

ELECTROPHYSIOLOGICAL INSIGHTS INTO TIMING ASPECTS OF DISCOURSE PROCESSING IN APHASIC PATIENTS

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ZUSAMMENFASSUNG

In drei ERP Experimenten wurden zeitliche Aspekte von “Discourse” Verarbeitung bei zwei Gruppen aphasischer Patienten und zwei Kontrollgruppen (eine studentische und eine Alters-gematchte gesunde Kontrollgruppe) untersucht. In zwei ERP Experimenten, hörten Versuchspersonen Satzpaare. Die beiden Faktoren Kontext (Discourse, Satz) und Kohärenz (Kohärent, Inkohärent) wurden gekreuzt: in der Discourse-Bedingung, wurde der Inhalt des ersten Satzes im zweiten weitergeführt; in der Satz-Bedingung hatten die beiden Sätze keinen Bezug zueinander. Die kritischen Wörter (kW), zu denen die EPRs erfasst wurden, waren jeweils die letzten Wörter des zweiten Satzes. Deren Übereinstimmung mit dem jeweiligen Kontext determinierte die Kohärenz. In Experiment 1 gab es eine semantische Beziehung zwischen dem kW und einem Inhaltswort des jeweiligen Kontextes; für die Kohärenz-Bedingung bedeutete das eine semantische Beziehung, und für die Inkohärenz-Bedingung eine semantische Violation. (Bsp.: (kW in GROSS, semantischer Bezug unterstrichen) Discourse: Bob covered his pancakes with maple syrup. He likes them very SWEET / SPICY. Satz: We went to see the famous performer. The gardener has mowed the LAWN / HAIR).

Für die beiden Kontrollgruppen wurde die Hypothese von interaktivem Verarbeiten von Discourse durch ein Fehlen von onset-Unterschieden der N400 Effekte in beiden Kontextbedingungen bestätigt. Dies zeigt, dass lokale und globale Kohärenz parallel und nicht seriell verarbeitet werden.

Für die aphasischen Patienten sollte die Grundlage ihres Verständnisproblems weiter untersucht werden. Genauer sollte untersucht werden, ob jenes auf Defizite in der lexikalischen Aktivierung oder Integration zurückgeführt werden können. Ausserdem sollte die Hypothese von heuristischem Gebrauch semantischer Information überprüft werden. Patienten wurden als High oder Low Comprehenders aufgrund ihres auditorischen Verständnisses im Boston Diagnostic Aphasia Examination (BDAE) klassifiziert. Die ERP Evidenz bestätigte die Hypothese eines zugrundeliegenden Defizites in lexikalischer Integration. Dieses Integrationsdefizit variiert sowohl mit der Stärke des Verständnisproblems als auch mit der Menge der zu integrierenden Information: die High Comprehenders zeigten eine grössere Verzögerung des N400 Effektes in der Discourse-relativ zur Satz-Bedingung, und Low Comprehenders zeigen keinen N400 Effekt in beiden

Bedingungen. Mit diesem Design konnte die Hypothese des heuristischen Gebrauchs semantischer Information nicht eindeutig beantwortet werden; genauer, es konnte nicht determiniert werden, ob die semantischen Beziehungen die Verarbeitung vereinfacht haben, oder ob die semantischen Violationen das Verarbeiten beeinträchtigt haben.

Ein zweites ERP Experiment mit dem gleichen Design wurde durchgeführt, um diesen Aspekt der Verarbeitung weiter zu untersuchen. In diesem Experiment musste der jeweilige Kontext in seiner Gesamtheit verstanden werden, ohne dass einzelne Wörter zum Verständnis des kW beigetragen haben. (Bsp.: Discourse: Joel's office is forty miles away. He does not like the long COMMUTE / CURTAINS. Sentence: Helen reached up to dust the chandelier. While skiing, Randy broke his LEG / NOSE.). Dieses Experiment bestätigt die Ergebnisse des ersten Experimentes für die beiden Kontrollgruppen. Für die Patientengruppen konnte gezeigt werden, dass sie eher von den semantischen Violationen beeinträchtigt wurden anstatt von den semantischen Beziehungen zu profitieren. Die Gruppe der High Comprehenders zeigt normale Effekte in der Satz-Bedingung und verspätete Effekte in der Discourse-Bedingung. Die Gruppe der Low Comprehenders zeigt eine Tendenz zu verspäteter Integration in der Satz-Bedingung und keine Anzeichen von Integration in der Discourse-Bedingung.

In einem abschliessenden 3-stimulus-oddball Experiment wurde die Sprach-Spezifität der N400 Effekte bestätigt. Die Kontrollgruppe zeigt sowohl eine P3a mit frontalem Maximum und eine P3b mit centro-posteriorem Maximum; die Gruppe der High Comprehenders zeigt keine P3a und einen Trend zu einer P3b, während die Gruppe der Low Comprehenders sowohl eine P3a und eine P3b zeigen. Die Tatsache, dass die Patienten eine Dissoziation zwischen der N400 und einer anderen endogenen ERP component zeigen, bestätigt, dass die defizitären N400 Effekte in der Tat sprach-spezifisch und keine allgemeine Folge der Hirnverletzung sind.

SUMMARY

In the present thesis, three ERP experiments were used to investigate timing aspects of discourse processing in two groups of healthy subjects and two groups of aphasic patients. In two experiments, subjects were auditorily presented with sentence pairs. The two factors Context (Discourse, Sentence) and Coherence (Coherent, Incoherent) were crossed: in the Discourse condition, the second sentence continued the context introduced by the first in a meaningful way; in the Sentence condition, the two sentences were unrelated in meaning. For both the Sentence and the Discourse condition, a coherent and an incoherent version were created by means of the respective fit of the final word of the second sentence to which ERPs were acquired. In Experiment 1, semantic relationships between the critical word (CW) and at least one content word in the respective preceding context determined the respective fit/misfit of the CW (CW in CAPS, semantic match underlined; Discourse: Bob covered his pancakes with maple syrup. He likes them very SWEET / SPICY. Sentence: We went to see the famous performer. The gardener has mowed the LAWN / HAIR). Note that this introduced a semantic match / violation for the Coherent and Incoherent conditions, respectively.

For the control groups, the hypothesis of interactive processing of discourse information was confirmed by the absence of onset differences of the N400 effects in both conditions which shows that both local (sentence) and global (discourse) coherence are processed concurrently and in parallel rather than serially.

For the groups of aphasic patients, the nature of their processing deficit should be further determined, i.e. whether their comprehension deficits were due to impaired lexical activation or lexical integration. Furthermore, the hypothesis of heuristic use of semantic information was investigated. Patients were classified as either High or Low Comprehenders based on their auditory comprehension scores on the Boston Diagnostic Aphasia Examination (BDAE). ERP evidence was obtained which confirmed the hypothesis of an underlying integration rather than an activation deficit. ERP evidence reveals an integration deficit which varies as a function of both the severity of the comprehension deficit and the amount of information that has to be integrated: High Comprehenders show a stronger delay of the N400 component in the Discourse than the Sentence condition, and Low Comprehenders do not show any effects in either context condition. The hypothesis of heuristic use of semantic

information could not be answered with the present design, i.e. it could not be determined whether the presence of a semantic relationship facilitated processing of the CW or whether the semantic violation impaired processing.

A second ERP experiment with a similar design was used to further investigate this aspect of aphasic comprehension. In this experiment, the fit of the CW was to be derived from the respective context in the absence of lexical relationships (Discourse: Joel's office is forty miles away. He does not like the long COMMUTE / CURTAINS. Sentence: Helen reached up to dust the chandelier. While skiing, Randy broke his LEG / NOSE.). This experiment confirmed the results for the control groups from Experiment 1, and for the patients, it showed that rather from profiting from the semantic relations, they suffered from the semantic violations. Yet, did the integration impairment vary as a function of the severity of the deficit. High Comprehenders did show integration with a normal time course in the Sentence and delayed integration in the Discourse condition. Low Comprehenders showed a tendency toward a delay in the Sentence and no signs of successful integration in the Discourse condition.

Finally, in a three-stimulus-oddball experiment, the language specificity of the N400 effects was confirmed: control subjects show a frontally distributed P3a component and a centro-posteriorly distributed P3b component. High Comprehenders do not show a P3a component, but they show a P3b component. Low Comprehenders do show both a P3a and a P3b component which rules out that the absence of N400 effects can be attributed to brain damage per se but that they are language specific.

1 INTRODUCTION

Both spoken language comprehension and production come very naturally and effortlessly to virtually every individual, and the ease and speed with which we construct a meaning representation of any given input is quite remarkable. Beneath this seemingly smooth and effortless process, a complex neuronal machinery orchestrates the analysis of the input at various levels of processing and at the same times keeps up with input coming in at a rate of about four to five words per second. When listening to spoken input, word meanings have to be retrieved from long-term memory and the rules of syntax allow words to be woven into an infinite number of sentences. Furthermore, single sentences in turn are usually combined in order to form a coherent discourse. Under natural circumstances, we rarely converse by means of single sentences and even more rarely by means of single words. Nevertheless does the study of lexical and sentence processing receive tremendous attention relative to discourse processing despite the ubiquity of the latter in every day conversations. Since several levels of information have to be computed in order to arrive at a sensible meaning representation, one important aspect in the study of language comprehension are aspects of timing and manner in the interaction between lexical, sentential and discourse information, i.e. when and how these types of discourse information interact with each other.

Oftentimes, the apparent ease with which we comprehend and produce language remains unappreciated until this capacity is impaired or even lost as a result of brain damage. Individuals suffering from aphasia as a consequence of damage in the perisylvian area of the left hemisphere experience a devastating incapacitation by the loss of their inability to communicate verbally. Investigations of the language deficits of aphasic patients do not only help to illuminate the exact nature of these deficits, but also provide insights into the structure of language comprehension and production under normal conditions.

Models of normal language comprehension (e.g. Frauenfelder & Tyler, 1987; Marslen-Wilson, 1987; 1989) postulate a “mental lexicon” which contains information about the word forms. This includes information about the physical (i.e., phonetic and phonological) properties, the grammatical (i.e. morphological and syntactic) roles and meaning (i.e. semantic) information of the respective candidate. Furthermore, the so-called “mental grammar” (e.g. Pinker, 1997, 1999) contains the rules according to which the sounds are structured into digitized segments (phonemes) that are then sequenced into fixed

combinations (words/morphemes). Furthermore, it contains the syntactic rules according to which sequences of words are organized into hierarchical phrases and sentences (syntactic structures) whose meanings are constructed systematically from the meanings of the words.

Three processes are crucial for normal comprehension of spoken language: lexical activation, lexical selection and lexical integration. In the first step of lexical activation, the incoming sensory information is mapped onto the entries in the mental lexicon and thereby activating all potential candidates matching the input at any given point. This is performed in a left-to-right fashion; i.e. as more information is coming in, the number of potential candidates is narrowed down to ideally one single candidate (e.g. the string ['kæpt] has ruled out e.g. ['kæp] (cap) and ['kæpitl] (capital) as candidates, but it still includes ['kæpt] (kept), ['kæptn] (captain), ['kæptiv] (captive) ['kæp'tiviti] (captivity) as possible candidates). In the process of lexical selection the candidate which best matches the physical properties of the input is then selected. In the case of words presented in isolation, this process is completed after the 'uniqueness point'; i.e. the necessary phonetic information that refers to only one lexical candidate. However, when words occur in context, their semantic and syntactic properties have to be woven together in order to achieve a higher order meaning representation which is accomplished in the final step of lexical integration. What is crucial for successful understanding is that these processes are performed with temporal precision. Timing is crucial both in absolute terms, i.e. with respect to each of these processes are performed and also in relative terms, i.e. how they are performed in relation to each other.

However, natural language comprehension goes beyond the level of the single sentence. Usually, sentences do not come as independent entities, but mostly they are interrelated. In order to fully decode the meaning of an utterance encompassing more than a single sentence (hence referred to as "discourse"), incoming information has to be related to prior context and both local and global coherence have to be computed.

Despite decades of research on the both the topics of discourse processing and aphasic comprehension deficits, the topic of discourse comprehension in aphasic patients has not yet received much attention in the past. Most of the research done on discourse processing in aphasic patients has focused on discourse production rather than comprehension.

In my thesis, I used the method of event related brain potentials (ERPs) to shed a first ray of light onto timing aspects of discourse comprehension in aphasic patients thereby

focusing on how discourse comprehension abilities vary as a function of the severity of the patients' comprehension deficits. Rather than classifying patients according to syndromes, they were classified according to the severity of their comprehension deficit. The major question I have addressed is how global discourse context and local sentence context interact in the real-time integration of words into sentences. Furthermore, I assessed the contribution that semantic or associative relationships between single words in the respective context contribute to the integration process. The primary goal of this was to understand timing aspects of discourse processing in aphasic patients and the role which lexical processing might play in this process; I focused primarily on one ERP component, the N400, which is sensitive to the process of lexical integration. Three ERP experiments were conducted; the first two experiments examined lexical integration of critical words into sentence and discourse contexts. In the first experiment, the effects of semantic violations in sentence and discourse contexts were examined; in the second experiment, the effects of high and low cloze probability in the two contexts were examined. The final experiment was a three-stimulus oddball paradigm designed to elicit a different ERP component, the P300. This was done in order to determine the language specificity of possibly abnormal language-related ERP effects; in the case of a correlation between N400 and P300 effects, the changes in ERP effects would be indicative of an unspecific consequence of brain damage. In contrary, a dissociation between N400 and P300 effects would be indicative of the language specificity of potentially abnormal N400 effects.

I am first going to review the methodology of ERPs and the components under investigation and then the relevant issues in psycholinguistics.

1.1 EVENT RELATED BRAIN POTENTIALS (ERPS)

ERPs continuously reflect the sensory and cognitive processing of stimuli in any modality and can be elicited without requiring an extraneous task. For the study of language processing, one can simply ask subjects to read or listen for comprehension without depending on discrete behavioral measures in a task which may be secondary to the process under investigation. This property renders ERPs as a supreme methodology to study language processing in aphasic subjects. One problem from using a secondary task requiring a discrete overt response is that aphasic patients may either not be able to comprehend *how* to perform that task or they might not be able to perform it at all. Thus, a false or even an absent

response makes it hard to distinguish whether a patient was not able to perform the task or simply did not understand what s/he was supposed to do. Having a subject merely listen for comprehension is as pure of a measurement of language comprehension as anyhow possible.

Different ERP components have been attributed to different aspects of processing, and of particular interest for the studies presented here were the N400, the late positive complex (LPC) and the P300 which I am going to describe in the following section along with a more general description of ERPs.

The voltage fluctuations at the membrane of large neuron populations are passively conducted to the surface of the scalp, and it is hence the post-synaptic activity of large neuron populations of pyramidal cells in the neocortex that is reflected in the electro-encephalogram (EEG) recorded at the scalp. By making a time-locked average to the presentation of events or classes of events, one can extract the information directly related to the processing of the events. By doing so, one averages out all background noise that is not directly related to the processing itself. In comparison to the background EEG, the amplitudes of these event-related potentials (ERPs) are relatively small. The process of signal averaging is necessary to enhance the signal to noise ratio in order to allow extraction of these relatively small signals. Depending on the latency and amplitude of the potential of interest, a minimum of 20 – 50 epochs have to be averaged together.

