2. *Grand average ERPs to critical words in sentence-medial and sentence-final positions. Time 0 is onset of critical words.*

with both the electrophysiological profile and current cognitive-functional theories of spoken-word processing.

CONCLUSIONS

So, what do these results actually tell us about spoken-word processing? One of the main findings of this thesis is the elicitation of the N200 component. It seems to be a stable component which can be modulated by a phonological manipulation. The N200 effect obtained in this thesis can only be explained in terms of influence from the sentential context. On the basis of the results obtained in this thesis, I conclude that in the context of spoken-word processing, the N200 is a reflection of the on-line lexical selection process. Following access to the mental lexicon, form-based information derived from phonological analysis on the basis of the onset phonemes of the presented word and content-based information derived from the context come together, in order to select the appropriate word from among a set of activated word candidates (cf. Marslen-Wilson, 1987; Norris 1994). If the contextual specifications support a form-based activated lexical candidate, a small N200 is elicited. If, however, none of the lexical candidates fit the context specifications well, either because the critical word is semantically anomalous or the sentence frame is not semantically constraining enough to point to a limited number of possible completions, a large N200 is elicited, reflecting difficulty in lexical selection.

The results from this thesis further revealed that the lexical integration process does not infinitely wait for the selection process to be completed. In the presence of a lexical candidate that fits the contextual specifications well, selection can take place quickly and integration of the candidate's meaning into the preceding context is not hindered, resulting in a very much reduced or even absent N400. However, in the case of a semantically anomalous word with onset phonemes that differ form a congruent candidate, in a semantically constraining sentence, the results indicate that lexical selection is difficult (large N200) and semantic integration (as reflected by the N400) is initiated before lexical selection on the basis of acoustic analysis is complete (i.e. onset of N400 precedes IP of critical word). This indicates that lexical selection and lexical integration are cascading processes and integration is attempted simultaneously for a number of lexical candidates that are compatible with partial acoustic input.

Finally, it has also become evident from the results of Chapter 4 that any source of contextual information is used immediately during spoken-word comprehension. If, on the basis of the interaction of a set of lexical candidates and the context specifications, a semantic anomaly is detected earlier than a syntactic anomaly, this time-course is reflected in the ERP waveform. These results then imply that the auditory language processing system works in an incremental fashion by using any information it receives, the moment it receives it.

Implications for models of spoken-word recognition

Models of spoken-word recognition should, first and foremost, encompass the principles of *incrementality* and *cascadedness* that follow from the findings in this thesis. The incrementality principle is a direct consequence of the incremental nature of speech perception. Different sources of information become available to the system at different time points in the acoustic signal and are used accordingly. The spoken-word recognition process, thus, entails a certain sequential nature. However, the subprocesses do not have discrete boundaries (i.e. semantic integration does not begin after lexical selection is completed). Instead, information from the lexical selection stage is passed onto the lexical integration stage before a discrete choice is made. This is what I refer to as the cascaded nature of spoken-word processing. In the context of sentence (or discourse) comprehension a model should also account for an early influence of all types of contextual information (i.e. semantic and syntactic).

On a more detailed level, the results of this thesis are best represented in a model that incorporates a bottom-up priority of phonological processing of the initial acoustic signal of the perceived word, thereby activating a set of lexical candidates, before top-down information starts to exert an influence. Examples of these kinds of bottom-up priority model are the Cohort model and Shortlist (Marslen-Wilson, 1987; Norris, 1994). However, these models do not fully specify the influence of sentential context information on spoken-word recognition. A plausible account would be that during the lexical selection stage, the lexical candidates are assessed on the basis of their semantic and syntactic features with respect to their goodness-of-fit within the preceding sentence frame. In the presence of lexical candidates that fit the contextual specifications well, further incoming acoustic information and top-down contextual information is used to narrow the number of candidates to the one that is most compatible with both form and content constraints. This candidate is subsequently integrated in the sentence context. If, however, none of the lexical candidates fit the context specifications well (either because the perceived word is anomalous or the context is of low constraint), selection of the proper candidate is difficult. Narrowing of the set of candidates can only take place on the basis of further incoming acoustic information.

The data presented in this thesis show that the auditory language processing system does not wait for the proper candidate to be selected, but attempts to integrate a (limited) number of candidates to arrive at a meaningful interpretation of the sentence. In the case of low constraining sentences, this course of action presumably fairly quickly results in recognition of the presented word. In the case of fully anomalous words, however, the integration process cannot aid in the word identification process. At some point, though, the system also identifies these anomalous words. Common sense experience tells me that the phonological analysis of the acoustic input does not stop after (attempted) selection or integration of a word, but rather continues until the entire word has been heard.

In this thesis, I have conveniently glossed over lower-level speech decoding problems such as the mapping of the acoustic input onto lexical entities (remember that in the introduction of this thesis, for simplification purposes it was assumed that phonemes are the units of speech perception) and the identification of word boundaries. There is a substantial amount of literature dealing with how listeners resolve these problems. It is beyond the scope of this thesis to go into these issues (for a review I refer to McQueen, in press), but a model of spoken-word recognition should also account for these lower-level speech decoding. In this respect, it is interesting to note that the homogeneity of the first 200 ms of the electrophysiological signal across the experiments seems to imply that the listeners in this study were capable of spotting the onset of the critical words (in semantically highly constraining sentences) almost immediately.

There is not a model of spoken-word comprehension that encompasses all of the aforementioned characteristics, as yet. However, fine-grained instruments for investigating the different processes related to spoken-word recognition, such as ERP recordings have proven to be in this thesis, as well as many other studies, will no doubt be a helpful tool in contributing to finding all of the pieces of a puzzle, the emerging picture of which will display a fully specified cognitive-functional theory of language comprehension.

A concluding remark

Writing a doctoral thesis gives a Ph.D. student the opportunity to show that he/she is capable of conducting a thorough study into a theoretically interesting scientific question. The result of this neurophysiological study shows that context indeed has an influence on spoken-word recognition. This conclusion follows from the four carefully controlled experiments that were conducted at the Max Planck Institute for Psycholinguistics. Preliminary results of a small field study, making use of a circle of family and friends as participants, seem to reveal that these results undoubtedly can be translated onto real-life situations. Measured by their exuberant reactions it was found that all participants were capable of easily and rapidly selecting and integrating the proper word after hearing “Finally, my thesis is /fɪ/”. This is a fine illustration of the efficiency of the spoken-language system inside as well as outside a sound attenuated booth.

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APPENDIX

Experimental materials

nr.	Cloze	Sentence context	Chapters 2 and 3	Chapter 4
6	100	Aan het einde van het schooluur gaat de	*bel/bes/pink*	*bel/bengelde/pluisde* voor de leswisseling
7	100	Als uitje gingen de vrienden een avondje gokken in een	*casino/kanarie/brochure*	*casino/castreerde/borduurde* op de Waalkade
8	100	Anneke heeft een bijbaantje waarbij ze gegevens moet invoeren in de	*computer/commissie/parasiet*	*computer/componeerde/presteerde* van een vervoersbedrijf
9	100	Bij het kopen van de auto koos Joris voor een betaling op lange	*termijn/terreur/pleister*	*termijn/terroriseerde/prakkezeerde* vanwege zijn financieën
10	100	Dat Maaike en Pieter elkaar in Rome tegenkwamen was puur	*toeval/toestel/biskwie*	*toeval/toeterde/bladerde* en niet afgesproken
11	100	De bloemist bezorgde bij Lisa een mooi	*boeket/boetiekje/pedaaltje*	*boeket/boetseerde/pauzeerde* rode rozen
12	100	De bokser woog negentig	*kilo/kiekjes/borrels*	*kilo/kieperde/duwde* schoon aan de haak
13	100	De docent had zijn klas duidelijk niet meer onder	*controle/conditie/toename*	*controle/contrasteerde/temperde* toen iedereen op de tafels klom
14	100	De eigenaar van de kledingzaak beschuldigde de vrouw van	*diefstal/diepgang/pudding*	*diefstal/diende/poederde* van een dure trui
15	100	De handen van de moordenaar zaten onder het	*bloed/bloempje/kamp*	*bloed/bloeide/kauwde* van het slachtoffer
16	100	De hond kreeg een koekje als	*beloning/belofte/kolonel*	*beloning/beloofde/drogeerde* voor zijn goede gedrag
17	100	De hond kwam aanlopen met een stok in zijn	*bek/berg/koor*	*bek/belde/kuurde* vol kwijl
18	100	De klimmers bereikten eindelijk de top van de	*berg/bek/tulp*	*berg/belde/trapte* in de Himalaya
19	100	De man laat zijn haar altijd doen bij een dure	*kapper/kapstok/deksel*	*kapper/kabbelde/denderde* in de Kalverstraat
20	100	De man maakte voor de koningin een diepe	*buiging/buidel/kegel*	*buiging/buitelde/kibbelde* tot op de grond
21	100	De moeder zette het overgebleven stuk taart in de	*koelkast/koepel/polder*	*koelkast/koesterde/piekerde* in de bijkeuken
22	100	De overval werd vastgelegd door een verborgen	*camera/cavia/theater*	*camera/camoufleerde/tintelde* boven de ingang
23	100	De tandarts trok bij Nico zijn achterste	*kies/kiel/pels*	*kies/kietelde/peuterde* met ontstoken wortels
24	100	De twee auto's waren betrokken bij een frontale	*botsing/bokser/tulband*	*botsing/borstelde/treuzelde* op de gevaarlijke autoweg
25	100	De wekker liep niet meer vanwege een lege	*batterij/baviaan/kronkel*	*batterij/baggerde/condenseerde* waardoor ik me versliep
26	100	De wijnglazen staan op de bovenste	*plank/plant/teugel*	*plank/plaste/tipte* in het keukenkastje
27	100	Een vereiste voor die baan was het spreken van tenminste twee vreemde	*talen/taarten/kersen*	*talen/taande/kiemde* waaronder Engels
28	100	Floor had vannacht een hele nare	*droom/droogte/ploeg*	*droom/droogde/polste* over slangen
29	100	Geduldig hielp de ober de lastige	*klant/klank/breuk*	*klant/klampte/braakte* met zijn bestelling
30	100	Het bedrijf had te kampen met een gebrek aan bekwaam	*personeel/perkament/kaviaar*	*personeel/permitteerde/componeerde* en schakelde een uitzendbureau in
31	100	Het bleek nogal lastig om de wijnfles te ontdoen van zijn	*kurk/kust/boon*	*kurk/kuchte/biechtte* ondanks de dure opener
32	100	Het hondje loopt nog maar op drie	*poten/posters/kaders*	*poten/pokerde/klauterde* sinds hij aangereden is
33	100	Marco gaat keurig ieder half jaar naar de	*tandarts/tante/pinguin*	*tandarts/talmde/pulkte* op controle
34	100	Na de begrafenis kreeg iedereen een kopje koffie met een plakje	*cake/ketel/dwang*	*cake/kegelde/damde* in een klein zaaltje
35	100	Na de botsing zat er in het portier van de auto een enorme	*deuk/deugd/braam*	*deuk/deugde/krenkte* onder het slot
36	100	Om de liftdeuren te sluiten moet je eerst drukken op de linker	*knop/knots/blouse*	*knop/knokte/bralde* met het zwarte tekentje
37	100	Oma gaat nog steeds elke zondagochtend naar de	*kerk/kern/trol*	*kerk/kerfde/trainde* voor de ochtendmis
38	100	Op kantoor gebruiken ze voor het kopieerwerk uitsluitend gerecycled	*papier/paté/kostuum*	*papier/passeerde/krioelde* voor een beter milieu
39	100	Sinds Debbie niet meer aan sport doet heeft ze een aanzienlijk slechtere	*conditie/controle/brigade*	*conditie/condoleerde/blameerde* dan voorheen
40	100	Tijdens de vliegreis mocht het jongetje een kijkje nemen in de	*cockpit/cocktail/drogist*	*cockpit/kokhalsde/dartelde* van de Boeing
41	100	Toen we net aan tafel zaten rinkelde plotseling de mobiele	*telefoon/telescoop/bioscoop*	*telefoon/telegrafeerde/biologeerde* van mijn broertje
42	100	Wegens de verbouwing geven ze op elk artikel een behoorlijke	*korting/korrel/bumper*	*korting/koppelde/bundelde* tot wel 70%!
43	100	De kersverse vader deed voor de visite muisjes op de	*beschuiten/beschaving/kreukel*	-
44	100	Deze veertienjarige pianist heeft duidelijk veel	*talent/tabak/buffels*	-

Experimental materials

nr.	Cloze	Sentence context	Chapters 2 and 3	Chapter 4
45	100	Het schrijven van de scriptie nam veel tijd in	*beslag/beschuit/kristal*	-
46	100	Manon houdt er niet van om op zaterdag te winkelen vanwege de enorme	*drukte/druppel/knikker*	-
47	100	Mijn vader ging op zijn achtiende in militaire	*dienst/diepte/pluim*	-
48	100	Na het misdrijf ging de politie op zoek naar de vermoedelijke	*dader/datum/pizza*	-
49	100	Naar eigen zeggen is Fiona soms een beetje traag van	*begrip/begin/trommel*	-
50	100	Over Martine's gezicht rolden een paar dikke	*tranen/tralies/parken*	-
51	97	Als ze geen sponsor kunnen vinden hebben de organisatoren een groot	*probleem/proces/kuiken*	*probleem/produceerde/domineerde* met de financieën
52	97	Bij de belangrijke volleybalwedstrijd zaten er veel mensen op de	*tribune/triomf/benzine*	*tribune/triomfeerde/balanceerde* met spandoeken
53	97	De artsen zijn op zoek naar een nier van een geschikte	*donor/doos/kroket*	*donor/doopte/kreukte* voor het ernstig zieke jongetje
54	97	De atleet werd beschuldigd van het gebruik van	*doping/dosis/pinda's*	*doping/doofde/plunderde* vlak voor de wedstrijd
55	97	De auto moest naar de garage voor een grote	*beurt/beurs/knoop*	*beurt/beulde/knoeide* en een periodieke keuring
56	97	De basketballers werden vanaf de bank begeleid door hun	*coach/koop/draad*	*coach/kookte/dramde* en trainer
57	97	De huishoudster nam de tafel af met een vochtig	*doekje/doel/plein*	*doekje/doezelde/puzzelde* om het stof te verwijderen
58	97	De jonge acteur maakte in de film zijn	*debuut/debat/panter*	*debuut/debatteerde/plezierde* als tegenspeler van Monique van de Ven
59	97	De Mercedes schoot door de hoge snelheid uit de	*bocht/borst/knul*	*bocht/bonsde/knipte* en knalde tegen een boom
60	97	De padvindertjes leren hoe ze de weg kunnen vinden met behulp van een	*kompas/complot/bisschop*	*kompas/compenseerde/bedankte* en een kaart
61	97	De schat werd van de zeebodem naar boven gehaald door drie ervaren	*duikers/duivels/prikkels*	*duikers/duimde/prakte* met persluchtapparatuur
62	97	De vader van het jarige kind had veel moeite met het opblazen van een	*ballon/ballade/trauma*	*ballon/bankierde/trakteerde* en het ophangen van de slingers
63	97	De waarzegster voorspelde de jongen zijn	*toekomst/toegang/bontjas*	*toekomst/toetste/babbelde* met een glazen bol
64	97	De zanger trad op voor een groot	*publiek/pupil/dressoir*	*publiek/pureerde/dresseerde* in Ahoy
65	97	Die boer loopt nog op	*klompen/klonten/draken*	*klompen/klotste/dreunde* door het dorp
66	97	Dorien werd helemaal gek van het druppelen van de	*kraan/kraag/buurt*	*kraan/kraakte/blikte* in de keuken
67	97	Er zat geen prik meer in de limonadefles zonder	*dop/dochter/pauw*	*dop/dolde/pluisde* die op het aanrecht stond
68	97	Flatbewoners kunnen vaak nog wel buiten zitten op hun	*balkon/ballet/kelner*	*balkon/bankierde/kleineerde* als het mooi weer is
69	97	Het verkooppercentage van die vertegenwoordiger ligt erg hoog door zijn vlotte	*babbel/balsem/kolom*	*babbel/balde/knelde* over zijn produkten
70	97	Het zieke meisje had hoge	*koorts/koorden/dauw*	*koorts/kooide/daagde* door de griep
71	97	In de lak van de auto zat een diepe	*kras/kracht/dorst*	*kras/krabde/bleekte* van het paaltje
72	97	In het sprookje zit de koning de hele dag op zijn	*troon/troost/bundel*	*troon/troostte/bouwde* te niksen
73	97	Jolanda leest in de trein een goed	*boek/boefje/pand*	*boek/boende/knalde* van Jan Wolkers
74	97	Midden in de stationshal hangt een grote	*klok/klos/brij*	*klok/klopte/draaide* met een zilveren wijzerplaat
75	97	Na het uitvallen van de elektriciteit verlichtte Carolien haar kamer met	*kaarsen/kaarten/deuren*	*kaarsen/kanoode/deukte* en waxinelichtjes
76	97	Nadat ze het stukje in de krant had gelezen schreef Sandra een boze	*brief/bries/twijg*	*brief/brieste/knarste* aan de redacteur
77	97	Om niet herkend te worden droeg de man een blonde	*pruik/pruim/dwerg*	*pruik/pruilde/dweilde* met krullen
78	97	Op de plek waar de wesp hem gestoken heeft zit nu een grote	*bult/bus/kous*	*bult/bukte/kletste* door het gif
79	97	Op zijn zestigste ging de man met	*pensioen/penseel/doperwt*	*pensioen/pendelde/dateerde* en werd er een groot feest georganiseerd
80	97	Vader zit altijd aan het hoofd van de	*tafel/taco/bonus*	*tafel/takelde/borrelde* met het avondeten
81	97	Voor de verjaardag van haar dochtertje deed de moeder zeven kaarsjes op de	*taart/taal/bijl*	*taart/tafelde/bottelde* met slagroom
82	97	De slachtoffers van de bomaanslag lagen bedolven onder het	*puin/puistje/dier*	-
83	97	Liesbeth noteerde de verjaardag van haar vriendin op de	*kalender/kabouter/bungalow*	-