Potentials always constitute a voltage difference between two points. Thus, in addition to the recording sites on the scalp, an additional electrode is used as the reference. The idea is to use a site of relative inactivity for that the signal recorded at scalp sites does not fluctuate as a function of the EEG activity at the reference site. One common site often employed as a reference is the mastoid bone, or the nose. One problem with mastoid reference is that this site is assumed to more inactive than is actually empirically tested (e.g. Curran, Tucker, Kutas & Posner, 1993). Furthermore, average references where each electrode is referenced to the average of all others, is common as well as is an electrode at the vertex of the skull (CZ). For recording purposes, it does not really matter which site is chosen as a reference, because off-line, all activity can be re-referenced to any site of combination of sites recorded. What one is left with is a series of positive and negative deflection with characteristic latencies, amplitudes and topographic scalp distributions referred to as components. Nomenclature and definition of components is quite diverse and non-unitary. The most common feature defining a component is its polarity (P for positive, N for negative); in

addition, its ordinal rank (e.g., N1, P2 – first negative and second positive peak) or peak latency (e.g., P300, N400) serve as identifiers. Some components are named according to their functional significance (e.g., MMN for mismatch negativity, SPS for syntactic positive shift), topographic distribution (e.g., (E)LAN for (early) left anterior negativity), or their proposed neuronal generator (e.g., ABR for auditory brainstem response).

1.1.1 The N400 & the LPC

In this thesis, I will focus on one particular ERP component, the so-called N400, a negative deflection in the ERP maximal over centro-posterior locations on the scalp. It is especially sensitive to semantic aspects of linguistic input and was first described by Kutas and Hillyard in 1980. They found the amplitude of the N400 increased in sentences ending with a semantic anomaly (e.g. “*He spread the warm bread with SOCKS*”¹) relative to those ending with a sentence-final congruent word (e.g. “*He spread the warm bread with BUTTER*”). This seminal paper led to a wide range of studies that are too numerous to cite here; for a recent overview see Friederici (2004). The N400 has been elicited both in the visual (e.g. Kutas & Hillyard, 1980; Bentin, McCarthy, & Wood, 1985) and auditory modality (e.g. Woodward, Owens, & Thompson, 1990; Friederici, Pfeifer & Hahne, 1993; Hagoort & Brown, 2000). Direct comparisons of the N400 to the same stimuli in the visual and auditory modalities (e.g. Holcomb & Neville, 1990; Anderson & Holcomb, 1995) show that different physical properties of the input leave the functional properties of the component unchanged. Furthermore, the N400 has been elicited in a large variety of spoken languages like e.g. Finnish (Juottonen, Revonsuo, & Lang, 1996), French (Astesano, Besson, & Alter, 2004), German (Friederici, Pfeifer & Hahne, 1993), Dutch (Hagoort & Brown, 2000), Chinese (Liu, Shu, & Wei, 2006) as well as in American Sign Language (Kutas, Neville, & Holcomb, 1987).

Semantic violations are sufficient but not necessary to elicit amplitude modulations of the N400; other factors affecting the amplitude of the N400 are word expectation and the position of a word in a sentence: the size of the N400 is inversely related to the cloze

¹ For citing example stimuli, I will use *italics*; critical words to which a dependent measure is obtained are in *CAPITALS*

probability² of a word and directly related to the position in a sentence (e.g. Kutas, Lindamood, & Hillyard, 1984; Connolly, Phillips, Steward, & Brake, 1992; Connolly, Phillips & Forbes, 1994). Larger N400 amplitudes are elicited by words with a low cloze probability and by words early in the sentences. Despite some debates about the exact functional significance of the N400 component, the most commonly accepted one is that it reflects the process of semantic integration rather than lexical activation or selection (e.g. Chwilla, 1996; Chwilla, Brown, & Hagoort, 1993; Brown & Hagoort, 1993; Swaab, Brown, & Hagoort, 1997, 1998). In a nutshell - the amplitude of the N400 varies as a function of the difficulty in integrating a word into its preceding context. Linguistic violations other than semantic ones leave the amplitude of the N400 unchanged. Syntactic violations (e.g. number or gender agreement) or dispreferred syntactic structures such as garden path sentences elicit different components (ELAN, P600). Thus, it can be concluded that the N400 reflects semantic aspects of an integration difficulty rather than general aspects of overall linguistic fit.

With respect to the neuronal generators of the N400, the evidence from intracranial ERPs, spatiotemporal source analysis from ERP & MEG studies and fMRI is not yet entirely conclusive. Intracranial ERPs are recorded directly from the cortex in patients undergoing evaluation for a surgical relief of medically intractable epilepsy. N400-like intracranial potentials have been recorded from the anterior medial part of the temporal lobe; these potentials were larger for open-class words than for close-class words and unpronounceable letter strings, larger for semantically unrelated than related word pairs, and larger for incongruent than congruent sentence completions (Nobre, Allison, & McCarthy, 1994; Nobre & McCarthy, 1995; McCarthy, Nobre, Bentin & Spencer, 1995; Elger, Kutas, Helmstädter, Brockhaus, van Roost, Heinze, 1997). One problem with interpreting intracranially obtained ERPs is that electrode placement is guided by clinical rather than experimental considerations; electrodes are only implanted where they are necessary and not where they might be experimentally desirable and thus, they can only be obtained at clinically relevant sites, which is usually confined to medial temporal structures. Further evidence from

² The cloze probability of a word is defined as the proportion of subjects who complete a given sentence fragment with that particular word

intracranial (Halgren, Baudena, Heit, Clarke, Marinkovic, Chauvel, & Clarke, 1994) and MEG recordings (Halgren, Dhond, Christensen, Van Petten, Marinkovic, Lewine, & Dale, 2002) as well as fMRI (Kiehl, Laurens, & Liddle, 2002; Hagoort, Hald, Bastiaansen, & Peterson, 2004) suggests another possible generator for the N400 in the left inferior frontal gyrus. Frishkoff, Tucker, Davey, & Scherg (2004) applied spatiotemporal source analysis to ERPs obtained in an N400 paradigm and found activity in left prefrontal cortex and left anterior cingulate during the initial detection of a semantic anomaly (~250 ms). In the critical interval (300 – 500 ms), regional sources were localized in left and right lateral prefrontal cortex, right temporal cortex as well as in the anterior and posterior cingulated cortex. Furthermore, left hemisphere activity preceded right hemisphere activity and the effects of semantic incongruity started earlier and were more persistent in the left hemisphere than the more transient effects in the right hemisphere. With respect to the neural origins of the N400, it can be concluded that it is more likely to reflect the activity of a large neuronal network which has a characteristic time course rather than being spatially and temporally confined to a small circumscribed brain area.

The LPC is a positive deflection emerging after about 500 ms after stimulus onset often elicited in conjunction with the N400. Even though it is elicited in linguistic contexts primarily to words in sentence-final positions, its functional significance is not limited to linguistic processes. Moreover, it has been most commonly attributed to reflect processes of (episodic) memory and familiarity in word repetition. For example, the repetition of both high and low frequency words elicit an N400 repetition effect, whereas only the repetition of low but not high frequency words elicits the LPC; this has been interpreted as a larger discrepancy between the baseline and experimental familiarity of low frequency words (e.g. Rugg, 1990). In contrast, Van Petten, Kutas, Kluender, Mitchiner, & McIsaac (1991) found larger LPC amplitudes to words that were not repeated than to words that were repeated when subjects read excerpts from a magazine. For a memory-related interpretation of the LPC see also Paller, Kutas, & McIsaac (1995) and Swick (1998).

However, the LPC is often elicited conjointly with the N400 and is likewise modulated by semantic context; this suggests that it is responsive to processing meaning aspects of the input. Juottonen, Revonsuo, & Lang (1996) investigated developmental aspects of the N400 and LPC in order to discriminate commonalities and differences between the linguistic properties of the two components. They found differential developmental

trajectories for the two components; while the N400 was elicited both in children and adults to semantically incongruous sentence endings, an LPC was obtained only for the adults but not the children. This is interpreted as recognizing the familiarity of a concept, a trait which might not consolidate until after childhood. The functional significance of the LPC in linguistics context might be best described as reflecting memory processes involved in sentence-wrap-up or reanalysis.

1.1.2 The P300

The P300 is one of the most extensively studied endogenous ERP components (e.g. Picton, 1992; Polich & Kok, 1995). For a recent review refer to Soltani & Knight (2000). It is elicited in a paradigm in which two stimuli are presented with different probabilities in random order. In the classical two stimulus oddball paradigm, subjects are required to discriminate the infrequent target stimulus (the so-called “oddballs”) from a frequent standard stimulus by either overtly or covertly reacting to the targets. The paradigm can be extended by adding a third class of stimuli (so-called “novel” stimuli) to which no response is required. In both cases, a positive-going wave is elicited, which reaches its maximum between 300 – 400 ms after stimulus onset in the auditory modality. Two functionally distinct subcomponents of the P300 can be distinguished. The P3a evoked by the novel stimuli has a frontally distributed maximum and can be functionally described as reflecting automatic novelty detection. The P3b is evoked by the target stimuli with a posteriorly distributed maximum and can be functionally described as reflecting voluntary target detection. Different neuronal generators for the P3a and P3b have been reported from lesion studies as well as from intracranial recordings. Lesion studies show that patients with focal brain lesions including patients with anterior temporal lobectomies (Johnson, 1988; Johnson & Fedio, 1987), bilateral mesial temporal lesions due to herpes simplex encephalitis result in significant P3b reductions at far lateral temporal and frontal sites suggesting that mesial temporal structures may either generate field potentials propagating to the surface or provide modulatory input necessary for P3b generations at these sites. Intracranial recordings from epileptic patients undergoing pre-surgical examination reveal neuronal generators for the P3b in multimodal association cortex including possibly the superior parietal lobule as well as limbic medial temporal lobe. (Halgren et al. 1995 a) and b)). Lesion studies (Scabini, 1992; Scabini & Knight, 1989; Knight & Scabini, 1998; Rule, Shimamura, and Knight, 2002) show

significant P3a reductions in patients with lateral prefrontal damage. This is corroborated by intracranial recordings from Baudena et al. (1995) who show P3a-like potentials originating in dorsolateral, orbitofrontal, and anterior cingulate cortices as well as the gyrus rectus.

1.2 FROM SINGLE WORDS TO COHERENT DISCOURSE

Language comprehension has been studied extensively at the level of single words and sentences, especially in reading. But natural language comprehension usually goes beyond the level of single sentences which have to be related to information provided by prior context in order to construct a coherent message representation.

Studies of language processing using word lists provide important information on the organization of the mental lexicon. Manipulating the relatedness between words in lists can help to elucidate the structure of semantic networks that exist between the single entries in the mental lexicon. Physically, sentences might also be understood as lists of words; however, in meaningful sentences, words are connected according to the laws of syntax, and the processing of words is fundamentally different in lists and sentences. Similarly, a coherent discourse is not merely realized by an additive accumulation of sentence-structures, but rather by establishing coherent relationships between single elements contained therein.

1.2.1 Effects of lexical association between words in lists, sentences, and discourse contexts

1.2.1.1 WORD LISTS

Words are processed faster and more accurately when they are preceded by a semantically or associatively related word, an effect referred to as semantic priming. The most common explanation for this phenomenon is the notion of automatic spreading of activation between related lexical nodes (Collins & Loftus, 1975). In this framework, words that are semantically or associatively related have strong links in semantic memory and when a word is processed, activation from the node representing that word can spread to related words and so lower their recognition thresholds by increasing their baseline activation.

Effects of semantic priming have not only been found with behavioral measures such as reduced reaction times and increased accuracy rates in lexical decision tasks and naming, but also with ERPs. For a comprehensive review of the behavioral literature, refer to Neely

(1991). Bentin et al. (1985) were the first to report ERP effects of semantic priming. Subjects were performing a lexical decision task while their EEG was recorded. In one third of the trials, the target words were preceded by a related prime word (e.g. “*bread-BUTTER*”). Priming effects were observed both behaviorally (reduced reaction times, increased accuracy) and electrophysiologically by a reduced amplitude of the N400 if a target word was preceded by a related prime. The modality of presentation does not affect the morphology of the N400. Holcomb and Neville (1990) showed comparable N400 priming effects of the same word pairs both in the visual and the auditory modality.

1.2.1.2 SENTENCES

However, the effects of association between words are not only obtained in lists of words, but also in sentences. Early behavioral studies investigated the interrelation of lexical and sentential processing with naming and lexical decision tasks. In a series of three experiments in which subjects named sentence-final target words preceded by prime presented coherent or scrambled sentences, Simpson, Peterson, Casteel & Burgess (1989) compared context effects which could arise from lexical priming alone to those which could arise from sentential contexts. They found that the latter had a stronger effect on the recognition of the target words than intralexical spreading of activation. In another series of three experiments, Duffy, Henderson, & Morris (1989) manipulated the strength of intralexical spreading of activation and its effect of naming visually presented targets. They conclude from their data that the priming effects they obtain originate from the *combination* of lexical items rather than from the contribution of single lexical items themselves or overall context, respectively.

Van Petten (1993) used ERPs to investigate the effects of associative priming when prime-target pairs were embedded in sentences. Lexically associated (e.g. *moon & stars*) and unassociated (e.g. *insurance & refused*) were embedded in congruent or anomalous sentences. The anomalous sentences had a legal syntactic structure but no cohesive message which distinguished them from simple lists of words. Effects of associative priming were obtained in both coherent and anomalous sentences and effects of sentence congruence were only obtained in coherent but not anomalous sentences, thus, associative priming is stronger than sentence congruency; In a follow-up study, Van Petten, Weckerly, McIsaac and Kutas (1997) further investigated the effects of lexical association and sentence congruency as a

function of working memory capacity. With the same materials, they found effects of associative priming irrespective of working memory capacity and effects of sentence congruency in the absence of lexical associations only for the medium and high but not the low working memory span groups; this shows that processing of sentence congruency is dependent on working memory capacity whereas associative priming is not. In another ERP study, Hoeks, Stowe & Doedens (2004) investigated the interactions between message-level and lexico-semantic information. Message-level constraints and lexico-semantic fit of the sentence-final critical words were crossed. The obtained ERP results indicate similar importance and independent influence of both lexico-semantic and message-level information.

1.2.1.3 DISCOURSE CONTEXTS

Behavioral studies examining the interplay between lexical and discourse information primarily focused on the effect of discourse context in the resolution of lexical ambiguities.

Till, Mross & Kintsch (1988) presented subjects with ambiguous prime words embedded in biasing discourse contexts and subjects had to perform a lexical decision to a target word which could be either a lexical associate of the prime or a thematic inference of the discourse. Facilitation was obtained at short SOAs for lexical associates and at long SOAs for thematic inferences. They interpret their results as being consistent with the view that lexical processing is initially independent of the meaning of an overall context (*“this process of construction begins conservatively with a context-free, bottom-up semantic interpretation of the word ... Meaning is a construction that takes time, quite appreciable time.”* Till et al, p. 294). Rayner, Pacht & Duffy (1994) biased the meaning of an ambiguous word by either pairing it with an associate or presenting it in a biasing sentence context in order to eliminate the subordinate bias effect. Neither lexical nor discourse bias could suppress the activation of the subordinate meaning of the ambiguity suggesting a bottom-up processing of lexical information even in the presence of a biasing context. In line with this, Binder & Morris (1995) and Binder (2003) showed that biasing contexts could not prevent the inappropriate activation of both subordinate and dominant meaning of an ambiguity providing support for the notion of the modular autonomy of lexical processing.

Schwanenflugel & White (1991) examined how immediate sentence context and prior discourse information are combined in the processing of words presented at the end of a four-

sentence passage using both a lexical decision and a naming task. Readers are sensitive to both types of information which is available prior to word recognition rather than during semantic integration. The authors conclude from their data that discourse, sentence and lexical information are processed interactively rather than modularly. More recently, Vu and colleagues concluded from a series of six naming experiments that a sentence context can be indeed strong enough in order to bias only the appropriate meaning of an ambiguity (Vu, Kellas, & Paul, 1998). In a later study (VU, Kellas, Metcalf, & Herman, 2000) they showed this is even stronger for discourse contexts and further support the notion of interactive processing of discourse information.

1.2.2 ERP Effects of coherence in sentence and discourse contexts

1.2.2.1 SENTENCE CONTEXTS

Semantic anomalies and their concomitant low plausibility are sufficient but not necessary to elicit an N400 effect. Another factor which influences the amplitude of the N400 is the cloze probability of a word in a given context.

A word which is semantically anomalous in a sentence is always very implausible; a word which has a low cloze probability may but does not have to be implausible given its sentence context. Several factors can determine the cloze probability of a word; for one, single words determining the semantic content of a given sentence can allow only one or very few words to be used to terminate it; it is important to note that in that case, all possible candidates will share semantic features (e.g. "*The gardener has mowed the LAWN/GRASS*") and any other completion of the sentence will yield a semantic violation (e.g. "*The gardener has mowed the HAIR/TABLE/...*"). However, instead of single words, it can also be the overall content of a sentence that allows only one very few candidates as the best completion; in this case, the possible candidates will not necessarily share semantic features (e.g. "*The tired runner stopped to catch his BREATH/DOG*"). As already mentioned above, low cloze can be achieved by means of a semantic violation or by a sentence fragment which in and of itself is not constraining at all (e.g. "*Helen reached up to dust the CHANDELIER/BOOKS/MANTLE/WINDOW/...*")

Numerous ERP studies which are too numerous to cite here have found N400 effects to semantically anomalous words in sentence contexts (e.g., Kutas & Hillyard, 1980; Chwilla

et al., 1995; Swaab et al., 1997; Federmeier, van Petten, Schwartz, & Kutas, 2003; Hagoort & Brown, 2000). Even though a semantic anomaly is sufficient to evoke an N400 effect, it is not necessary. Words that are congruent but less expected in a given context also elicit an N400. Kutas & Hillyard (1984) and Kutas et al. (1984) have proposed that the amplitude of the N400 varies as an inverse linear function of the cloze probability of the word.

For example, take the sentence fragment “*I like cream and sugar with my_____*”; which can be completed both with “*coffee*” and “*tea*”. Even though both “*coffee*” and “*tea*” are both coherent and plausible completions for the given sentence fragment, “*tea*” has a lower cloze probability than “*coffee*” and will thus elicit an N400 in the given context.

1.2.2.2 DISCOURSE CONTEXTS

Only a few ERP studies have so far addressed the effects of discourse contexts on lexical integration in a local sentence context.

St. George, Manes & Hoffman (1994) were the first to show ERP evidence for the importance of a discourse schema on the processing of single words. Subjects read ambiguous paragraphs describing everyday activities which do not appear to be logical unless provided with a disambiguating title (Cooling & Lachman, 1971; Bransford & Johnson, 1972)³. ERPs were obtained to all content words in the paragraphs and the N400 was significantly larger to the words presented in the untitled than in the titled condition suggesting that it was the discourse schema which facilitated integration of each word.

Federmeier & Kutas (1999a & b) did not explicitly examine discourse processing, but the effects of long-term semantic memory during sentence processing. They presented subjects with two-sentence scenarios which established the expectation of a particular exemplar of a semantic category to terminate the second sentence. That did end either with the expected exemplar, an unexpected exemplar from the same semantic category or an

³ e.g. “... *Some don't like the smell or the lack of control. So some people are scared to try it even if they've dreamed of it since they were a kid reading about it in books and watching it on television. A running start is uncommon, although there are some who do it. Typically, success requires that you start with your left leg, and make sure that it is securely in place. Then swing your body high into the air. The direction matters*” [excerpt from the passage describing horseback riding]

unexpected exemplar from a different and unexpected category (e.g. “*They wanted to make the hotel look more like a tropical resort. So along the driveway they planted rows of PALMS/PINES/TULIPS*”) and found the amplitude of the N400 varying as a function of semantic fit of the respective endings and so showed that the overall context could constrain the expectation of one specific exemplar of a semantic category.

Van Berkum, Hagoort & Brown (1999) varied coherence in single sentences and in three-sentence scenarios. Subjects read sentences (e.g. “*Jane told her brother that he was exceptionally QUICK/SLOW*”) presented both in isolation and when preceded by a context which biased one, but not the other version (in this case, “*QUICK*”). When presented in isolation, both versions of the sentence elicited N400 amplitudes which were comparable to the semantic anomalies in single sentences used as a control condition (e.g. “*Gloomily, they stood around the GRAVE/PENCIL of the president*”). When presented with the biasing discourse context, a larger N400 was evoked in the incoherent than the coherent version. This N400 effect had the same time course and topographic distribution than that of the control condition; this supports the idea that a discourse context can influence lexical integration at the local sentence level in an interactive fashion. The same result was also found for the auditory presentation of the same materials (van Berkum, Zwitterlood, Hagoort, & Brown, 2003). ERP correlates of discourse-level semantic effects have also been found in cartoons (West & Holcomb, 2002) and videos (Sitnikova, Kuperberg & Holcomb, 2003).

1.2.3 Processing of local and global coherence in a discourse context

In order to comprehend a discourse, local sentence information has to be related to the prior context. Discourse scenarios can provide a vehicle to study the interplay between local and global coherence and their timing aspects. A sentence that is locally coherent (e.g. “*He likes them very SPICY*”), can be globally incoherent if the subject of the sentence is introduced as putting maple syrup on pancakes. An alternate sentence (“*He likes them very SWEET*”) is both locally and globally coherent. The time course at which words that are both locally and globally coherent (“*SWEET*” in the example) are integrated into a discourse context can be contrasted to the case when the critical words are locally coherent but globally incoherent (“*SPICY*” in the example), which will help to identify at which point in time the discourse context affects the processing of words in the local sentence context. This can be further contrasted to conditions in which the congruency of the local sentence context is

manipulated in the absence of global context (e.g., *They went to see the famous performer. The gardener has mowed the LAWN/HAIR*).

The bulk of research local vs. global coherence in discourse has been done in text comprehension and focused on reading using both pre-existing literary or technical texts and artificial textoids⁴. According to the minimalist hypothesis by McKoon & Ratcliff (1992), currently processed information is mapped only onto those propositions that are present in short-term memory. This information is then mapped onto information which is no longer in short term memory only in the case of a break in local coherence. In contrast, other models (O'Brien & Myers, 1985; O'Brien & Albrecht, 1992; Albrecht & O'Brien, 1993; Myers, O'Brien, Albrecht & Mason, 1994; Albrecht & O'Brien, 1993) suggest that there is constant mapping of local and global context irrespective of coherence breaks.

Long and Chong (2001) found that proficient readers were disrupted only by global inconsistencies and that poor readers were also disrupted by local inconsistencies. For an overview on discourse processing see Graesser, Millis, & Zwaan (1997). These studies on text comprehension used off-line measures of comprehension such as probe-recognition, recall protocols, and true/false statements. Off-line measures are capable of measuring the results of comprehension, but they do not shed light onto the comprehension process as it unfolds in real-time. No matter under which conditions and at what point in time local context is matched with the global context, the latter has to be retrieved from memory, and one focus of the current studies is how and when both healthy adults and aphasic patients relate local and global context.

1.2.3.1 MODULAR VS. INTERACTIVE MODELS

One controversial aspect of the nature of language processing is in how far bottom-up and top-down processes determine the analysis of the input and thus the construction of a meaning representation. With respect to timing aspects of the processing of sentence vs. discourse contexts, two classes of models make opposing predictions.

⁴ Textoids are passages of text consisting of several sentences created for the experimental purpose at hand.

According to *modular, bottom-up models* (Fodor, 1983), language processing is considered a modularly organized cognitive faculty that itself is composed of a number of sub-modules. They are thought to be organized hierarchically with increasing levels of complexity from bottom to top. According to modular models, information can be processed in a particular module only if it has been processed by the preceding lower-order modules (e.g. Rayner, Carlson & Frazier, 1983; Frazier & Rayner, 1987; Garrod & Terras, 2000). Applied to the processing of discourse relative to sentence contexts, this class of models predict that the local sentence context has to be processed before a higher order representation of a discourse can be constructed, i.e. the integration of a word into a discourse context should be delayed relative to a sentence context. (See also Till et al., 1988; Rayner et al., 1994; Binder & Morris, 1995; Binder, 2003)

In contrary, *interactive, top-down models* (e.g. Marslen-Wilson & Tyler, 1987), Jackendoff, 1999; MacDonald, Pearlmutter, & Seidenberg, 1994; McClelland & Elman, 1986; Tanenhaus & Trueswell, 1995) do not consider separate and serial modules for the processing of different types of linguistic information. Language processing is rather considered as a steady interaction between the bottom-up processing of the sensory input and the top-down influence of context on the construction of meaning representation. They argue for a simultaneous activation of phonological, syntactic, semantic and referential information; in other words, information is integrated *as* it is processed instead of *after* it is processed. According to this class of models, the overall context-information exerts its influence in a top-down manner onto the considerably lower levels of linguistic analysis. According to this view, the top-down influence of the overall context can directly guide lexical processes at the local sentence level and no timing differences should be observed between sentence and discourse processes. (See also Schwanenflugel & White, 1991; Vu et al, 2000; Van Berkum et al., 1999 & 2003)

1.2.4 Discourse in the brain

1.2.4.1 THE ROLE OF THE RIGHT HEMISPHERE

The superiority of frontal and temporo-parietal areas of left hemisphere (LH) for most linguistic tasks is a very well established fact if not *the* example of lateralization of a cognitive faculty. However, when it comes to higher order language functions involved in

comprehending complex natural language – as e.g. when drawing inferences from linguistic input and integration of the overall context – the right hemisphere (RH) also plays an important role; for a recent overview see Jung-Beeman (2005). Qualitatively different sensitivity to semantic relations have been ascribed to the two cerebral hemispheres: while the LH is sensitive to semantically or associatively closely related concepts (e.g. “*arm-leg*”), the right hemisphere seems to be more sensitive to more distantly related word pairs (e.g. “*arm-nose*”). There is evidence both from lesion studies and from fMRI for a RH superiority in comprehending metaphors (e.g. Gagnon, Goulet, Giroux, & Joannette, 2003; Rinaldi, Marangolo, & Baldeassarri, 2004), jokes (Brownell, Michel, & Powelson, & Gardner, 1983; Coulson & Williams, 2005; Coulson & Wu, 2005) or prosody (e.g. Pell, 2006).

There is also manifold evidence for the notion that the right hemisphere might be crucially involved in processing discourse information (e.g. Tompkins, Baumgaertner, Lehman, Fassbinder, 2000; Tompkins, Lehman-Blake, Baumgaertner, & Fassbinder, 2001; Tompkins, Fassbinder, Lehman Blake, Baumgaertner, & Jayaram, 2004). For an overview see Brownell & Martino (1998). More specifically, its role has been proposed as processing those aspects that go beyond the phonological, semantic, and syntactic properties of the linguistic input and so creating coherence. In an fMRI version (St George, Kutas, Martinez & Sereno, 1999) of the ERP study conducted by St George et al. (1994), overall greater RH activation was found for the untitled than the titled paragraphs. The right middle temporal sulcus was more active in the untitled than the titled condition, and the reverse pattern was found for the left temporal sulcus. In another fMRI study, Robertson, Gernsbacher, Guidotti, Robertson, Irwin, Mock & Campana (2000) found greater right than left frontal activation for comprehending coherent discourse than unconnected sentences. Long, Baynes, & Prat (2005) examined the organization of explicit text concepts in the two hemispheres and found that text concepts were represented in both hemispheres, whereas that representation was structured propositionally only the left but not the right hemisphere. They found further that the organization of text concepts in the right hemisphere was not related to semantic priming. Thus, the right hemisphere is sensitive to conceptual aspects of discourse, but not on a semantic level. Grindrod & Baum (2005) showed that patients with RH damage were unable to use a discourse context to disambiguate an ambiguous word as opposed to LH damaged patients who were unable to lexically access and integrate ambiguous words.

1.2.4.2 THE ROLE OF FRONTAL AREAS

Under the notion however, that inference generation and construction of coherence draws on more general executive functions, one might assume that rather a bilaterally distributed frontal executive networks subserve these processes.

For example, McDonald (1993) states that language deficits after RH damage closely resemble those described after prefrontal damage irrespective of the lateralization of the lesion. In a series of studies, Evelyn Ferstl and her colleagues (Ferstl & von Cramon, 2001, 2002, Zysset, Samson, Ferstl, & von Cramon, 2003; see also Channon & Crawford, 2000) have provided evidence from both lesion studies and from fMRI for the involvement of medial frontal networks in establishing coherence and cohesion irrespective of laterality.

In a developmental fMRI study, Dapretto, Lee, & Caplan (2005) found similar cortical networks subserving discourse processing in typically developing children (8 – 11 years) and healthy adults; appraisal of conversation logic was subserved by a left-lateralized cortical network encompassing frontal and temporal areas, and the appraisal of changes in conversation topics engaged bilateral fronto-temporal areas with a RH bias. This shows that the neural architecture for fundamental communicative functions is established already very early during development.

1.3 APHASIA

Aphasia refers to the acquired loss or impairment of language comprehension and/or production abilities. The most common etiology of aphasia are cerebro-vascular accidents (CVAs) in the middle cerebral artery (MCA) which can be of either hemorrhagic or embolic origin. The MCA arises from the internal carotid and is one of the major arteries that supplies blood to the brain; it projects mainly to lateral cerebral cortex, encompassing inferior frontal and anterior temporal lobes, as well as insular cortices, i.e. into those cortical areas crucially involved in language comprehension and production. In patients younger than 40 years of age, cervical artery dissection can be a significant cause of stroke. Internal carotid artery dissections are the most common and can occur both intra- and extracranially with the former being more rare and more severe. The pathophysiology of carotid dissection remains largely unclear; however, they often occur in previously healthy individuals and usually result as a consequence of various degrees of mechanical trauma.