Experimental materials

nr.	Cloze	Sentence context	Chapters 2 and 3	Chapter 4
84	97	Na het avondeten las de strenge vader altijd voor uit de	*bijbel/beitel/koelte*	-
85	97	Oma kan niet goed zien zonder haar	*bril/brits/keet*	-
86	97	Toen Arjan alle reparatiekosten bijelkaar optelde, kwam hij uit op een behoorlijk	*bedrag/bedrijf/kozijn*	-
87	93	‘s Zondags maken mijn ouders vaak een wandeling in het	*bos/bot/kwik*	*bos/bofte/krijste* van Leersum
88	93	Als ik een antwoord niet zeker weet vul ik de vraag eerst in met	*potlood/potgrond/drama*	*potlood/pompte/draafde* zodat ik het nog kan veranderen
89	93	Dat televisiestation zit bij ons niet meer op de	*kabel/kaper/bistro*	*kabel/kaatste/bietste* sinds we van exploitant gewisseld zijn
90	93	De bank bewaart al zijn goudvoorraden in een	*kluis/kluif/brein*	*kluis/kluifde/drenkte* onder de grond
91	93	De firma viert haar honderdjarig	*bestaan/bestel/kauwgom*	*bestaan/bestelde/plamuurde* met een groot feest
92	93	De geëmigreerde vrouw snakte naar een zak zoete	*drop/drollen/knapen*	*drop/dromde/kwaakte* en een pot pindakaas
93	93	De man wilde naar het buitenland met een verlopen	*paspoort/pastor/decaan*	*paspoort/pakte/keerde* maar werd bij de douane tegengehouden
94	93	De ober haalde de lege glazen op met een	*dienblad/diepvries/tandem*	*dienblad/diende/klaagde* met handvaten
95	93	De ondernemer wachtte nog even met het ondertekenen van het nieuwe	*contract/conflict/tempo*	*contract/confronteerde/baseerde* voor 4 jaar
96	93	Fiona pakte een schone handdoek uit de	*kast/kar/bok*	*kast/kalfde/drilde* in de badkamer
97	93	Het orkest lette goed op de bewegingen van de	*dirigent/diplomaat/politie*	*dirigent/divergeerde/prepareerde* tijdens het moeilijke muziekstuk
98	93	In de kamer van de tiener hangen de muren vol met	*posters/poten/trossen*	*posters/popelde/treiterde* van haar favoriete zangeres
99	93	In de wieg lag een slapende	*baby/bever/toren*	*baby/beefde/trouwde* met gebalde knuistjes
100	93	Met de kerst eten veel Amerikanen	*kalkoen/karton/bandiet*	*kalkoen/kalkte/broeide* met een lekkere vulling
101	93	Na de bankoverval gingen de dieven ervandoor met de	*buit/buik/crèche*	*buit/buitelde/kwijlde* van 3 miljoen gulden
102	93	Na de inbraak in de galerie hingen een aantal schilderijen niet meer op hun	*plaats/plaag/druif*	*plaats/plaagde/druiste* aan de wand
103	93	Na de verkiezingen was de PvdA de grootste	*partij/parkiet/daalder*	*partij/parkeerde/dupeerde* van Nederland
104	93	Na het breken van de antieke vaas toonden de jongetjes enig	*berouw/beroep/kaneel*	*berouw/bereikte/polijstte* aan hun oma
105	93	Na vele uren deden de reddingswerkers nog een laatste	*poging/pose/divan*	*poging/pookte/dipte* om de jongen te redden
106	93	Omdat Petra het in bed zo koud had, pakte ze een extra	*deken/degen/paleis*	*deken/deponeerde/pronkte* uit de kast
107	93	Opa klopte de tabak uit zijn	*pijp/pijn/douche*	*pijp/peinsde/dampte* in de asbak
108	93	Toen de onfortuinlijke jongen door het weiland liep werd hij getroffen door de	*bliksem/blikjes/truffel*	*bliksem/blinkte/troonde* en raakte hij zwaargewond
109	93	Toen Rudy na de val in de wond keek zag hij zelfs het	*bot/bos/kalf*	*bot/bokste/keurde* van zijn scheenbeen
110	93	De vrachtwagen kwam door een uitwijkmanouvre terecht in de zachte	*berm/berk/kroeg*	-
111	93	De wanden van de woonkamer schreeuwden om nieuw	*behang/beheer/kritiek*	-
112	93	Voor de kankerbestrijding hield Iris bij de mensen in de buurt een	*collecte/collage/bikini*	-
113	90	Als het mooi weer is gaan we vaak varen met onze	*boot/boom/tap*	*boot/boomde/teerde* in Vinkeveen
114	90	Anke hangt haar jas aan de	*kapstok/kapper/bankier*	*kapstok/kantelde/bibberde* in de hal
115	90	De dierenverzorger gaf de aap een lekkere	*banaan/baret/tempel*	*banaan/bazuinde/trotseerde* om op te peuzelen
116	90	De Keukenhof wordt jaarlijks druk bezocht door buitenlandse	*toeristen/toernooien/behoeften*	*toeristen/toeterde/bazelde* met dure fototoestellen
117	90	De merel zit in de hoogste	*boom/boot/teil*	*boom/bootste/treurde* luid te kwetteren
118	90	De mollige peuter volgt op advies van de dokter een	*dieet/diner/colbert*	*dieet/dineerde/combineerde* zonder suiker
119	90	Door de negatieve invloed van zijn vrienden kwam Nico op het slechte	*pad/pak/deeg*	*pad/paste/deelde* en pleegde een roofoverval
120	90	Doordat de ramen tegen elkaar open stonden zat Irene op de	*tocht/top/buis*	*tocht/tolde/baarde* en vatte ze kou
121	90	Er is droog weer voorspeld maar ik voelde net al een	*druppel/drukte/banket*	*druppel/drumde/baande* op mijn hoofd vallen
122	90	Het land liep onder water na het doorbreken van de	*dijk/deining/peer*	*dijk/deinsde/prutste* die nog niet versterkt was