1.3.1 Aphasic syndromes

The study of aphasic syndromes in modern times was initiated by the French neurologist Paul Broca who described a patient who was able to utter only a single syllable (“tan”) after a stroke. From the post-mortem examination of that patient’s brain in 1861 which revealed damage to the opercular and triangular sections of the left inferior frontal gyrus, Broca concluded that this area was crucially involved in speech production (Broca, 1861a, 1861b). Hence, not only was that part of cerebral cortex named “Broca’s area”, but also the concomitant syndrome keeps bearing his name. Almost a century later, CT investigations revealed that the lesion comprises not only lateral prefrontal areas, but that actually it extends much more deeply into subcortical structures (Signoret, Castaigne, Lhermitte, Abelanet, & Lavorel, 1984). Broca’s aphasia is characterized by impairments in speech output such as effortful and telegraphic speech production. The speech of these patients consists mainly of content words and is largely devoid of function words. The speech of these patients is characterized by poor grammar affecting which affects both inflectional morphology and syntactical structure, thus, Broca’s aphasia is also referred to as *agrammatic aphasia* or *agrammatism*. Despite the poor speech production of Broca’s aphasics, their comprehension abilities are less impaired. The nomenclature suggests a strong link between Broca’s area and Broca’s aphasia – such that a lesion in Broca’s area is sufficient to cause Broca’s aphasia and that Broca’s aphasia results necessarily from a lesion in Broca’s area. However, the preponderance of the evidence fails to support that apparent link between the structure, Broca’s area and the syndrome, Broca’s aphasia (e.g. Dronkers, 2000).

Thirteen years later, the German neurologist Carl Wernicke (Wernicke, 1874) stated that damage to the posterior part of the superior temporal gyrus in the vicinity of primary auditory areas results in a qualitatively different pattern of language impairment. Patients suffering from Wernicke’s aphasia show a somewhat complementary pattern of symptoms from those suffering from Broca’s aphasia: the former experience severe comprehension difficulties while their speech output is fluent with preserved articulation and prosody. Patients suffering from Wernicke’s aphasia use a lot of phonematic and/or semantic paraphasias (e.g. “bread” instead of “thread”; “table” instead of “chair”), and neologisms, unprecedented word creations which have no entry in the phonetic or semantic lexicon, thus their speech output appears largely devoid of semantic content.

The two areas are connected via a fiber bundle, the arcuate fasciculus. Disconnection of the arcuate fasciculus results in conduction aphasia which is characterized by preserved comprehension and production abilities and the failure to repeat what has just been heard (e.g. Geschwind, 1965). Recent evidence suggests that the connection is bi-directional instead of unidirectional with inferior prefrontal areas projecting back to superior temporal areas (Matsumoto, Nair, LaPresto, Najm, Bingaman, Shibasaki, & Luders, 2004) and that there are two parallel pathways rather than a single one (Catani, Jones & ffytche, 2005)

Despite the apparent logic of the lesion-symptom mapping approach which proposes links between a lesioned area and an observed symptom, the accumulated evidence implies that the nature of the relationships between brain and behavior is much more complex and less straight forward.

A more recent approach, the voxel-based lesion-symptom mapping (Bates, Wilson, Saygin, Dick, Sereno, Knight & Dronkers, 2003), builds on the logic of functional neuroimaging; correlations are computed for each lesioned voxel and any continuous behavioral measure. This procedure yields very well circumscribed locations for some (e.g. verbal fluency) and less well circumscribed areas for other faculties (e.g. comprehension).

So, rather than classifying the patients who participated in my studies according to clinical syndromes, I decided to classify them according to the severity of their comprehension deficits. In the following section, I am going to review the literature on the nature of aphasic comprehension deficits.

1.3.2 The nature of aphasic comprehension deficits

In line with the framework of the model of normal language comprehension described earlier, on the one hand, aphasic comprehension deficits can be characterized as either a loss of stored linguistic information; this can encompass the loss of either the mental lexicon or the mental grammar. On the other hand, aphasic comprehension deficits can be characterized as a processing deficit; this processing deficit can affect any of the three proposed stages of processing (lexical activation, selection, integration) necessary for successful language comprehension. Evidence has been reported for each of these assumptions, and I am going to summarize the relevant literature in the following section.

1.3.2.1 COMPREHENSION DEFICITS AS LOSS OF STORED INFORMATION

Studies using off-line tasks such as sentence-picture matching (e.g. Berndt & Caramazza, 1980), object naming (e.g. Goodglass & Baker, 1976), semantic categorization (e.g. Grober, Perecman, Keller, & Brown, 1980), semantic judgment (e.g. Caramazza, Berndt, & Brownell, 1982) have provided support for the notion that aphasic comprehension deficits result from a loss or distortion of stored semantic information. Grodzinsky on the other hand (1984, 1986) suggests that aphasic comprehension deficits are due to a loss of syntactic rather than semantic information.

However, Linebarger, Schwartz, & Saffran (1983) have shown that agrammatic aphasics are still able to detect syntactic violations and have concluded that this information can not be completely lost in these patients.

In off-line tasks, subjects are required to execute a task which is dependent on the end-product of the comprehension process. Subjects can give their responses long after the relevant linguistic processes have been completed; furthermore, it can not be excluded that they use strategies unrelated to the linguistic process under investigation in order to execute the response. Thus, from an off-line task it is hard to make definite statements about a possible loss or real-time processing deficits of stored linguistic representations.

1.3.2.2 COMPREHENSION DEFICITS AS REAL-TIME PROCESSING DEFICITS

On-line tasks on the other hand tap into language processing as it unfolds in real-time without making the subject aware of the actual process under investigation. Subjects can be asked to decide whether a sequence of letter or sounds are a word or not (lexical decision task) or simply to name a visually presented word (naming task). Both lexical decision and naming are susceptible to priming, i.e. subjects are faster to pronounce a given letter string or to decide whether it is a word if it is preceded by a semantically or associatively related word (e.g. “*bread* – *BUTTER*”). In order to closely monitor the timing aspects of language processing in real-time, ERPs are superior to any other method; first, they have excellent temporal resolution and provides a continuous rather than one discrete measure; and second, in order to examine language processing, subjects can be merely asked to listen, and therefore freeing both subject and experimenter from the constraints of extraneous task demands.

1.3.2.2.1 ACTIVATION DEFICITS

Activation deficits have been described to comprise both lexical and syntactic information. A number of studies have described aphasic comprehension deficits as deficits in the ability to access necessary information in a timely manner. A number of experiments using lexical decision tasks in priming paradigms have proposed a reduced activation of lexical information as the source for comprehension deficits in both Broca's and Wernicke's aphasics (e.g. Milberg & Blumstein, 1981; Blumstein, Milberg, & Shrier, 1982; Milberg, Blumstein, & Dvoretzky, 1988; Prather, Zurif, Love, & Brownell, 1997; Milberg, Blumstein, Giovanello & Misiurski, 2003; Utman, Blumstein, & Sullivan, 2001; Misiurski, Blumstein, Rissman, & Berman, 2005; Martin, 2005). By and large, these studies focused mainly on phonological aspects of processing and comprised single words in the company of other words.

On the other hand, Friederici & Kilborn (1991) suggest that it is the inability to access syntactic rather than semantic knowledge in a timely manner which causes the comprehension deficits. They show that agrammatic aphasics have not lost their syntactic knowledge, but that they suffer from an inability to access the necessary information in a timely manner. They conclude that language processing breaks down once the activation of necessary information is not performed with the normal temporal pattern. In order to compensate for the deficient processing abilities, aphasic patients have been proposed to resort to heuristic processing strategies by relying more strongly on the semantic content in order to aid processing (e.g. Caramazza & Zurif, 1976; Milberg, Blumstein, Katz, Gershberg, & Brown, 1995; Hagoort, Wassenaar, & Brown, 2003).

1.3.2.2.2 INTEGRATION DEFICITS

An alternative explanation for the nature of the processing deficits of aphasic patients focuses on impairment in the process of lexical integration rather than lexical activation (e.g. Hagoort, 1989; Hagoort, 1997; Hagoort, Brown, & Swaab, 1996; Hagoort, 1997; Swaab et al., 1997, 1998, Kojima & Kaga, 2003). They used ERPs to investigate semantic and associative priming (Hagoort et al., 1996; Hagoort, 1997), spoken sentence comprehension (Swaab et al., 1997) and lexical ambiguity resolution in sentence context (Swaab et al., 1998). In all three studies they found that both the latency and the amplitude of N400 effects varied with the severity of the comprehension deficits of the aphasic patients. Since the N400

is a very likely indicator of semantic integration (e.g. Chwilla, 1996; Chwilla et al., 1995), they inferred that their ERP effects are indicative of an integration rather than an activation deficit in these patients. Szlag, von Steinbüchel & Pöppel (1997) had patients with various brain lesions mentally group sequences of identical acoustic stimuli presented at different frequencies and showed that only patients with Broca's aphasia have lost the ability of automatic temporal integration; thus they provide a more general account of temporal aspects underlying the integration deficit of Broca's aphasics.

Revonsuo & Laine (1996) report a case study in which they used an N400 paradigm in order to investigate the recovery from comprehension deficits in an aphasic patient 2 ½ months and 5 ½ months after his stroke. These authors do not find morphological or latency differences in the N400 effects between the patient and an age- and education matched control group. In the first testing, however, there was a large discrepancy between the ERP effects and explicit judgment of semantic aspects of the material which was absent during the second testing indicating that implicit semantic activation at the conceptual level can take place even in the absence of conscious or explicit comprehension.

1.4 APHASIA AND DISCOURSE

The research on aphasia and discourse has mainly focused on discourse production (e.g. Ulatowska, North, Haynes, 1981; Ulatowska, Doyel, Stern, Haynes, North, 1983; Ulatowska, Freedman, Stern, Doyel, Haynes & North, 1983; Caplan & Evans, 1990; Glosser, & Deser, 1991; Ulatowska & Olness, 2000; Weinrich, McCall, Boser, & Virata, 2002) and comprehension of larger passages such as stories (e.g., Brookshire & Nicholas, 1984; Wegner, Brookshire, & Nicholas, 1984) and other lengthier passages of text. These studies have found largely preserved macrostructures of discourse production in aphasic patients; despite the apparent linguistic deficits of these patients, they appear to maintain able to produce main aspects of the gist of the discourse.

Only one study so far has focused on integration processes in discourse comprehension of aphasic patients (Chapman & Ulatowska, 1989). The authors focused on processing of references and have found that aphasic patients are no longer able to use textual cues to disambiguate pronouns but that they are still able to use extratextual cues to do so. The general conclusion from these studies is an apparent dissociation between lexico-

syntactic impairments and largely preserved management of discourse as a whole, i.e. a dissociation between micro-and macro- levels of discourse processing in aphasic patients.

So far, the integration of single words into discourse contexts in aphasic patients has not been examined. Also, no ERP studies aimed at examining discourse comprehension in aphasic patients have been conducted.

1.5 THE PRESENT THESIS

Three ERP experiments were conducted. In two experiments, the N400 component was used to examine timing aspects of lexical integration in sentence and discourse contexts in aphasic patients and neurologically unimpaired age-matched control subjects. In a control experiment, a three stimulus oddball paradigm was used to elicit the two subcomponents of the P300 – the P3a and the P3b. This was done in order to provide an internal control for the potentially abnormal N400 ERP effects.

The critical words (CWs) to which the ERPs were obtained were the final words in auditorily presented sentence and discourse contexts. The most minimally possible form of discourse, a two-sentence-scenario, was chosen. In both experiments, the factors Context (Sentence, Discourse) and Coherence (Coherent, Incoherent) were crossed. In Experiment 1, lexical relationships between the CWs and content words in the respective preceding context determined their coherence. This was chosen in order to determine whether aphasic patients would rely more heavily on the semantic content and the relationships between single words to help comprehension. This manipulation produced a semantic violation in both contexts, which is the strongest condition to elicit an N400 effect. In Experiment 2, no such lexical relations between single words were used to determine the coherence of the respective contexts. It served as a control to determine whether patients relied more heavily on the lexical content of single words in the first experiment or whether they are able to process sentence and discourse contexts as a whole.

2 EXPERIMENT 1:

SEMANTIC VIOLATIONS IN SENTENCE AND DISCOURSE CONTEXTS

The goal of the present experiment was to further determine whether the underlying nature of aphasic processing deficits. The hypothesis of an activation vs. an integration deficit was to be extended to discourse contexts by contrasting lexical integration in sentence and discourse contexts in aphasic patients and two control groups. Furthermore, the role of lexical processing in either context condition was examined.

On more general grounds, it should be further investigated whether discourse is processed in a modular or an interactive fashion and to which degree semantic violations are processed in both contexts. For the patient groups, this provides the possibility to test the hypothesis of heuristic use of semantic information.

The goal of this experiment was to determine whether aphasic patients rely more strongly on lexical information to aid comprehension in sentence and discourse contexts; the factors Context (Sentence, Discourse) and Coherence (Coherent, Incoherent) were crossed.

Aphasic comprehension deficits have been described as resulting from activation (Milberg & Blumstein, 1981; Blumstein, et al., 1982; Friederici & Kilborn, 1989; Milberg et al., 2003; Prather et al., 1997; Misiurski et al., 2005; Utman et al., 2001) and integration (Hagoort, 1989; Hagoort, 1997; Hagoort et al., 1996; Hagoort, 1997; Swaab et al., 1997, 1998; Szelag et al., 1997) deficits. Furthermore, it has been proposed that aphasic patients rely heuristically on semantic content in order to achieve comprehension (e.g. Caramazza & Zurif, 1976; Milberg et al., 1995; Hagoort et al., 2003). Two groups of aphasic patients and two control groups listened to sentence pairs in two conditions: in the Sentence condition, the two sentences were unrelated, and in the Discourse condition, they made a short story. The CWs to which the ERPs were obtained were the final words of the second sentences of the pairs. The overall fit of the CWs was determined by lexical-semantic relationships between the CWs and content words in the respective preceding contexts determined; this yielded a semantic fit in the Coherent conditions and a semantic violation in the Incoherent conditions.

2.1 HYPOTHESES

Hypothesis 1: Modular processing of discourse

For the hypothesis of modular processing of discourse information, ERP effects should be delayed in the Discourse relative to the Sentence condition.

Hypothesis 2: Interactive processing of discourse

For the hypothesis of interactive processing of discourse information, no onset differences of the N400 effects in the two context conditions should be obtained.

Hypothesis 3: Activation deficit in aphasia

Under the assumption of aphasia as an activation deficit, lexical-semantic relationships between the CWs and preceding content words should help patients in comprehension of the CWs. Because the effects of lexical association are relatively short-lived, this effect should be stronger in the sentence than the discourse condition: the N400 effects should be bigger in the Sentence than the Discourse condition.

Hypothesis 4: Integration deficit in aphasia

If comprehension deficits of aphasic patients are due to an integration deficit, the amount of context to be integrated should critically affect processing: thus, N400 effects should be delayed in the Discourse relative to the Sentence condition.

Hypothesis 5: Right hemisphere contribution to discourse processing

Under the hypothesis that the right hemisphere is mainly recruited for discourse processing, the discourse abilities should be largely preserved in the LH patients; it should not be more strongly affected than sentence processing.