Experimental materials

nr.	Cloze	Sentence context	Chapters 2 and 3	Chapter 4
123	90	Iedere ochtend voordat hij naar zijn werk gaat koopt de man een	*krant/krans/dweil*	*krant/kraste/deinde* bij de kiosk
124	90	In dat café staat er vaak een leuke jongen achter de	*bar/bal/krent*	*bar/balkte/krulde* bier te tappen
125	90	In de drogisterij stond er een lange rij voor de	*kassa/kasplant/bochel*	*kassa/kalkte/bulderde* te wachten
126	90	Na een avondje stappen had Jasper de volgende dag een behoorlijke	*kater/kade/bunker*	*kater/kakelde/bungelde* van de alcohol
127	90	Na het geweldige concert stond de hele zaal op zijn	*kop/kok/bad*	*kop/kolkte/bakte* door het enthousiaste publiek
128	90	Naar aanleiding van het opsporingsbericht kreeg de politie een anonieme	*tip/tik/crême*	*tip/tikte/danste* over de dader
129	90	Op de hoek van de straat komt een warme	*bakker/balk/tombe*	*bakker/balsemde/toverde* te zitten
130	90	Op de wangen van het verlegen meisje verscheen een	*blos/blok/kwal*	*blos/blokte/kwelde* toen ze de vraag beantwoordde
131	90	Overtreders van de wet kunnen hier rekenen op een eerlijk	*proces/probleem/knipsel*	*proces/probeerde/controleerde* met een onpartijdige rechter
132	90	Spanje is erg aantrekkelijk vanwege het gunstige	*klimaat/cliché/dossier*	*klimaat/klierde/dempte* en de prachtige stranden
133	90	Toen de vrouw last bleef houden van haar maag ging ze naar de	*dokter/dollar/perzik*	*dokter/dommelde/preekte* voor een consult
134	90	Ze maakten een tocht door de woestijn op een	*kameel/kabaal/docent*	*kameel/kampte/deerde* en sliepen ‘s nachts in een tent
135	90	De jonge kangoeroe paste niet meer in zijn moeders	*buidel/buiging/tomaat*	-
136	90	De vertraagde trein zou vertrekken vanaf een ander	*perron/persoon/dichter*	-
137	90	Met z’n vijven hielden ze de herrieschopper in	*bedwang/bedrog/trompet*	-
138	90	Opa houdt zijn broek omhoog met	*bretels/brevetten/toastjes*	-
139	87	Bram kon wel door de grond zakken na die enorme	*blunder/blubber/trofee*	*blunder/bluste/kweekte* van gistermiddag
140	87	De arts was blij met de goede vooruitgang van de	*patiënt/parade/drempel*	*patiënt/paradeerde/drapeerde* op de intensive care
141	87	De pianist verschoot van kleur bij het aanslaan van de verkeerde	*toets/toendra/boor*	*toets/toefde/bikte* tijdens zijn solo
142	87	De student kwam niet rond van zijn uitwonende	*beurs/beurt/clown*	*beurs/beurde/klikte* van vierhonderd gulden
143	87	De twee directeuren waren verwikkeld in een verhitte	*discussie/diskette/kazerne*	*discussie/distilleerde/presenteerde* over geldzaken
144	87	De vakantiegangers hadden veel moeite met het opzetten van hun	*tent/tank/bluf*	*tent/tankte/bromde* tijdens de storm
145	87	De verkoper verpakte de radio in een	*doos/donor/keel*	*doos/doofde/kreunde* met een rood lint eromheen
146	87	De wandelaar van de vierdaagse liep moeilijk omdat hij last had van een	*blaar/blaas/trein*	*blaar/blaakte/kwijnde* op zijn hiel
147	87	Natasja stopte de boeken in haar nieuwe	*tas/tak/boei*	*tas/talmde/bonkte* met ruches
148	87	Omdat Kirsten zin in cola had haalde ze op het station een	*blikje/bliksem/trede*	*blikje/bliksemde/trappelde* uit de automaat
149	87	Ronald is in de badkamer bezig met het witten van het	*plafond/plateau/dessert*	*plafond/plaveide/deserteerde* en een wand
150	87	Toen de hotelgasten het brandalarm af hoorden gaan ontstond er	*paniek/patat/design*	*paniek/patrouilleerde/decoreerde* in de eetzaal
151	87	Voor de popgroep uit elkaar ging, gaf ze nog een laatste	*concert/consult/budget*	*concert/conserveerde/berispte* voor haar fans
152	87	Om het zwartrijden tegen te gaan, rijden er in Amsterdam conducteurs mee op de	*tram/tred/baai*	-
153	87	De politieagent werd geraakt door een	*kogel/cobra/planeet*	-
154	83	De barones nodigde een aantal gasten uit voor een overheerlijk	*diner/dieet/couplet*	*diner/dirigeerde/coupeerde* met dure wijnen
155	83	De marktkoopman had veel moeite met het opzetten van zijn	*kraam/kraal/prins*	*kraam/kraaide/drentelde* door de harde wind
156	83	De meester heeft dit jaar een erg rustige	*klas/klap/biels*	*klas/klampte/bruinde* om les aan te geven
157	83	De premier kreeg de opdracht voor het vormen van een nieuw	*kabinet/cabaret/tentamen*	*kabinet/kakelde/dupliceerde* nadat het vorige gevallen was
158	83	De twee kleine jongetjes waren op de stoep aan het spelen met een	*bal/bar/knie*	*bal/bakte/knoopte* en een paar lege blikjes
159	83	De uitzinnige fan klom vliegensvlug op het	*podium/polisje/dokument*	*podium/poogde/dwaalde* en vloog de zanger om de hals
160	83	De voetballer trapte de bal in de richting van het	*doel/doekje/parfum*	*doel/doemde/pleegde* van de tegenpartij
161	83	Henk bouwde in de achterdeur een luikje voor de	*kat/kam/bruid*	*kat/kafferde/duikelde* zodat deze altijd naar buiten kan

Experimental materials

nr.	Cloze	Sentence context	Chapters 2 and 3	Chapter 4
162	83	Het kleine jongetje groef in het zand een diepe	*kuil/kuit/bon*	*kuil/kuierde/duchtte* met zijn schepje
163	83	Het vrouwtje veegde de vloer met een oude	*bezem/beker/krater*	*bezem/bedelde/kliederde* gemaakt van twijgen
164	83	Ivo kreeg op zijn werk een compliment van zijn	*baas/baard/korf*	*baas/baalde/knielde* over zijn goede advies
165	83	Maartje keek geboeid toe hoe een vlinder tevoorschijn kroop uit zijn	*cocon/kopie/betoog*	*cocon/codeerde/bazuinde* van zijde
166	83	Omdat Gemma niet wist waar de Bosstraat lag keek ze even op de	*kaart/kaars/doorn*	*kaart/kaatste/dopte* van Haarlem
167	83	Omdat Pim niet zo goed was in wiskunde kreeg hij van een klasgenootje	*bijles/bijlagen/tennis*	*bijles/beitelde/knipperde* in kansberekenen
168	83	Op de keukentafel zat een muisje te knabbelen aan de	*kaas/kaap/broche*	*kaas/kaapte/dreinde* die was blijven liggen
169	83	De koetsier zorgt geod voor zijn	*paarden/parels/kreet*	-
170	80	De bouw van het schuurtje bleek nog een heel	*karwei/karkas/toilet*	*karwei/kamde/draalde* voor Hans
171	80	De minister was benieuwd naar het stemgedrag van de	*kiezer/kievit/prairie*	*kiezers/kiepte/dweepte* in Friesland
172	80	De toneelspeler vergat spontaan zijn	*telst/tekkel/bord*	*tekst/temde/bloeide* en sloeg dicht
173	80	De voorzitter werd ontslagen door het	*bestuur/bestek/comfort*	*bestuur/behangde/tolereerde* wegens wangedrag
174	80	Er waren zoveel ratten in de omgeving dat je kon spreken van een ware	*plaag/plaats/dreun*	*plaag/plaatste/douchte* voor het kleine dorpje
175	80	Harry is slager van	*beroep/berouw/kanvas*	*beroep/beroofde/tuinierde* en amateur-voetballer
176	80	Het afval van de snackbar wordt bewaard in een grote	*container/conventie/therapie*	*container/consumeerde/boetseerde* in het steegje
177	80	Het meisje zwaaide de matroos uit vanaf de	*kade/kater/bokaal*	*kade/kaapte/boorde* in Rotterdam
178	80	In de lente ruiken de meeste bomen zo lekker door de	*bloesem/bloeding/kwelling*	*bloesem/bloedde/kwetste* die dan uitkomt
179	80	Karel sloeg met de hamer per ongeluk hard op zijn	*duim/duif/krijt*	*duim/duizelde/knuffelde* en schreewde het uit
180	80	Koos kocht voor zijn vrouw een grote bos	*bloemen/bloed/cola*	*bloemen/bloesde/kriekte* en een doos bonbons
181	80	Na jaren voor iemand anders gewerkt te hebben startte Luuk zijn eigen	*bedrijf/bedrag/kneuzing*	*bedrijf/bedekte/posteerde* in Eindhoven
182	80	Omdat er ‘s nachts geen openbaar vervoer meer reed, moesten we met de	*taxi/tarwe/koning*	*taxi/tartte/knielde* naar het hotel
183	80	Omdat het jongetje stout was geweest kreeg hij een pak voor zijn	*broek/broeder/touw*	*broek/broedde/tornde* van zijn moeder
184	80	Op zijn zestiende verjaardag kreeg de jongen van zijn ouders een	*brommer/brokstuk/tendens*	*brommer/brokkelde/tuimelde* en een helm kado
185	80	Ria volgt in de avonduren een Franse	*cursus/curve/tijger*	*cursus/cultiveerde/dreigde* op de universiteit
186	77	De strenge lerares draagt haar haar altijd in een	*knot/knol/duik*	*knot/knorde/dooide* als ze voor de klas staat
187	77	De toneelbouwers waren erg tevreden met hun mooie	*décor/dekaan/cultuur*	*décor/declareerde/blondeerde* voor het drama
188	77	De voetballers namen deel aan een groot	*toernooi/toerist/bassin*	*toernooi/toerde/blufte* in Duitsland
189	77	De zakenman droeg een mooi grijs	*pak/pad/krot*	*pak/pafte/kwetterde* naar de voorstelling
190	77	Doordat Els de voordeur nog op slot moest doen miste ze net de	*bus/bult/kous*	*bus/bulkte/ketste* naar het station
191	77	Het volleybalteam won met de eerste plaats een grote	*beker/bezem/kriebel*	*beker/bezemde/kreukelde* gevuld met champagne
192	77	Mariette werkt als secretaresse op	*kantoor/kanteel/dooier*	*kantoor/kampeerde/blondeerde* in Utrecht
193	77	Na het overlijden van haar man raakte de vrouw in een diepe	*depressie/defensie/cabine*	*depressie/delegeerde/corrigeerde* die lang duurde
194	77	Voor de wedstrijd begon sloeg de hardloper snel een	*kruis/kruik/beeld*	*kruis/kruimelde/blakerde* en deed een schietgebedje
195	77	Het hoofd van de afdeling voert een strak	*beleid/belang/kapel*	-
196	73	Bij Saskia in de tuin hangt er een schommel aan een dikke	*tak/tas/biet*	*tak/tapte/botste* van de appelboom
197	73	De moeder gaf haar kinderen een kopje thee met een	*koekje/koekoek/tiran*	*koekje/koelde/prijkte* toen ze uit school kwamen
198	73	De plaatselijke jeugd gaat op vrijdag altijd dansen in de	*disco/distel/puree*	*disco/dipte/plofte* naast de snackbar
199	73	Het meisje moest van haar tandarts een	*beugel/beuk/toneel*	*beugel/beukte/knapte* tot haar achttiende
200	73	Omdat de topleiders elkaar niet konden verstaan werd er gebruik gemaakt van een	*tolk/tosti/bed*	*tolk/tobde/baarde* bij de vergadering

Experimental materials

nr.	Cloze	Sentence context	Chapters 2 and 3	Chapter 4
201	73	Ome Bart is ‘s avonds vaak te vinden in het	*café/kanaal/toetje*	*café/capituleerde/pretendeerde* op de hoek
202	73	Petra kreeg voor haar verjaardag een plant in een mooie	*pot/pols/draai*	*pot/porde/dempte* voor op de vensterbank
203	73	De kleinkinderen gaan iedere week bij opa op	*bezoek/beklag/trechter*	-
204	73	Marianne kreeg op haar verjaardag veel mooie	*kado’s/kadavers/pauzes*	-
205	70	Bij het skieën brak Jeroen zijn rechter	*been/beest/trots*	*been/beefde/tetterde* op twee plaatsen
206	70	De geheime dienst had veel moeite met het ontcijferen van de	*code/coma/dienaar*	*code/coachte/dampte* op de diskette
207	70	De stewardess had een ladder in haar	*panty/penning/dealer*	*panty/pelde/durfde* nadat ze was blijven haken
208	70	De zangeres kwam het podium weer op voor een	*toegift/toevlucht/crisis*	*toegift/toefde/kronkelde* waar het publiek luidkeels om vroeg
209	70	Het verloofde stel is bezig met de voorbereidingen voor de	*bruiloft/bruikleen/koplamp*	*bruiloft/bruiste/tekende* in juni
210	70	Met mooi weer lig ik graag te zonnen in de	*tuin/tuit/bak*	*tuin/tuimelde/boterde* van mijn ouders
211	70	Nadat Marc in het water gevallen was, zwom hij snel naar de	*kant/kans/beet*	*kant/kapte/bloosde* van de rivier
212	70	Op het erf lag een waakhond aan de	*ketting/kermis/borstel*	*ketting/kermde/duurde* te slapen
213	70	Tegen de plaatsing van raketten voerden de demonstranten openlijk	*protest/procent/croissant*	*protest/profileerde/converseerde* op het Binnenhof
214	70	De schilder maande de vrouw stil te blijven zitten voor haar	*portret/portaal/coureur*	-
215	70	Elk voorjaar staat het zuiden van het land weer op zijn kop vanwege	*carnaval/karnemelk/bouillon*	-
216	70	Voor zijn vermoeden over wie de dader was had de rechercheur geen enkel	*bewijs/bewind/knaagdier*	-
217	67	De schilder kleurde de details in met een klein	*penseel/pensioen/doolhof*	*penseel/pensioneerde/doubleerde* van varkenshaar
218	67	Er waren veel artsen in de stad vanwege een groot	*congres/contrast/trottoir*	*congres/concurreerde/prefereerde* over hersenchirurgie
219	67	Hij moest bij het politiebureau zijn voor het indienen van een	*klacht/klapdeur/domein*	*klacht/klapperde/banjerde* tegen zijn buren
220	67	Mike’s ouders schrokken toen ze hoorden dat hij lid was van een gevaarlijke	*bende/bengel/tango*	*bende/bengelde/knikkerde* die drugs dealde
221	67	Op zijn werk drinkt Joost heel wat	*koffie/koffers/brancards*	*koffie/kocht/blaatte* met suiker
222	67	Toen de auto voor hem bij groen licht bleef staan duwde André op zijn	*claxon/klaproos/broeikas*	*claxon/klasseerde/dunkte* om de bestuurder te waarschuwen
223	67	Voor het exclusieve dineetje goot Inge de wijn over in een	*karaf/kadet/terras*	*karaf/kanaliseerde/behaagde* van kristal
224	67	Dat Tessa ook niets had gewonnen was voor Monique een schrale	*troost/troon/beer*	-
225	67	De eigenaar van de poes zocht voor de jonge katjes een goed	*tehuis/tekort/bordes*	-
226	63	De bejaarde man zit in de winter het liefst dicht bij zijn	*kachel/cactus/dozijn*	*kachel/kakte/dregde* om warm te blijven
227	63	De botsing vond plaats op een gevaarlijke	*kruising/kruimel/boodschap*	*kruising/kruiste/bobbelde* net buiten de stad
228	63	De reparateur van de verwarmingsketel constateerde een mechanisch	*defect/delict/krediet*	*défect/decoreerde/presideerde* en verholp het probleem
229	63	De visser zat de hele ochtend al vergeefs te turen naar zijn	*dobber/dolk/kerel*	*dobber/dompelde/knetterde* die niet onder ging
230	63	Het jongetje met griep had opgezette	*klieren/kliekjes/boorden*	*klieren/kliefde/brabbelde* en hoestte hevig
231	63	Het meisje hielp haar moeder bij het ompoten van de	*planten/planken/dreiging*	*planten/plakte/droomde* in de huiskamer
232	63	In het warenhuis greep een bewaker de jonge dief in de	*kraag/kraan/boog*	*kraag/kraamde/bokte* toen hij de winkel uit wilde lopen
233	63	Italië is voor Yvonne een waar	*paradijs/paviljoen/kenteken*	*paradijs/parafraseerde/beredeneerde* door het warme weer
234	63	Op zijn achttiende ging de vrome jongen in het	*klooster/kloofje/detail*	*klooster/kloofde/piepte* om monnik te worden
235	60	Anton bekijkt de sterrenhemel graag door zijn dure	*telescoop/telefoon/bediende*	*telescoop/telefoneerde/bombardeerde* op zolder
236	60	De gezagvoerder van het vliegtuig werd onder schot gehouden door een van de	*kapers/kabels/bobbels*	*kapers/kakelde/boemelde* met een pistool
237	60	De man gaf de kassière een vals	*biljet/biljart/kunstje*	*biljet/bibberde/trotseerde* van honderd gulden
238	60	De oude dame verstopt haar juwelen in een kistje met dubbele	*bodem/boter/kalmte*	*bodem/bowlde/kwakte* sinds er een keer ingebroken is
239	60	De terrorist bracht de politie op een	*dwaalspoor/dwaasheid/kwartaal*	*dwaalspoor/dwaalde/knikte* door van auto te wisselen