Hypothesis 6: Medial prefrontal contribution to discourse processing

However, if medial prefrontal areas are recruited in establishing coherence, a dissociation between patients with lateral and medial prefrontal damage should be observed: patients with lateral prefrontal damage should be impaired in sentence processing, and patients with medial prefrontal damage should be impaired in discourse processing; patients with both lateral and medial prefrontal damage should be impaired in both contexts.

2.2 METHODS

2.2.1 Subjects

Four groups of subjects participated in the Experiment: two control groups and two groups of aphasic patients.

2.2.1.1 CONTROL GROUPS

2.2.1.1.1 YOUNG CONTROLS

Subjects in the group of young controls were 25 (15 female) students and employees of Duke University and native speakers of American English. Their mean age was 23.3 years (range 19-35 years) and on average, they had 16.5 years of education (range 13 – 27 years). All were right handed according to the Edinburgh handedness inventory (Oldfield, 1971) and none had any current or prior neurological or psychiatric disorders or any hearing problems. Subjects were paid \$10/hour for participation. Five subjects were excluded from the analyses because their data were contaminated by a substantial number of artifacts, with the data of 11 of the female and 9 of the male participants being submitted to further data analyses.

2.2.1.1.2 ELDERLY CONTROLS

Subjects were 12 elderly subjects (6 female) from the Davis, CA community recruited through a newspaper ad. Mean age of participants was 61.6 years (range 52 – 82 years); mean years of education was 16.8 years (range 13 – 20 years). All were right handed and none had any current or prior neurological or psychiatric disorders or was taking any psychotropic medication. They were paid \$10/hour for participation. Initially, 20 subjects (six from the Durham, NC area) were tested and only those were selected who were matched with respect to both age, gender and education to the patients described below.

2.2.1.2 APHASIC PATIENTS

Twelve brain damaged (4 female) patients were recruited through the Department of Speech Pathology at the University of California at Davis Medical Center in Sacramento, CA and through the Northern California Veterans Administration hospital in Martinez, CA. All aphasic patients were tested with the Boston Diagnostic Aphasia Examination (BDAE) Short Form (Goodglass & Kaplan, Barresi, 2001) which was administered by a native speaker of American English. Since stimuli were administered in the auditory modality, classification into High and Low Comprehenders was based on the three auditory comprehension subtests

(basic word discrimination, commands, complex ideational materials). Table 1 summarizes the relevant aspects of the individual patient history and BDAE comprehension scores. Severity rating was based on the average percentile of the auditory comprehension score and classification into High and Low Comprehenders was done based on the overall severity rating (0, 1, 2: Low Comprehenders; 3, 4, 5 High Comprehenders). All but two patients (one ambidextrous one left-handed individual) were right handed. Subjects were paid \$15/hour for participation.

2.2.1.2.1 HIGH COMPREHENDERS

Based on the three BDAE Auditory Comprehension subtests, seven patients were classified as High Comprehenders (3 female); the mean age of the patients was 56 years (range 34 – 68 years) and mean years of education was 16 years (range 12 – 20 years). All but one of the High Comprehenders were right handed; one individual was left handed. Two of the patients were on anticonvulsant medication (Dilatin®, Phenobarbitol). MRI and CT information was available for six of the seven High Comprehenders. In one case, CT information was not available in digital format. Lesions were reconstructed with MRICro® software, and the reconstructions for five of the seven High Comprehenders are displayed in Figure 1.

2.2.1.2.2 LOW COMPREHENDERS

Based on the three BDAE Auditory Comprehension subtests, five patients were classified as Low Comprehenders (one female); the mean age of these patients was 60.6 years (range 49 – 77 years) and mean years of education was 13 years (range 9 – 14 years). All but one patient were right handed; one individual was ambidextrous. Four of the patients were taking anticonvulsant medication (Tegretol®, Lamictal®, Neurontin, Gabapentin®, Keppra®) and two were taking antidepressants (Nortriptyline, Prozac®). MRI and CT information was available for two of the five Low Comprehenders. In one case, only a transcript of a CT scan was available. Lesions were reconstructed with MRICro® software, and the reconstructions for two of the five Low Comprehenders are displayed in Figure 2.

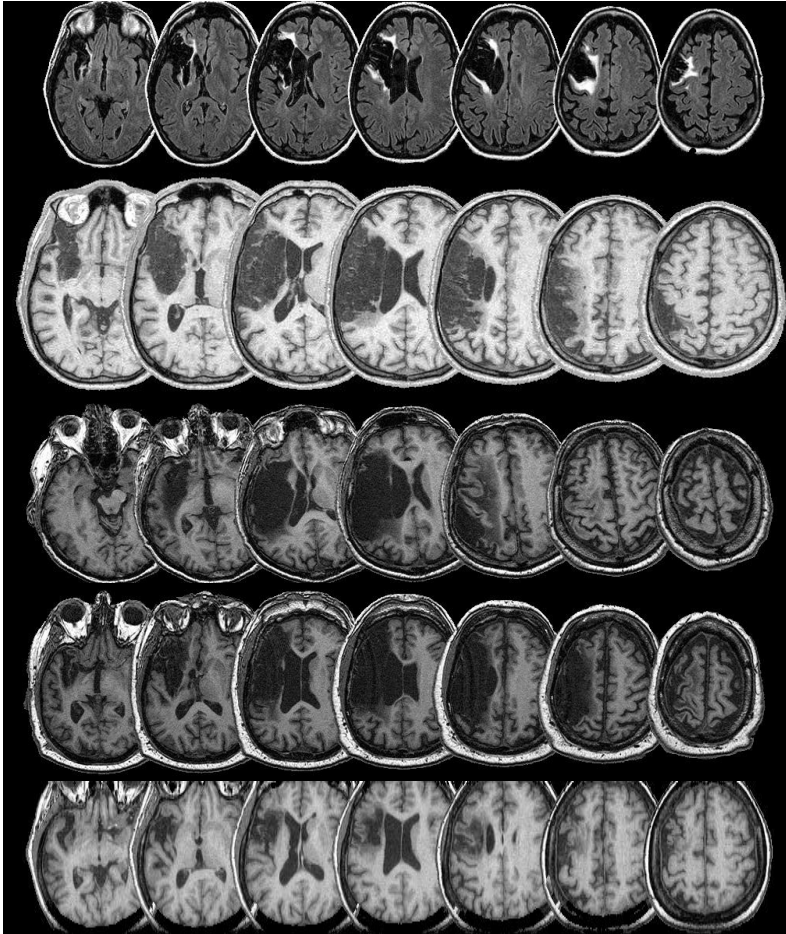


Figure 1 MRI Lesion information for five of the seven High Comprehenders (patients BS, EB, EP, JS, NJ)

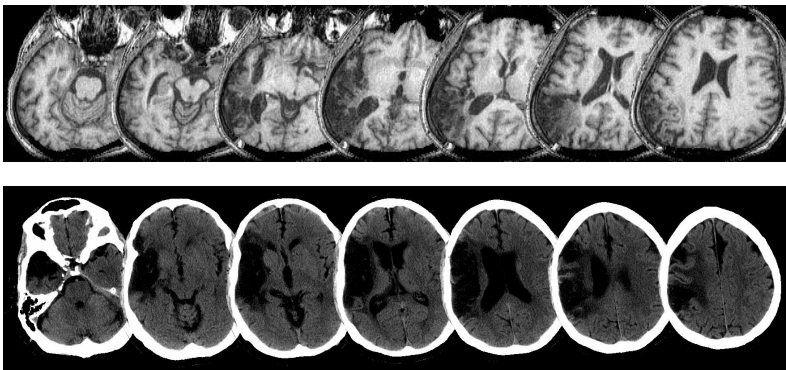


Figure 2 MRI and CT Lesion information for two of the five Low Comprehenders (patients AT and BW)

Table 1

Individual patient information for patients who participated in Experiment 1. Patients were classified as High and Low Comprehenders based on their auditory comprehension scores (basic word discrimination, commands, complex ideation) in the BDAE

| PAT | group | sex | age | handed | edu | etiology | lesion location | auditory comprehension avg %ile severity | | | | |
|-----|-------|-----|-----|--------|-----|----------------------|--|--|-------|--------|------|---|
| | | | | | | | | BWD* | C** | CIM*** | | |
| NJ | HI | F | 65 | R | 14 | MCA CVA ⁺ | inf. frontal, insula | 16/16 | 9/10 | 6/6 | 90.0 | 4 |
| EP | HI | M | 61 | R | 16 | MCA CVA ⁺ | inf., mid. & medial frontal, parietal, sup. temporal, insula | 15.5/16 | 10/10 | 5/6 | 78.3 | 3 |
| BS | HI | F | 45 | R | 20+ | CAD ⁺⁺ | inf. & mid. frontal, insula | 14.5/16 | 10/10 | 6/6 | 81.7 | 3 |
| JS | HI | M | 61 | R | 12 | MCA CVA ⁺ | inf., mid. & medial, parietal, insula, subcortical | 14/16 | 9/10 | 5/6 | 60.0 | 3 |
| EB | HI | M | 35 | R | 14 | CAD ⁺⁺ | inf. & mid. frontal, parietal, insula, subcortical | 15/16 | 10/10 | 5/6 | 76.7 | 3 |
| CM | HI | F | 53 | L | 14 | MCA CVA ⁺ | inf. & mid. frontal ⁵ | 15/16 | 9/10 | 5/6 | 66.7 | 3 |
| GF | HI | M | 69 | R | 18 | heart attack | n.a. | 16/16 | 9/10 | 6/6 | 90.0 | 4 |
| MB | LO | F | 77 | R | 12 | MCA CVA ⁺ | superior temporal, temporo-parietal ⁶ | 14.5/16 | 4/10 | 1/6 | 23.3 | 1 |
| BW | LO | M | 67 | amb | 12 | MCA CVA ⁺ | inferior & middle frontal, parietal, insula | 13.5/16 | 6/10 | 2/6 | 26.7 | 1 |
| DS | LO | M | 50 | R | 16 | MCA CVA ⁺ | n.a. | 14.5/16 | 6/10 | 6/6 | 56.7 | 2 |
| AT | LO | M | 57 | R | 14 | MCA CVA ⁺ | superior temporal, parietal | 13.5/16 | 5/10 | 3/6 | 28.3 | 1 |
| PP | LO | M | 51 | R | 13 | MCA CVA ⁺ | n.a. | 11/16 | 6/10 | 5/6 | 16.7 | 0 |

⁺ left Middle Cerebral Artery Cerebro-Vascular Accident

⁺⁺ left Carotid Artery Dissection

* Basic Word Discrimination

** Commands

*** Complex Ideational Materials

severity rating: 0 = extreme; 1 = severe; 2 = moderate; 3 = mild-moderate; 4 = mild; 5 = none

⁵ no digitized version of the CT was available

⁶ transcript of medical record available

2.2.2 Materials

The CWs, to which ERPs were obtained were the final words of auditorily presented sentence pairs. The factors Context (Discourse vs. Sentence, i.e. global vs. local) and Coherence (coherent vs. incoherent) were crossed. In the Discourse condition, the CW was always locally coherent and it was rendered globally coherent or incoherent by the preceding sentence. In the Sentence condition, the content of the second sentence alone determined the local coherence of the CW in the absence of any global context. The CW was rendered coherent or incoherent by the content words in the respective preceding context. In the Discourse condition, the semantic mismatch was between the CW and the final word of the first sentence, and in the Sentence condition, the semantic mismatch was between the CW and the preceding content words in that sentence. In order to objectively quantify the degree of semantic relatedness between the critical words, the method of Latent Semantic Analysis (LSA) (Foltz, Kintsch, & Landauer, 1998) was used⁷. LSA is a technique to measure coherence of texts: two vectors for two adjoining segments of text are compared in a high-dimensional semantic space and provides a measure of the degree of semantic relatedness between the segments which is expressed in a cos value. This technique provides accurate and objective measures of coherence. The near neighbors procedure revealed a high degree of semantic overlap between the critical words and their respective counterparts in both contexts (cos values: coherent: 0.341; incoherent: 0.004; $t=80.32$; $p<0.0001$). Moreover, the Sentence Comparison Procedure was used to quantify the degree of coherence between the two sentences; it revealed high values of coherence for the Discourse condition and low

Coherence was implemented by means of a semantic match in the respective conditions. For the sentence Condition, this induced a semantic violation and thus differences in plausibility between the two context conditions.

⁷ The online version of the LSA was used (<http://lsa.colorado.edu>)

Table 2

Examples of stimulus pairs for the discourse and sentence conditions used in Experiment 1. Critical words (CWs) to which ERPs were obtained are printed in CAPITALS. Semantically matching words are underlined

| SENTENCE | | |
|-----------|--|--|
| noun | | |
| coh | They went to see the famous performer. | The gardener has <u>mowed</u> the LAWN. |
| inc | They went to see the famous performer. | The gardener has mowed the HAIR. |
| verb | | |
| coh | The Indian carried an arrow and a bow. | The baker has another <u>cake</u> to <u>BAKE</u> . |
| inc | The Indian carried an arrow and a bow. | The baker has another cake to SPILL. |
| adjective | | |
| coh | Let me take your hat and coat. | The weightlifter is very STRONG. |
| inc | Let me take your hat and coat. | The weightlifter is very TASTY. |
| DISCOURSE | | |
| noun | | |
| coh | Uncle Ron from Wisconsin is a <u>farmer</u> | He likes to work in his <u>FIELDS</u> . |
| inc | Uncle Ron from Wisconsin is a farmer | He likes to work in his BAR. |
| verb | | |
| coh | Karen bought a reliable <u>car</u> | Now, she enjoys <u>DRIVING</u> |
| inc | Karen bought a reliable car | Now, she enjoys CHATTING. |
| adjective | | |
| coh | Bob covered his pancakes with <u>maple syrup</u> . | He likes them very <u>SWEET</u> . |
| inc | Bob covered his pancakes with maple syrup. | He likes them very SPICY. |

2.2.2.1 PRETESTS

Initially, a total of 75 scenarios per condition were created. In order to establish that the created materials complied with the desired criteria and to exclude alternative explanations for the ERP results, they were submitted to a series of four pretests with a total of 110 subjects.

2.2.2.1.1 CLOZE PROBABILITY TEST

The sentence material was first submitted to a cloze probability test. For the Discourse condition, it should be confirmed that both the coherent and incoherent versions of the second

sentences were equally likely without the preceding sentence. Moreover, it should be excluded that the coherent final word could be selected based upon the contents of the second sentence only. For the sentence condition, it should be established that the coherent ending was indeed the one with the highest cloze probability and that the incoherent ending should never be given as a response.

Sentences were presented in written form and random order with the final word omitted. Subjects were instructed to complete the sentence in a meaningful way with first word that came to their mind. The entire set of the 150 sentences was presented to 20 subjects who were all native speakers of English and either students or employees of Duke University. They were given course credit for their participation or participated deliberately.

Rejection criterion for the discourse scenarios was a value for cloze probability of higher than 30% and for the sentence scenarios it was a value lower than 50%.

The results of the cloze probability test are given in Table 3. Statistical analyses confirmed overall low cloze probability with no differences for the coherent and incoherent endings in the Discourse condition ($t < 1$) and a significant difference for the Sentence condition ($t = 34.55$; $p < 0.000$) with high cloze probability in the coherent and low cloze probability in the incoherent condition.

For the discourse scenarios, the results of the cloze probability test confirm that the final word of the second sentence can not be derived based upon the contents of that sentence alone. For the sentence scenarios, it reveals a high cloze probability for the coherent and a zero cloze probability for the incoherent endings indicating that the coherent ending is immediately retrieved when the sentence is presented in isolation and that the incoherent ending has never been given as a response. The cloze probability test lead to the rejection of nine items altogether, of which five were discourse scenarios and four were sentence scenarios.

Table 3
Mean cloze probability in percent. Values in brackets refer to standard deviations

| | DISCOURSE | SENTENCE |
|-----------------|-------------|---------------|
| noun | | |
| coherent (SD) | 2.25 (5.95) | 84.21 (16.43) |
| range | 0 – 10 | 65 – 100 |
| incoherent (SD) | 1.75 (3.72) | 0 (0) |
| range | 0 – 10 | 0 |
| verb | | |
| coherent (SD) | 3.5 (6.3) | 75.75 (21.96) |
| range | 0 – 20 | 50 – 95 |
| incoherent (SD) | 2.25 (6.97) | 0 (0) |
| range | 0 – 10 | 0 |
| adjective | | |
| coherent (SD) | 2.25 (5.72) | 60.75 (22.72) |
| range | 0 – 25 | 50 – 95 |
| incoherent (SD) | 1 (2.61) | 0 (0) |
| range | 0 – 10 | 0 |

2.2.2.1.2 PLAUSIBILITY TEST

After the cloze procedure, the remaining 141 items were submitted to a plausibility test. This was done in order to establish that there were no differences in plausibility for the coherent and incoherent endings of the discourse scenarios so that differences in the ERPs to the coherent and incoherent endings could not be attributed to differences in plausibility. Although the incoherent ending of the sentence scenarios was never given as a response, it should be established that the manipulated semantic violation was indeed anomalous. The two versions of the plausibility test were constructed. The coherent and incoherent versions of the second sentences of both the discourse- and sentence scenarios were assigned to either version of the plausibility test. Sentences were presented in written form in random order, and subjects were asked to rate their plausibility on a scale from 1 to 5 with 1 being not plausible at all and 5 being very plausible. Subjects were 40 students and employees of Duke University. They were given course credit for their participation or participated deliberately. The rejection criteria were the following: for the discourse it was an average plausibility of less than 3.5 for both endings and a difference between coherent and incoherent endings of more than 2. For the sentence scenarios, the rejection criterion for the coherent versions was

also an average value of less than 3.5, and for the incoherent version, it was an average value of more than 2.5 or a difference of less than 2. Results are displayed in Table 4.

Table 4
Mean rating of plausibility on a scale from 1 - 5. Values in brackets refer to standard deviations

| | DISCOURSE | SENTENCE |
|-----------------|-------------|-------------|
| noun | | |
| coherent (SD) | 4.43 (0.28) | 4.59 (0.22) |
| range | 3.75 – 4.85 | 4 – 4.95 |
| incoherent (SD) | 4.38 (0.39) | 1.28 (0.32) |
| range | 3.5 – 4.9 | 1 – 2.45 |
| verb | | |
| coherent (SD) | 4.45 (0.31) | 4.61 (0.29) |
| range | 3.65 – 4.95 | 4.1 – 5 |
| incoherent (SD) | 4.24 (0.42) | 1.44 (0.34) |
| range | 3.5 – 4.95 | 1 – 2.25 |
| adjective | | |
| coherent (SD) | 4.42 (0.33) | 4.64 (0.18) |
| range | 3.65 – 4.8 | 4.25 – 4.95 |
| incoherent (SD) | 4.35 (0.30) | 1.49 (0.36) |
| range | 3.7 – 4.85 | 1.05 – 2.3 |

For the discourse-scenarios, the plausibility test revealed no differences in plausibility for the coherent and incoherent endings ($t=1.93$, $p>0.5$). For the sentence-scenarios, it revealed a high plausibility for the coherent and a low plausibility for the incoherent (i.e. the anomalous) endings ($t=54.505$, $p=0$). The plausibility test lead to the rejection of four of the sentence scenarios.

2.2.2.1.3 COHERENCE TESTS

Following the plausibility procedure, the remaining 137 items were submitted to a final set of pretests in order to test the coherence of the sentence pairs. This was done in order to assess the relationship between the two sentences of a pair. In other words, it should be established that the discourse scenarios were indeed coherent in the sense that the second sentence formed a continuation of the context given by the first sentence and that there was no such relationship between the sentences of the sentence scenarios.

2.2.2.1.3.1 *Coherence Test 1*

In the first coherence test, a qualitative measure was obtained. Both versions of the sentence pairs were presented in written form in two opposing columns and subjects were asked to rate whether the sentence pairs were coherent or not in the sense that the second sentence provided a continuation of the context introduced by the first one. In case they thought they were coherent, subjects were asked to indicate which one of the sentence pairs they thought was the more coherent one. Subjects were 20 students from Duke University receiving course credit. The coherence test did not lead to the rejection of any of the items tested.

2.2.2.1.3.2 *Coherence Test 2*

In the second coherence test, the two versions of a pair were distributed over two lists and subjects were asked to rate the coherence of a given sentence pair on a scale from 1 to 5 with 1 meaning “not coherent at all” and 5 meaning “very coherent”. A total of 30 subjects participated, and the results further corroborated those of the first coherence test. Results are summarized in Table 5. Significant effects were obtained for both context ($F(1,1)=408.94$; $p<0.000$), condition ($F(1,1)=98.54$; $p<0.000$), and for the interaction between the two ($F(1,2)=74.49$; $p<0.000$). This further quantifies the notion that the discourse scenarios were indeed rated overall as more coherent than the sentence scenarios and that the coherent discourse scenarios were more coherent than the incoherent ones as revealed by the highly significant post-hoc test ($t=34.53$; $p<0.000$). The results of the two coherence tests confirm that the discourse scenarios were rated as being overall coherent in the sense that the second sentence continued the context laid out by the first in a meaningful way and that that was much more so for the coherent than the incoherent versions. They also confirmed that the sentence scenarios were not considered coherent in the sense the discourse scenarios were.

Table 5

Mean ratings of the coherence of the sentence pairs on a scale 1 – 5. Values in brackets refer to standard deviations

| | | DISCOURSE | SENTENCE |
|-----------|-----------------|-------------|-------------|
| noun | | | |
| | coherent (SD) | 4.86 (0.31) | 1.20 (0.19) |
| | range | 4 – 5 | 1 – 2 |
| | incoherent (SD) | 2.5 (0.58) | 1.15 (0.15) |
| | range | 2 – 4 | 1 – 2 |
| verb | | | |
| | coherent (SD) | 4.39 (0.29) | 1.31 (0.23) |
| | range | 3 – 5 | 1 – 2 |
| | incoherent (SD) | 2.41 (0.65) | 1.00 (0.18) |
| | range | 2 – 5 | 1 – 2 |
| adjective | | | |
| | coherent (SD) | 4.52 (0.34) | 1.21 (0.15) |
| | range | 3 – 5 | 1 – 2 |
| | incoherent (SD) | 2.31 (0.64) | 1.12 (0.18) |
| | range | 2 – 4 | 1 – 2 |

2.2.2.1.4 SUMMARY OF RESULTS

A total of 110 subjects participated in the four pretests. The results confirm that the materials indeed matched the desired criteria:

The cloze procedure revealed that the coherent and incoherent endings of the discourse scenarios were equally likely when presented in isolation. This rules out that differences in the ERP to the final words of the discourse scenarios could be attributed to differences in cloze probability for the respective endings. For the sentence scenarios, it was confirmed that the coherent ending was the best completion of that sentence and that the anomalous incoherent ending one never came up. The plausibility test revealed no differences in plausibility for the coherent and incoherent endings of the Discourse condition, ruling out that this could account for possible differences in the ERPs. For the sentence scenarios, it was confirmed that the anomalous ending did not make any sense.

Finally, the coherence test revealed that the discourse scenarios were indeed coherent, in the sense that the second sentence provided a meaningful continuation of the context introduced by the first sentence and that the coherent ending was considered indeed more

coherent than the incoherent one. For the sentence scenarios, it was confirmed that there was no such relationship between the two sentences.

2.2.2.2 SELECTED MATERIALS

Of the initial 150 scenarios, 137 survived the series of pretests. Prior to conducting the pretests, it was aimed to have 20 scenarios ending in a noun, a verb, and an adjective for both the discourse and the sentence conditions, yielding a total of 120 scenarios. Of the remaining scenarios, 17 were randomly discarded to yield equally many scenarios in all conditions. These items were used as items for the practice session and for start up items for each trial. The final words were matched with respect to written lexical frequency, number of phonemes, letters, syllables, and duration. Stimulus characteristics are summarized in Table 6.

2.2.2.2.1 SENTENCE CONDITION

There were neither differences with respect to written lexical frequency (Francis & Kučera, 1982) nor duration. The mean log lexical frequency for the coherent and incoherent final words were 3.79 and 3.01 (range 0 – 6.67 and 0 – 6.38), respectively, and the mean duration of the coherent and incoherent final words were 515.66 and 507.78 ms (range 285 – 826 and 310 – 783, respectively), neither of these differences were significant with $F(1,227)=2.37$, $p=0.095$ and $F<1$, respectively. The mean number of letters for the coherent and incoherent final words in the sentence scenarios was 5.03 and 4.9 (range 3 – 11 and 3 – 9, respectively), the mean number of phonemes was 4.02 and 3.81 (range 2 – 9 and 2 – 6, respectively), the mean number of syllables was 1.45 and 1.28 (range 1 – 3 and 1 – 2, respectively), none of these differences were significant, all $F_s<1$. The mean number of words in the first sentence of the sentence scenarios was 7.08 (range 4 – 10), and their mean duration was 2437 ms (range 1331 – 4848). The mean number of words in the second sentences was 8.08 (range 5 – 11), and the mean duration was 2233 ms (range 1436 – 3348) for the coherent and 2324 ms (range 1385 – 3467) for the incoherent versions, respectively.

2.2.2.2.2 DISCOURSE CONDITION

The mean number of letters for the coherent and incoherent final words in the discourse scenarios was 5.3 and 5.31 (range 3 – 11 and 3 – 10, respectively), the mean number of phonemes was 4.33 and 4.4 (range 2 – 10 and 2 – 8, respectively), the mean

number of syllables was 1.5 and 1.55 (range 1 – 4 and 1 – 3, respectively), none of these differences were significant, all $F_s < 1$. There were neither differences with respect to written lexical frequency (Francis & Kučera, 1982) nor duration. The mean log lexical frequency for the coherent and incoherent final words were 3.25 and 3.01 (range 0.69 – 5.14 and 0 – 5.35, respectively), and the mean duration of the coherent and incoherent final words were 550.25 and 562.76 ms (range 330 – 835 and 298 – 879, respectively), neither of these differences were significant with $F(1,227)=2.29$, $p=0.1310$ and $F < 1$, respectively. The mean number of words in the first sentence of the discourse scenarios was 8.25 (range 4 – 14), and their mean duration was 2649 ms (range 1560 – 4511). The mean number of words in the second sentences of the discourse scenarios was 7.36 (range 4 – 13), and the mean duration was 2358 ms (range 1408 – 3604) for the coherent and 2403 ms (range 1373 – 3816) for the incoherent version, respectively.

The scenarios were evenly distributed over 4 blocks with coherent and incoherent versions of the same scenarios always separated by one intervening block. Each block contained an equal number of sentence and discourse scenarios and equal numbers of sentences ending in a noun, a verb and an adjective, respectively. Each block started with two start-up items which were items that either did not pass any of the pretests or that were randomly discarded from the original list after the pretests.

In addition to the four experimental blocks, a practice session was created in order to make subjects familiar with the recording procedure and blinking.

Table 6
Summary of Stimulus characteristics

| | cloze probability (in %) | plausibility (1 – 5) | lexical frequency (log) | duration (in ms) |
|------------|-----------------------------|-------------------------|----------------------------|---------------------|
| Discourse | | | | |
| Coherent | 1.91 | 4.43 | 3.25 | 516 |
| Incoherent | 1.16 | 4.32 | 3.01 | 507 |
| Sentence | | | | |
| Coherent | 73.99 | 4.62 | 3.79 | 547 |
| Incoherent | 0 | 1 | 3.01 | 574 |

2.2.2.2.3 *RECORDING OF THE MATERIALS*

The materials were spoken by an experienced female speaker who had undergone intensive voice and speech training at the Duke University Department of Drama. The sentences were spoken in a sound attenuated booth and were recorded in one session. Materials were recorded onto a DAT tape and sampled onto the hard disk using an external digital sound card (Creative Sound Blaster Extigy). The sampling was done on a Mono Channel at a sampling rate of 44100 Hz and a resolution of 16 bit using Cool Edit Pro; this software was also used to edit the sound files and mark the onset of the final words.

2.2.3 **EEG Experiment**

2.2.3.1 PROCEDURE

Prior to participation, written consent was obtained by a form approved by the Duke University Medical Center Institutional Review Board. Furthermore, subjects had to give a short medical history report in order to exclude any history of psychiatric or neurological disorders, complete the Edinburgh Handedness Questionnaire (Oldfield, 1971) and report which languages they spoke.

The Young Controls were tested individually in a dimly lit sound attenuated booth sitting in a comfortable recliner. All other groups were tested in an electromagnetically shielded and sound proofed booth sitting in a comfortable chair. They listened to the sentence scenarios via Sennheiser HD circumaural headphones while their EEG was recorded. The only task was to listen attentively to the sentences; subjects were told that the experimenter would interrupt the presentation in random intervals in order to ask them to repeat the previously heard stimuli. This was performed four times per block and done in order to make sure subjects were indeed listening attentively. Each block was about 11 min long, with a total duration of stimulation of about 45 min. In order to minimize the contamination of the EEG by oculomotor artifacts, subjects were asked to keep their eyes fixated to a white cross which was displayed on a computer screen as long as the sentences were being played and which remained on the screen for another 2500 ms after the offset of the final word. It was then replaced by a green cross for 3000 ms, and subjects were told that this was the time when they could blink. The cross turned white again 1000 ms before the next sentence was played.

2.2.3.2 EEG RECORDING

The EEG was recorded from 32 tin electrodes mounted in an Electrocap with 19 electrode placements according to the 10-20 system (Jasper, 1958) at FP1, FP2, F3, F4, F7, F8, C3, C4, T3, T4, P3, P4, T5, T6, O1, O2, FZ, CZ, and PZ. Three symmetric lateral pairs were added at interspersed locations at FC1, FC2, FC5, FC6, CP1, CP2, CP5, CP6, and two additional midline sites were included as well at AFZ and POZ. Vertical and horizontal eye movements were monitored via a left sub-orbital electrode referred to FP1 and a bilateral external canthus montage, respectively. The right mastoid was used as the recording reference, and the left mastoid was also recorded for later off-line algebraic re-referencing. Impedances were kept below 5 k Ω . The EOG and EEG recordings (band pass 0.01 – 30 Hz) were amplified with Neuroscan® SynAmps amplifiers and continuously digitized at 250 Hz. Data were stored on a hard disk along with stimulus codes for off-line averaging and data analysis.