Experimental materials

nr.	Cloze	Sentence context	Chapters 2 and 3	Chapter 4
240	60	Nadat het vliegtuig in zee was gestort dreven er overal grote	*brokstukken/brommers/tweelingen*	*brokstukken/bromde/timmerde* op de golven
241	60	Omdat Tom wist dat zijn vrienden van bier hielden haalde hij twee	*kratten/krasloten/toernees*	*kratten/krabbelde/ploeterde* bij de slijter
242	60	Dat woord komt alleen voor in het Limburgse	*dialect/diagram/programma*	-
243	60	Het omvallende wijglas zorgde voor een vlek in ons nieuwe	*tapijt/taboe/bekken*	-
244	57	De ober die ons de menukaart had gegeven vroeg even later naar onze	*keuse/keuken/takel*	*keuze/keuvelde/telde* voor het hoofdgerecht
245	57	Om de gezondheid te bevorderen verhoogt de regering opnieuw de accijns op	*tabak/talent/plezier*	*tabak/taxeerde/poseerde* en alcohol
246	57	De fietsendief knipte de ketting door met een grote	*tang/tand/korst*	-
247	57	In het circus was er een meisje dat liep over een	*koord/koorts/duit*	-
248	57	Na lang zoeken vond de student een betaalbare	*kamer/kano/tube*	-
249	57	Onno loopt altijd met een veerkrachtige	*tred/tram/bast*	-
250	53	Bij het belastingkantoor stond de vrouw in de rij voor de	*balie/basis/knobbel*	*balie/baalde/knutselde* voor de aangiftes
251	53	De auto kwam langs de snelweg stil te staan met een lege	*tank/tent/brug*	*tank/tergde/brouwde* zonder reserve-brandstof
252	53	De kleuters stonden in een grote	*kring/kribbe/dwaas*	*kring/krikte/daalde* te zingen
253	53	De oude man merkte dat hij aan zijn rechteroor last kreeg van een toenemende	*doofheid/doofpot/keizer*	*doofheid/doopte/knabbelde* en ging naar de audioloog
254	53	De patiënt klaagde tegen zijn arts over een hevige	*pijn/pijp/dief*	*pijn/peilde/dekte* in zijn onderrug
255	53	De president hield een korte	*toespraak/toestand/knipoog*	*toespraak/toerde/knisperde* op televisie
256	53	De schermer trok snel zijn	*degen/deken/paleis*	*degen/degradeerde/proefde* toen de wedstrijd begon
257	53	De schildwacht stond uren bij de poort van een	*kasteel/kastanje/training*	*kasteel/catalogiseerde/torpedeerde* op wacht
258	53	Doordat het dure halssnoer gebroken was lag de vloer bezaaid met	*parels/paarden/knuppels*	*parels/paaide/doelde* en mooie kralen
259	53	Toen de verhuizers de piano lieten vallen gaf dat een harde	*klap/klas/beek*	*klap/klakte/bolde* op de vloer
260	50	De kleren van oma worden op zolder bewaard in een grote	*kist/kip/prei*	*kist/kibbelde/priemde* van eikenhout
261	50	De politieagent gaf de hardrijder een flinke	*boete/boeman/kubus*	*boete/boerde/kneedde* toen hij de maximumsnelheid overschreed
262	50	Doordat de trein vertraging had kwam de student te laat op zijn	*college/collega/tandpasta*	*college/collecteerde/balanceerde* statistiek
263	50	Erwin wilde uitleggen waarom hij te laat was maar kreeg geen	*kans/kant/beul*	*kans/kamde/breide* om iets te zeggen
264	50	Willeke deed een kaartje op de	*post/pop/kuif*	*post/pofte/kwekte* voor Maarten's verjaardag
265	50	De neppiloot bleek inderdaad niet in het bezit te zijn van een	*brevet/bretel/toeslag*	-
266	50	Met de loten in de hand zat het echtpaar gespannen te wachten op de eerste	*trekking/trektocht/butlers*	-

SAMENVATTING

CONTEXTUELE INVLOEDEN OP GESPROKEN-WOORDVERWERKING: EEN ELEKTROFYSIOLOGISCHE BENADERING

Het begrijpen van gesproken taal vraagt om een nauwe samenwerking tussen een aantal complexe cognitieve processen. Ga maar eens na, in een normaal gesprek identificeert een luisteraar razendsnel individuele woorden uit een *spraak-waterval*, haalt hij/zij de betekenis en grammaticale vorm van die woorden uit het geheugen (het *mentale lexicon*) op en integreert vervolgens deze informatie om tot een betekenis van een hele zin of heel gesprek te komen. Hierbij is de luisteraar zich niet eens bewust dat hij/zij zo hard moet werken om de spreker te kunnen begrijpen! Processen die specifiek te maken hebben met het herkennen van individuele gesproken woorden spelen een centrale rol in taalbegrip. In het algemeen wordt verondersteld dat gesproken-woordherkenning onderverdeeld kan worden in drie lexicale processen (d.w.z. processen die werken op het niveau van woorden): *toegang verkrijgen* tot het mentale lexicon waar ongeveer 40.000 woorden zijn opgeslagen, *selectie* van het juiste woord en *integratie* van de betekenis van een woord in de voorafgaande context. Tezamen nemen deze lexicale processen vaak minder dan een halve seconde in beslag. Het doel van de huidige studie was meer inzicht te krijgen in gesproken-woordherkenning en de invloed die informatie uit de zinscontext uitoefent op de lexicale processen die hieraan ten grondslag liggen.

In de literatuur over taalbegrip bestaat er voldoende evidentie voor de aanname dat invloeden van de voorafgaande context een rol spelen in het *on line* verwerken van gesproken woorden. De bestaande theoretische modellen op het gebied van gesproken-woordherkenning onderscheiden zich onder andere in het moment waarop informatie uit de context zijn invloed begint uit te oefenen. Een aantal modellen gaat uit van de veronderstelling dat context pas een effect kan hebben nadat een woord op basis van het akoestische signaal is herkend. Deze modellen worden *autonoom* of *modulair* genoemd. Andere, zogenaamde *interactieve* modellen beweren dat context al een invloed uitoefent voordat het begin van het woord gehoord is. Anders gezegd kan de context er al voor zorgen dat er een aantal mogelijke woorden voorspeld wordt. Een derde klasse modellen gaan er vanuit dat de waarheid hier ergens tussenin ligt. Zij werken onder de aanname dat er op basis van de eerste *fonemen* (klanken) van een woord, een aantal mogelijke woordkandidaten wordt geactiveerd (opgehaald uit het mentale lexicon). Bijvoorbeeld, op basis van de beginklanken "*bee*", worden de woorden *been*, *beker, beven*, *bever*, *bezem*, *bedelaar*, *beter,* enz. opgehaald. Daarna wordt op basis van de informatie uit de context en de akoestische analyse van het doorlopende spraaksignaal het juiste woord geselecteerd. Vervolgens wordt de betekenis van het woord geïntegreerd in de voorafgaande zin.