2.2.3.3 SOUND DELIVERY

The young control group was tested at Duke University, where a Creative® Sound Blaster Audio PCI 64 V sound card was used for stimulus delivery. For the presentation of stimulus materials, the software package "Presentation" was used. All other subject groups were tested at the University of California at Davis. There, stimuli were delivered at 65dB above hearing threshold; the digital output of a Creative® Sound Blaster Audigy II card was converted back to analog in order to assure better sound quality by feeding into a Benchmark® DAC 1 Digital to Analog Converter. The output of the DAC 1 was then fed into an UltraCurve Pro® DSP8024 which allowed volume adjustment in 0.5 dB steps separately for each ear. The final delivery of the sound was controlled by a Mackie® 1604 VLZ PRO 16 Chan Mixer. This setup allowed the experimenter to monitor the sound delivered to the subject's headset as well as talk to the subject both via the headset and via speakers in the subject room.

2.2.3.4 HEARING ASSESSMENT

In order to compensate for potential hearing loss, prior to participation, the hearing of the Elderly Controls and the aphasic patients was examined with a clinical Audiometer (GSI 61 2 channel Clinical Audiometer, VIASYS Healthcare, Inc.). The volume of the stimuli was

differentially adjusted by means of an UltraCurve Pro® DSP8024 to be 65dB above threshold for each ear. The entire sound system was calibrated by means of the Brüel & Kjaer 2238 Mediator sound level meter and the Brüel & Kjaer Artificial Ear 4153.

2.2.3.5 OCULAR ARTEFACT REDUCTION FOR PATIENT GROUPS

Trying to keep aphasic patients from withholding eye blinks for a defined period of time and executing them in another would have invoked a go-nogo task comprising the control of executing and withholding eye blinks at predefined periods. Thus, it was refrained from instructing patients to blink only during the presentation of the green cross. Oculomotor artifacts were reduced using the “Ocular Artefact Reduction” routine implemented in Scan4.3 from Neuroscan®. The algorithm implemented in this routine works by calculating an average artifact waveform in the eye channel, and also the averaged phase-locked artifact transmission in each EEG channel. A covariance value is then calculated in each EEG channel, and this COV value is used in a regression equation where:

$$\text{corrected chan} = (\text{original chan}) - (\text{eye chan} * \text{original chan's COV value with eye chan}).$$

2.2.3.6 DATA ANALYSIS AND DATA REDUCTION

Prior to off-line averaging, all single trial waveforms were screened for amplifier blocking, DC drift, muscle and oculomotor artifacts. This was done over an epoch of 1400ms, starting 200 ms before the onset of the final word. Trials contaminated by artifacts were rejected. For each subject, average waveforms were computed across the remaining trials for each condition after normalizing to a 100 ms pre-stimulus baseline.

2.3 RESULTS

Repeated measures of variance ANOVAs were performed on the mean amplitude of the ERPs to the CWs in five epochs: 0 – 100, 100 – 300, 300 – 500, 500 – 700, 700 – 1000 ms, all relative to a 100 ms pre-stimulus baseline. An initial 2 x 2 x 29 ANOVA was performed with the following within-subject factors: Context (Discourse, Sentence), Coherence (Coherent, Incoherent), and Electrode Site (29 sites). All analyses were done over artifact free or artifact corrected trials and included Subjects as a random factor. In the case of a significant interaction of the experimental factors with Electrode Site, further analyses were performed containing the additional factor Location (Anterior: FP1, FP2, F3, F4, F7, F8, FC1, FC2, FC5, FC6, AFZ, FZ; Posterior: CP1, CP2, CP5, CP6, P3, P4, T5, T6, O1, O2, PZ, POZ). This was done to test for apparent anterior-posterior differences in the distribution of the ERP effects. Two sets of pair wise comparisons were performed. The first set compared the effects of Coherence within the Discourse and Sentence conditions. The other set of analyses compared the effects of Context within the Coherent and Incoherent conditions. Finally, in order to compare the onset of the effects in the Discourse and Sentence conditions, additional analyses were performed on the mean amplitude of the N400 effects (the difference waves) in consecutive 50 ms time windows. For evaluating effects with more than one degree of freedom in the numerator, the Greenhouse-Geisser correction was used to compensate for inhomogeneous variances and covariances across treatment levels (Greenhouse & Geisser, 1959). The respective adjusted p-values are reported. Because of the within-subjects design, subjects were presented both the coherent and incoherent versions of the sentence pairs, therefore, a first set of ANOVAs examined the possible effects of repetition. Coherent and incoherent versions of the same pair were separated by one intervening block, such that each version of the pair appeared in either the first or the second half of the experiment. In this set of ANOVAs, the factor Order (1st half, 2nd half) was included. Note however, that only the sentence pairs, but not the CWs themselves were repeated. For none of the four subject groups, the factor Order interacted with any other experimental factor (all $F_s < 1$), and was hence neglected. All analyses reported here were performed on the entire data set. In the group of High Comprehenders, due to clipping in one subject, ERPs could only be averaged until 950 ms after stimulus onset. For reasons of comparability between groups, ERPs are only plotted between -100 and 900 ms; analyses were performed in the reported windows.

2.3.1 Young Controls

2.3.1.1 OVERALL ANALYSES

Grand average ERPs to the CWs in the Sentence and Discourse conditions are displayed in Figures 3 and 4 and for the Coherent and Incoherent conditions in Figures 5 and 6. Overall rejection rates were 14.43% with 14.2% in the Discourse and 14.55% in the Sentence condition. The results of the initial OMNIBUS ANOVA (*F* values and significance levels) investigating the effects of Context and Coherence in the five time windows are displayed in Table 7.

Table 7

***F* values and significance levels of the OMNIBUS ANOVAs on the effects of Context and Coherence for the Young Controls**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|--------------------------------|--------|---------|-----------|-----------|-----------|------------|
| CONTEXT | 1,19 | 10.96** | 12.27** | <1 | 3.79 | 1.80 |
| CON x ELEC ⁺ | 28,532 | 4.01** | 3.06* | 3.15* | 10.28*** | 4.33** |
| COH | 1,19 | <1 | 46.31*** | 82.98*** | 31.81*** | <1 |
| COH x ELEC ⁺ | 28,532 | 1.42 | 7.58*** | 34.03*** | 9.74*** | 4.85** |
| CONT x COH | 1,19 | <1 | <1 | 6.07* | 6.10* | <1 |
| CONT x COH x ELEC ⁺ | 28,532 | 1.87 | 3.62** | 1.96 | 1.38 | 9.49*** |

p<0.05 ** p<0.01 ***p<0.001

+Greenhouse-Geisser adjusted *p* values

In the earliest time window between 0 and 100 ms, the only significant main effect was obtained for Context, with ERPs elicited in the Discourse Condition being more negative than in the Sentence Condition. This factor interacted with Electrode Site. In the window between 100 and 300 ms, significant main effects were obtained for Coherence with more negative ERPs in the Incoherent than the Coherent condition and for Context with more negative ERPs in the Discourse than the Sentence condition. Both Context and Coherence interacted with Electrode Site, but not with each other. In the N400 time window (300 – 500 ms), a main effect of Coherence was found with more negative ERPs in the Incoherent than the Coherent condition and an interaction between Coherence and Context; the effect of Coherence was more pronounced in the Sentence than the Discourse condition. Both Coherence and Context significantly interacted with Electrode Site. In the window 500 – 700

ms, a main effect of Coherence was found with more positive ERPs in the Coherent than the Incoherent condition and an interaction between Coherence and Electrode Site. Coherence significantly interacted with Context, and the difference between the Coherent and Incoherent condition was more pronounced in the Discourse than the Sentence condition; Context also interacted with Electrode Site. In the latest time window between 700 and 1000 ms, both Coherence and Context interacted with Electrode Site; the three-way interaction between all factors was significant as well; at posterior electrodes, the coherent Sentence condition was less negative than all other conditions which appear to show no differences.

2.3.1.2 EFFECTS OF COHERENCE

Figure 3 displays the ERPs to the coherent and incoherent CWs for the Sentence condition and the Figure 4 for the Discourse condition. The results of the ANOVAs (F values and significance levels) for the effects of Coherence are displayed in Tables 8 and 9 for the Sentence and Discourse conditions, respectively.

2.3.1.2.1 SENTENCE CONDITION

Figure 3 displays the ERPs for the coherent and incoherent endings in the Sentence condition. No sensory components (N1-P2) be distinguished, and no early differences are obtained. The waveforms start to diverge about 100 ms after the onset of the CW. An N400 is found in the Incoherent, but not the Coherent condition. This N400 in turn is followed by a positivity which is maximal over posterior electrodes and which reaches its maximum in the window between 700 and 1000 ms. Coherent and incoherent endings appear to differ in the late time window.

Table 8

***F* values and significance levels of the ANOVAs on the effect of Coherence in the Sentence condition for the Young Controls**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|-------------------------------|--------|---------|-----------|-----------|-----------|------------|
| COH | 1,19 | <1 | 17.04*** | 80.78*** | 38.74*** | <1 |
| LOCATION | 1,19 | <1 | 2.34 | 3.92 | 1.99 | 11.04** |
| COH x LOC | 1,19 | <1 | <1 | 10.63** | <1 | 25.16*** |
| COH x LOC x ELEC ⁺ | 11,209 | 1.16 | 4.11* | 42.48*** | 16.19*** | 5.67** |

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

+Greenhouse-Geisser adjusted p values

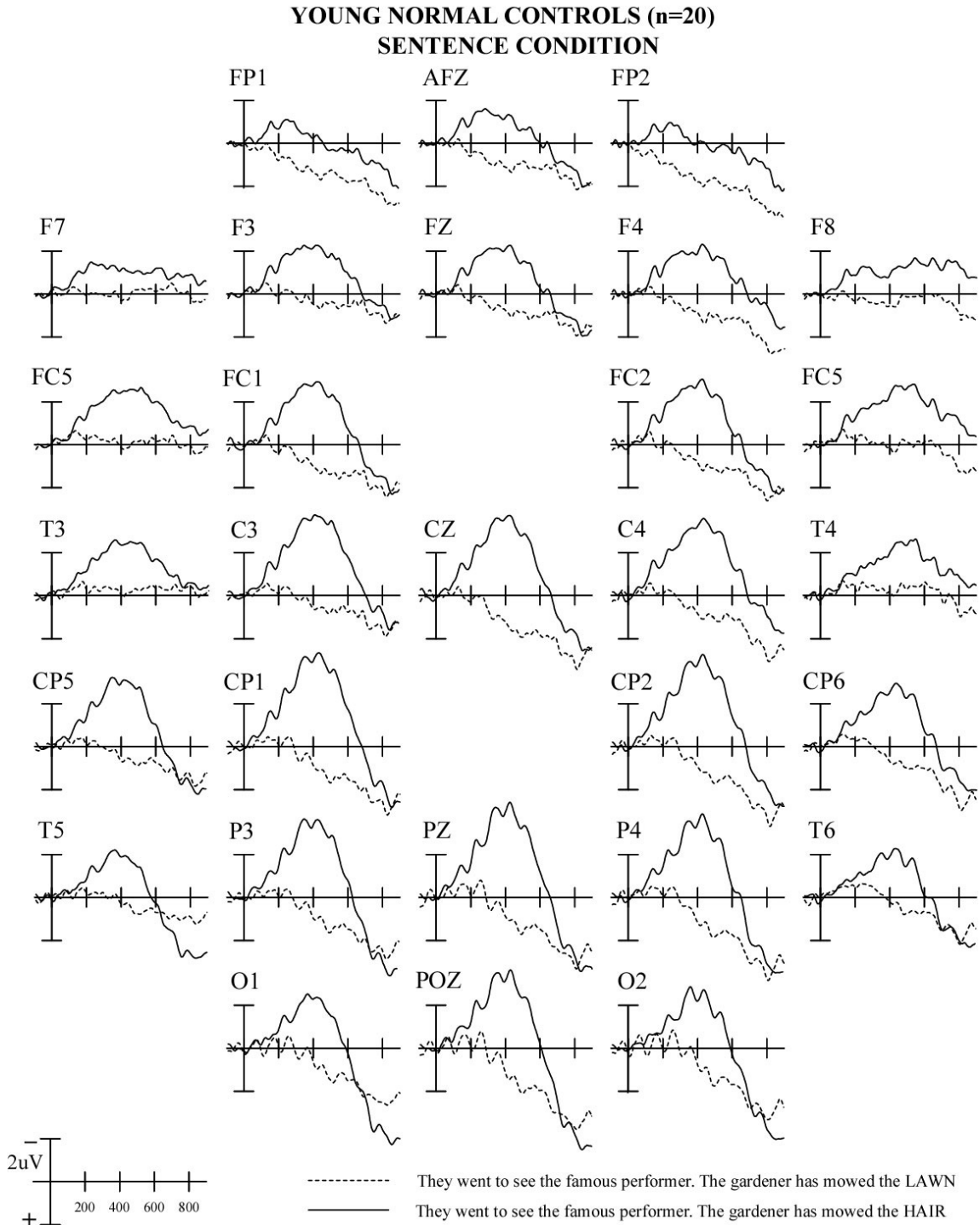


Figure 3 Grand Average ERP waveforms for the Young Controls to the coherent (dashed line) and incoherent (solid line) final words in the Sentence Condition

In the window between 0 and 100 ms, none of the effects tested reached significance. However, the waveforms for the coherent and incoherent CWs do start to diverge at around 100ms after stimulus onset. Analyses in the window 100 – 300 ms reveal that the ERPs to the incoherent CWs are more negative than to the coherent CWs. At around 400ms after stimulus onset, a clear negative peak is observed at centro-posterior electrode sites in the incoherent relative to the coherent endings. The planned pair-wise comparisons show a highly significant main effect. This effect was more pronounced at the posterior electrodes as indicated by the interaction with Location. The N400 effect is followed by a positivity between 500 and 1000 ms which was investigated in two consecutive time windows (500 – 700 ms; 700 – 1000 ms). In the window 500 – 700 ms, a main effect of Coherence was found with more positive ERPs in the Incoherent than the Coherent condition. Coherence did not interact with Location, but the three-way interaction between Coherence, Location and Electrode indicates general distributional differences for the effect. In the very late time window (700 – 1000 ms), the interaction between Coherence and Location shows that ERPs are overall more positive in the Incoherent than the Coherent condition over posterior sites.

2.3.1.2.2 DISCOURSE CONDITION

Figure 4 shows that no clear N1-P2 complex can be distinguished for the coherent and incoherent CWs in the Discourse condition. The waveforms start to diverge at about 100 ms after stimulus onset. A broad negative deflection with a centro-posterior distribution and a peak at around 400 ms is found in the Incoherent, but not the Coherent condition. This negativity is followed by a positivity that is maximal between 700 and 1000 ms. It is more pronounced over posterior than anterior electrode sites, and no obvious differences between Coherent and Incoherent conditions can be observed.