Een methode die uitermate geschikt is voor het volgen van het tijdsverloop van complexe cognitieve processen zoals de verwerking van gesproken taal is het registreren van hersenpotentialen. Hersenpotentialen maken deel uit van een continue registratie van de elektrische activiteit in de hersenen, het elektro-encefalogram (EEG). Deze neurale activiteit wordt middels elektroden aan de schedel opgevangen. In elektrofysiologische experimenten kunnen als gevolg van een externe gebeurtenis (het aanbieden van een stimulus zoals een gesproken woord of een plaatje) regelmatigheden in het EEG voorkomen die in de tijd gekoppeld zijn aan het moment waarop de stimulus werd aangeboden. Door stukken EEG-signaal die gekoppeld zijn aan een zelfde soort stimulus te middelen, kunnen de regelmatigheden in het EEG-signaal, zgn. *event-related potentials* (ERPs), zichtbaar gemaakt worden. Deze ERPs geven dus de neurale activiteit weer die gerelateerd is aan de verwerking van de externe gebeurtenis of stimulus en kunnen derhalve gebruikt worden als index voor de perceptuele en cognitieve processen die zich afspelen tijdens verwerking van de stimulus. Het ERP-signaal bestaat uit een serie positieve en negatieve pieken, die componenten worden genoemd. Normaliter worden ERP-componenten benoemd aan de hand van hun polariteit (negatief of positief voltage) en hun latentie (tijdstip waarop het signaal de hoogste waarde bereikt, gemeten in milliseconden vanaf het moment waarop de stimulus begint). De P300 is bijvoorbeeld een positieve component met een maximaal voltage op 300 milliseconden (ms) na het begin van de aangeboden stimulus. In de literatuur worden ERP-signalen vaak met de negatieve voltages omhoog afgebeeld. Zo ook in deze dissertatie.

Voor een aantal ERP-componenten is aangetoond dat zij gerelateerd zijn aan de verwerking van verschillende soorten informatie die noodzakelijk zijn voor taalbegrip. Zo blijkt de amplitude van de N400, een negatieve component die 400 ms na het begin van een stimulus piekt, beïnvloed te worden door de mate waarin de *semantiek* oftewel betekenis van een woord in een voorafgaande zin past. Hoe moeilijker het woord in de context is in te passen, hoe groter de amplitude van de N400. De P600 en de LAN (Left Anterior Negativity, een negatieve component die links frontaal op de schedel de maximale amplitude bereikt) blijken daarentegen gerelateerd te zijn aan de *syntaxis* of grammaticaliteit van een woord.

Door gebruik te maken van neurofysiologische indicatoren van verschillende taalverwerkingsprocessen, zoals de N400, LAN en P600, werden in deze dissertatie verschillende aspecten op het snijvlak van gesproken-woord- en zinsverwerking onderzocht. In hoofdstuk 2 van deze dissertatie wordt beschreven hoe aan de hand van een ERP-experiment onderzocht werd op welk moment informatie uit de voorafgaande context een invloed uitoefent op woordherkenning. De proefpersonen die deelnamen aan het experiment luisterden naar zinnen die eindigden op een woord dat (a) in semantisch opzicht *congruent* was (de betekenis van het woord paste goed in de zin), of (b) in semantisch opzicht *anomaal* was (de betekenis paste niet in de zin) en begon met dezelfde fonemen als het congruente woord, of (c) in semantisch opzicht anomaal was en begon met fonemen die verschilden van die van het congruente woord. Bijvoorbeeld: "Het vrouwtje veegde de vloer met een oude *bezem/beker/krater*". Het moment waarop het ERP-signaal van één van de twee semantisch anomale condities begint af te wijken van de congruente conditie, het begin van een *congruentie-effect*, geeft aan dat op dat moment context een invloed uitoefent op het woordherkenningsproces.

De resultaten lieten zien dat het begin van het congruentie-effect tussen de experimentele condities met *bezem* en *krater*, op 220 ms na het begin van het gesproken woord lag. Het begin van dit congruentie-effect lag 50 ms voor het begin van het congruentie-effect tussen de condities met *bezem* en *beker*. Dus, op 220 ms na het begin van een woord heeft context al een effect op gesproken-woordherkenning. Bovendien zagen de congruentie-effecten er verschillend uit. Daar waar in het geval van het verschil tussen de *bezem*- en *beker*-conditie enkel een N400-effect te zien was, ging in het geval van het verschil tussen de *bezem*- en *krater*-conditie een vroeg negatief effect vooraf aan het N400-effect. Dit vroegere effect bereikte een maximale amplitude op 200 ms na begin van het woord en werd daarom het N200-effect genoemd. Het N200- en N400-effect hadden een verschillende topografische verdeling (hadden op andere plaatsen op de schedel een maximale amplitude). Een verschil in de topografische verdeling van de effecten duidt op activiteit van (gedeeltelijk) afzonderlijke groepen neuronen en levert dus evidentie voor de bewering dat deze twee effecten verschillende processen weergeven.

Het optreden van het N200-effect werd toegeschreven aan invloeden van de zinscontext op de verwerking van gesproken woorden. Zoals de N400 een ERP-component is die in de context van gesproken-woordverwerking de moeilijkheid van semantische integratie weergeeft, lijkt de N200 een indicator voor het proces van lexicale selectie, waar informatie over de woordvorm verkregen uit een fonologische analyse van de beginklanken van een woord en inhoudsinformatie, afgeleid uit de context, samenkomen om het juiste woord uit een set van geactiveerde kandidaten te selecteren. De amplitude van de N200 wordt geacht aan te geven of een initiële beoordeling van de set kandidaten die op basis van de beginfonemen is geactiveerd, de aanwezigheid openbaart van een kandidaat met de semantische eigenschappen die voldoen aan de contextuele specificaties. Met andere woorden, er wordt een kleine N200 opgewekt als de set een goede kandidaat bevat en er wordt een grote N200 opgewekt als dit niet het geval is.

Nu er een elektrofysiologische indicator voor het lexicale selectieproces gevonden leek te zijn, werd deze gebruikt om meer inzicht te verkrijgen in het lexicale selectieproces. Het experiment beschreven in hoofdstuk 3 stelde drie vraagstukken aan de orde. Kunnen de resultaten van het eerste experiment gerepliceerd worden? Hoe zien de bouwstenen van het lexicale selectieproces eruit? En wat is de temporele relatie tussen lexicale selectie en semantische integratie? Door gebruik te maken van gesproken zinnen die eindigden met een semantisch congruent of een semantisch anomaal woord met beginfonemen die verschilden van die van het congruente woord (bijv. “Het vrouwtje veegde de vloer met een oude *bezem/krater*”), konden de belangrijkste resultaten van het eerste experiment gerepliceerd worden. Het congruentie-effect begon op 190 ms na begin van het woord en bestond uit een N200-effect, gevolgd door een N400-effect met verschillende topografische verdelingen op de schedel.

Om het tweede vraagstuk te kunnen beantwoorden, kregen de deelnemers gesproken zinnen aangeboden die in semantisch opzicht ofwel zeer sturend waren en eindigden op een woord met een hoge voorspelbaarheidsfactor (bijv. “Het vrouwtje veegde de vloer met een oude *bezem*”), of juist helemaal niet sturend waren en dus eindigden op een woord dat onmogelijk voorspeld kon worden (bijv. “Het volgende woord is *bezem*”). De resulterende ERP-signalen lieten een N200-effect zien, dat in de tijd duidelijk gescheiden was van het N400-effect: Beide componenten waren in laatstgenoemde conditie groter dan in de eerder genoemde conditie. Dit duidt erop dat gedurende het lexicale selectieproces beoordeling plaatsvindt op basis van de semantische eigenschappen die niet losgekoppeld kunnen worden van de lexicale kandidaten. De afwezigheid van sterke contextuele beperkingen zorgt ervoor dat het moeilijk is om te beoordelen of een kandidaat in de geactiveerde set goed past in de voorafgaande zinscontext, immers alle kandidaten passen even goed. Dit resulteert in een grote N200.

Het derde vraagstuk in hoofdstuk 3 betrof de vraag of semantische integratie volgt op lexicale selectie van één kandidaat, of dat deze processen in *cascade* optreden (d.w.z. dat semantische integratie al gepoogd wordt vóórdat het selectieproces is afgerond). Om dit vraagstuk te onderzoeken, kregen de deelnemers semantisch sturende zinnen te horen die eveneens eindigden op semantisch congruente dan wel anomale woorden, maar waarbij de zinsfinale woorden nu slechts deels werden aangeboden (bijv. "Het vrouwtje veegde de vloer met een oude *be/kra*"). Een uitgebreide *gating*-taak was vantevoren uitgevoerd om uit te zoeken of het afbreekpunt van elk woord vooraf ging aan het *identificatiepunt* (IP) van dat woord. Dat wil zeggen dat de woorden werden afgebroken voordat ze, wanneer ze in isolatie zouden worden aangeboden, herkend konden worden. De resultaten lieten een N200-effect zien, gevolgd door een N400-effect. Deze bevinding werd gezien als evidentie voor het feit dat lexicale selectie en semantische integratie cascaderende processen zijn. Het semantische integratieproces wordt opgestart nog voordat selectie van één (anomale) kandidaat is afgerond (als je bedenkt dat een *cascade* een kleine waterval is, had men op basis van de kaft van deze dissertatie wellicht al kunnen vermoeden dat dit de bevinding zou zijn!). Een aanvullend experiment, waarbij de volledig gepresenteerde zinsfinale woorden waren opgesplitst in een groep van woorden met een vroeg IP en een groep van woorden met een laat IP bevestigde deze resultaten. De factor vroeg of laat IP beïnvloedde noch het begin van het N400-effect, noch de piek van de N400. In het geval van woorden met een vroeg IP, met een gemiddelde van 230 ms na begin van het woord, zette het congruentie-effect 50 ms voor het IP in. In het geval van woorden met een laat IP, met een gemiddelde van 340 ms, zette het congruentie-effect 140 ms voor IP in.

Deze resultaten wijzen erop dat het semantische integratieproces niet wacht totdat één kandidaat is geselecteerd op basis van een fonologische analyse van het spraaksignaal. In de aanwezigheid van een lexicale kandidaat die voldoet aan de contextuele specificaties, kan selectie snel plaatsvinden en wordt integratie van de betekenis van de kandidaat in de voorafgaande zinscontext niet gehinderd, wat resulteert in een zeer lage N400. Echter, in het geval van een semantisch anomaal woord met beginfonemen die afwijken van een congruente kandidaat, geven de resultaten aan, dat in een semantisch sturende zin, lexicale selectie moeilijk is (een grote N200) en semantische integratie (weergegeven door de N400) wordt opgestart voordat het selectieproces is afgerond (begin N400-effect ligt voor IP). Dit duidt erop dat lexicale selectie en semantische integratie cascaderende of deels overlappende processen zijn en er pogingen worden ondernomen tot semantische integratie van een aantal kandidaten dat nog overeenkomt met het akoestische signaal.

De experimenten in hoofdstuk 2 en 3 lieten duidelijk zien dat context al vroeg een invloed kan uitoefenen op het begrijpen van gesproken-woorden. In hoofdstuk 4 werd het relatieve tijdsverloop van het gebruik van verschillende aspecten van contextuele informatie, zoals semantisch en syntactische (grammaticale) informatie, tijdens gesproken-woordverwerking onderzocht. Volgt de informatieverwerking de incrementele manier waarop verschillende bronnen van informatie in het spraaksignaal beschikbaar komen, of dient specifieke syntactische informatie over de grammaticale categorie waartoe een woord behoort eerst verwerkt te zijn, voordat semantische integratie plaats kan vinden? Er zijn een aantal aanwijzingen in de literatuur die de laatste veronderstelling van seriele verwerking ondersteunen. Om dit te onderzoeken werd er aan de deelnemers van het laatste experiment semantisch sturende zinnen aangeboden met een kritisch woord dat (a) in semantisch en syntactisch opzicht *congruent* was (d.w.z. dat het woord qua betekenis en grammaticaliteit goed in de zin paste), of (b) in semantisch en syntactisch opzicht *incongruent* was (niet paste), en begon met dezelfde fonemen als het congruente woord, of (c) in semantisch en syntactisch opzicht incongruent was en begon met fonemen die verschilden van die van het congruente woord. Bijvoorbeeld: “Het vrouwtje veegde de vloer met een oude *bezem/bedelde/kliederde* gemaakt van twijgen”. Voor beide condities met een semantisch en syntactisch incongruent woord werd het moment bepaald waarop het woord in syntactisch opzicht niet langer paste in de voorafgaande context, in dit geval het moment waarop het woord geen zelfstandig naamwoord meer bleek te zijn, maar een werkwoord. Dit moment werd het *category violation point* (CVP; woordcategorie-schendingspunt) genoemd en lag gemiddeld op 336 ms na begin van het woord voor de conditie met *bedelde* en 324 ms voor de conditie met *kliederde*.

De resultaten toonden een N200-effect in de conditie met *kliederde* t.o.v. de conditie met *bezem*. Daarbij lag het begin van het congruentie-effect op 170 ms na begin van het kritische woord. Beide incongruente condities wekten een grote N400 op, gevolgd door een LAN gekoppeld aan CVP en een P600. Daar waar het N400-effect problemen in semantische integratie aanduidt, blijkt uit literatuur dat zowel de LAN als de P600 gerelateerd zijn aan de syntactische verwerking van een woord. Een belangrijke bevinding is dat in beide incongruente condities, de N400 inzette voordat informatie over de woordcategorie was vrijgekomen. Dus in het geval van *bedelde*, zette de N400 in vóór CVP, dat voor *de* ligt. Als je dan bedenkt dat het woord op dat moment nog niet herkend kan zijn (immers het woord kan dan ook nog het semantisch anomale, maar syntactisch congruente zelfstandig naamwoord *bedelaar* worden), komt deze bevinding overeen met de resultaten van de twee experimenten die in hoofdstuk 3 zijn beschreven, waaruit bleek dat semantische integratieprocessen van start kunnen gaan voordat de akoestische informatie selectie van een unieke (anomale) kandidaat mogelijk maakt.

Deze resultaten zijn een duidelijke indicatie dat in tegenstelling tot eerdere resultaten beschreven in de literatuur, kennis van de syntactische woordcategorie niet nodig is voordat semantische integratie kan plaatsvinden. Het blijkt dat er tijdens de verwerking van gesproken woorden direct gebruik gemaakt wordt van elke bron van contextuele informatie. Als op basis van een interactie van een set lexicale kandidaten met contextuele specificaties, een semantische schending eerder wordt gedetecteert dan een syntactische schending, wordt dit tijdsverloop zichtbaar in het ERP-signaal. Deze bevindingen werden derhalve geïnterpreteerd als evidentie voor een cascade-model voor het proces van herkenning van gesproken woorden. Een dergelijk model zou uit moeten gaan van een optimaal gebruik van contextuele informatie, door semantische en syntactische informatie-verwerking in parallel plaats te laten vinden na activatie van een set kandidaten op basis van een fonologische analyse van de eerste fonemen van een woord, en lexicale integratie van start te laten gaan met een beperkt aantal kandidaten dat nog overeenkomt met het akoestische signaal.

Tenslotte lijkt een kleine toets in de praktijk, waaraan een aantal familie-leden en vrienden deelnamen, uit te wijzen dat ook buiten de experimentele omgeving context al vroeg een effect uitoefent op gesproken-woordherkenning. Afgemeten aan hun uitbundige reacties bleek dat alle deelnemers eenvoudig en snel het juiste woord konden selecteren en integreren na het horen van de woorden: "Eindelijk ben ik klaar met het schrijven van mijn *proe*".

Curriculum Vitae

Dannie van den Brink werd in Utrecht geboren op 21 augustus 1973. Na het behalen van haar gymnasiumβ-diploma aan Rijksscholengemeenschap Schoonoord te Zeist studeerde zij Spraak- en Taalpathologie aan de Katholieke Universiteit Nijmegen. In de periode van haar scriptie-onderzoek werkte zij als onderzoeksassistent aan het Max Planck Instituut voor Psycholinguistiek (MPI) in Nijmegen. Kort voor het behalen van haar doctoraaldiploma werd haar in mei 1998 een promotieplaats aangeboden bij de onderzoeksgroep 'Neurocognition of Language Processing' van het MPI. Van augustus 2001 tot september 2003 was ze als junior onderzoeker verbonden aan de afdeling Neurologie van het Universitair Medisch Centrum St. Radboud in Nijmegen voor het landelijke Langlopend Onderzoek Dyslexie. Vanaf september 2003 is ze als post-doc onderzoeker werkzaam bij het F.C. Donders Centre for Cognitive Neuroimaging in een samenwerkingsverband met de afdeling Psychiatrie van het UMC st. Radboud te Nijmegen op het onderzoeksproject 'Brain Imaging van Taalproblemen bij Volwassenen met Autisme'.

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