Table 9

F values and significance levels of the ANOVAs on the effect of Coherence in the Discourse condition for the Young Controls

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|-------------------------------|---------------------|---------|-----------|-----------|-----------|------------|
| COH | 1,19 | <1 | 20.28*** | 23.71*** | 7.20* | <1 |
| LOCATION | 1,19 | 7.36* | <1 | <1 | 28.72*** | 22.90*** |
| COH LOC | 1,19 | 2.13 | 8.50** | 32.84*** | 5.41* | 1.46 |
| COH x LOC x ELEC ⁺ | 11,209 ⁺ | <1 | 12.24*** | 18.14*** | 6.85** | 1.69 |

* p<0.05 ** p<0.01 ***p<0.001 +Greenhouse-Geisser adjusted p values

**YOUNG CONTROLS (n=20)
DISCOURSE CONDITION**

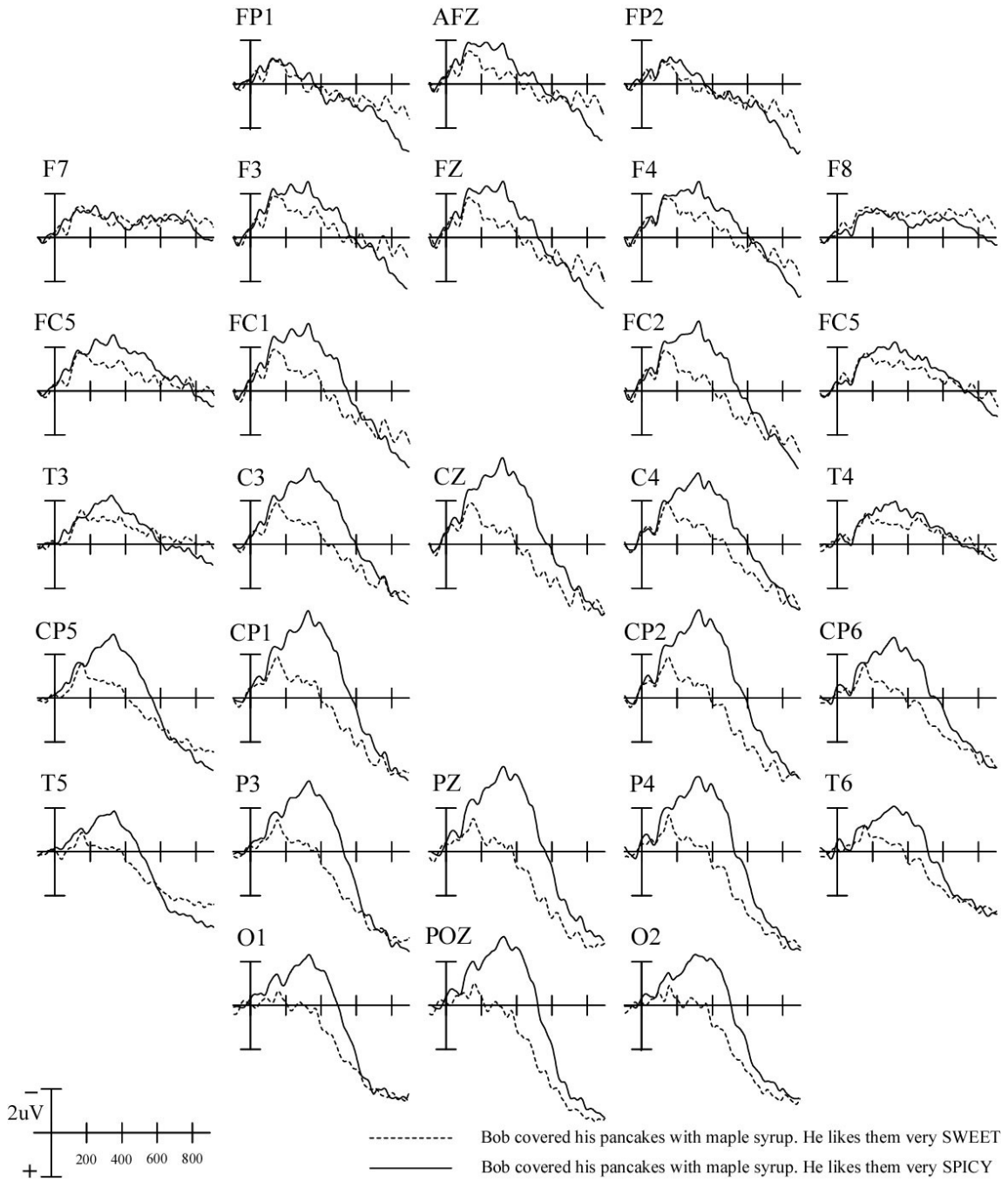


Figure 4 Grand Average ERP waveforms for the Young Controls to the coherent (dashed line) and incoherent (solid line) final words in the Discourse Condition

In the window between 0 and 100 ms, no differences between coherent and incoherent CWs can be observed. Whereas, there was a main effect of Location; ERPs were more negative at anterior than posterior electrode sites in both conditions. The waveforms in the Coherent and Incoherent conditions start to diverge at about 100 ms post stimulus onset. In the window 100 – 300 ms, a main effect of Coherence was obtained, and ERPs were more negative in the Incoherent than the Coherent condition. This effect interacted with Location, and the effect of Coherence was more pronounced at anterior than posterior electrodes. At around 400ms after stimulus onset, a clear negative peak is observed at centro-posterior electrode sites for the Incoherent relative to the Coherent conditions. This N400 effect was investigated in the window 300 – 500 ms. In this window, a highly significant main effect of Coherence was obtained with overall more negative ERPs in the Incoherent than the Coherent condition. That effect interacted again with Location, and in this time window, the effect was more strongly pronounced over the posterior than the anterior electrodes. The N400 effect is followed by a positivity between 500 and 1000 ms which reaches its maximum between 700 and 1000 ms. This positivity was investigated in two consecutive time windows (500 – 700 ms; 700 – 1000 ms). In the window 500 – 700 ms, a main effect of Coherence was found; coherent endings elicited more positive-going ERPs than incoherent endings. Also, a main effect of Location was found with more positive-going ERPs at posterior than anterior sites, and the effect of Coherence was more pronounced at posterior than anterior sites as revealed by the interaction between Coherence and Location. In the late window (700 – 1000 ms), a main effect of Location was found. ERPs were overall more positive-going at posterior than anterior electrode sites. The coherent and incoherent endings did not differ from each other at either location.

2.3.1.3 EFFECTS OF CONTEXT

The waveforms for the coherent and incoherent CWs in the Discourse and Sentence conditions are re-arranged in Figures 5 and 6 in order to display the effects of Context: Figure 5 displays a direct comparison of the ERPs to the coherent CWs in the Discourse and Sentence conditions and Figure 6 for the incoherent CWs, respectively. The results of the ANOVAs (F values and significance levels) are summarized in Table 10 and 11 for the Coherent and Incoherent conditions, respectively.

2.3.1.3.1 COHERENT CONDITION

Already right after the onset of the CW, ERPs are more negative in the Discourse than the Sentence condition. This effect is more strongly pronounced at anterior than posterior electrodes. This pattern persists until about 300 ms after stimulus onset. Between 300 and 500 ms, i.e. in the N400 time window, no differences between the conditions are found at posterior electrodes (i.e. at the N400 topography). Whereas, ERPs remain to be more positive in the Discourse than the Sentence condition at anterior sites. In the late time windows, a positivity is obtain in both context conditions, it is more pronounced in the Discourse than the Sentence condition at posterior electrodes.

Table 10

F values and significance levels of the ANOVAs on the effect of Context in the Coherent condition for the Young Controls

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|--------------------------------|--------|---------|-----------|-----------|-----------|------------|
| CONTEXT | 1,19 | 2.16 | 4.72* | 4.11 | <1 | <1 |
| LOCATION | 1,19 | 1.58 | <1 | 3.11 | 14.83** | 11.23** |
| CONT x LOC | 1,19 | 6.74* | 10.49** | 10.25** | 65.59*** | 54.95*** |
| CONT x LOC x ELEC ⁺ | 11,209 | 1.27 | 1.24 | 2.40 | 1.43 | 2.51* |

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

+Greenhouse-Geisser adjusted p values

In the earliest window (0 – 100 ms), an interaction between Context and Location is obtained: ERPs are more negative for the Discourse than the Sentence condition at anterior sites. This pattern persists in the following window (100 – 300 ms); furthermore, a main effect of Context is obtained with more negative ERPs in the Discourse than the Sentence condition. In the N400 time window (300 – 500 ms), no effect of context was obtained. The interaction between Context and Location was significant with more negative ERPs in the Discourse than the Sentence condition at anterior sites and no differences at posterior sites. In both late windows the patterns of results are qualitatively similar: there is a main effect of Location with more positive-going ERPs at posterior than anterior electrodes. Context significantly interacted with Location: ERPs were more positive in the Sentence than the Discourse condition at posterior sites.

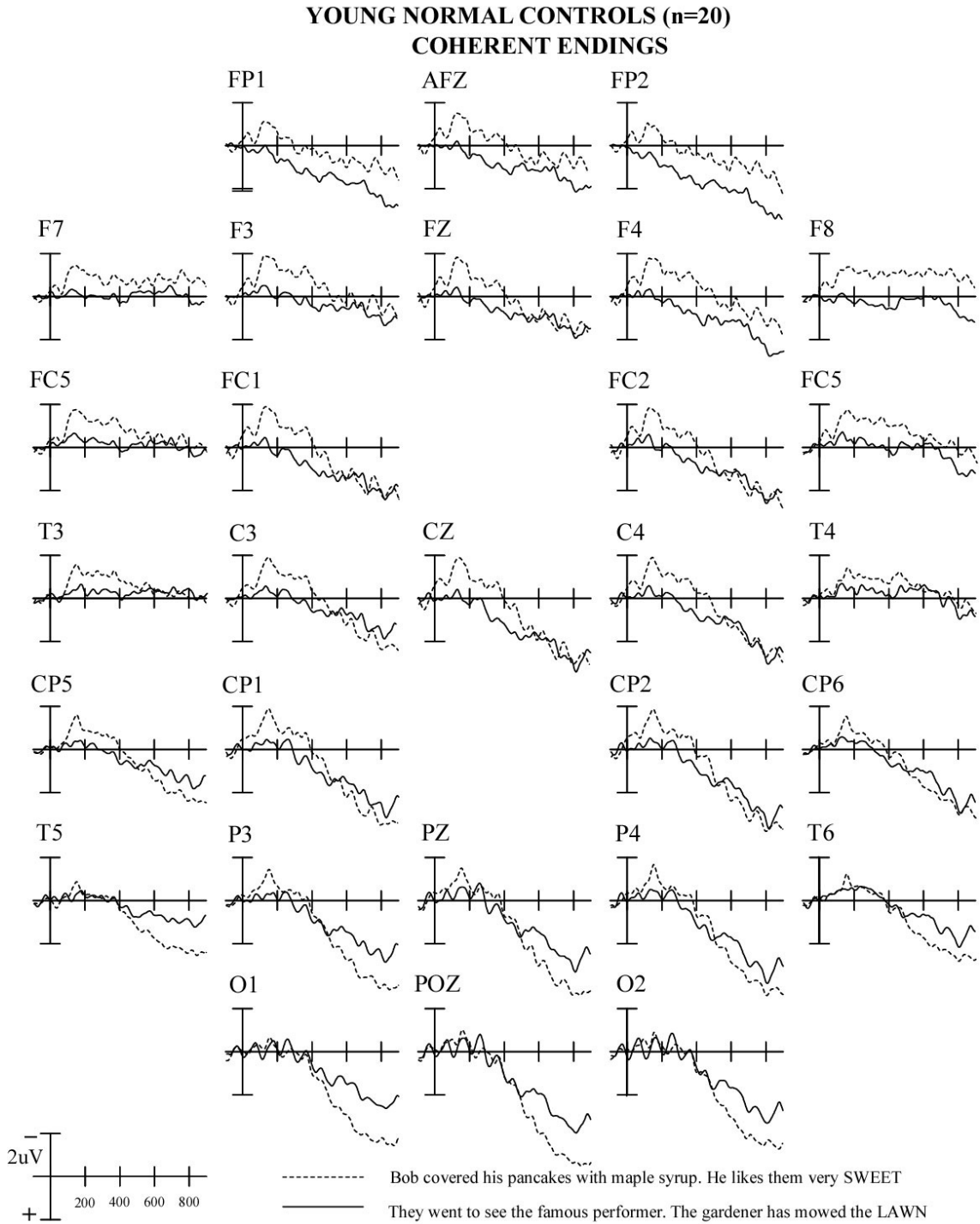


Figure 5 Grand Average ERP waveforms for the Young Controls in the Coherent condition elicited by the discourse (dashed line) and sentence (solid line) contexts

2.3.1.3.2 INCOHERENT CONDITION

Figure 6 displays the waveforms for the incoherent endings in the Discourse and Sentence conditions. Similar to the Coherent condition, the waveforms start to diverge immediately after the onset of the CW. This effect appears to be more pronounced at anterior than posterior electrodes. The ERPs elicited by the discourse context remain more negative than those elicited by the sentence context until about 300 ms after the onset of the CW. In both conditions, an N400 is elicited with a centro-posterior distribution. This N400 effect seems to be more prolonged in the Sentence than the Discourse condition. It is followed by a positivity which appears to be larger in the Discourse than the Sentence condition and more pronounced at posterior than anterior electrode sites.

Table 11

***F* values and significance levels of the ANOVAs on the effect of Context in the Incoherent condition for the Young Controls**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|--------------------------------|--------|---------|-----------|-----------|-----------|------------|
| CONTEXT | 1,19 | 7.76* | 6.91* | 1.81 | 8.29** | 1.71 |
| LOCATION | 1,19 | <1 | 1.68 | 9.26** | 6.49* | 21.83*** |
| CONT x LOC | 1,19 | 1.06 | <1 | <1 | 5.75* | <1 |
| CONT x LOC x ELEC ⁺ | 11,209 | 5.36** | 3.61* | <1 | 1.98 | 1.40 |

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

+Greenhouse-Geisser adjusted p values

In both early windows, a main effect of Context with more negative ERPs in the Discourse than the Sentence condition was obtained. In the N400 time window (300 – 500 ms), there was a main effect of Location with more negative ERPs at the posterior than the anterior electrodes (i.e. the typical N400 topography). Like in the Coherent condition, no effect of Context was found in this time window. Visual inspection of the wave forms indicates no onset differences, but a more prolonged effect in the Sentence condition. This was confirmed statistically by further fractioning this bin into an earlier (300 – 400 ms) and a later (400 – 500 ms) half. The effect of context was not significant in the earlier half ($F < 1$) and highly significant in the later half ($F(1,19) = 5.99$; $p = 0.0243$) indicating no onset difference but a more prolonged effect in the Sentence than the Discourse condition. In the window

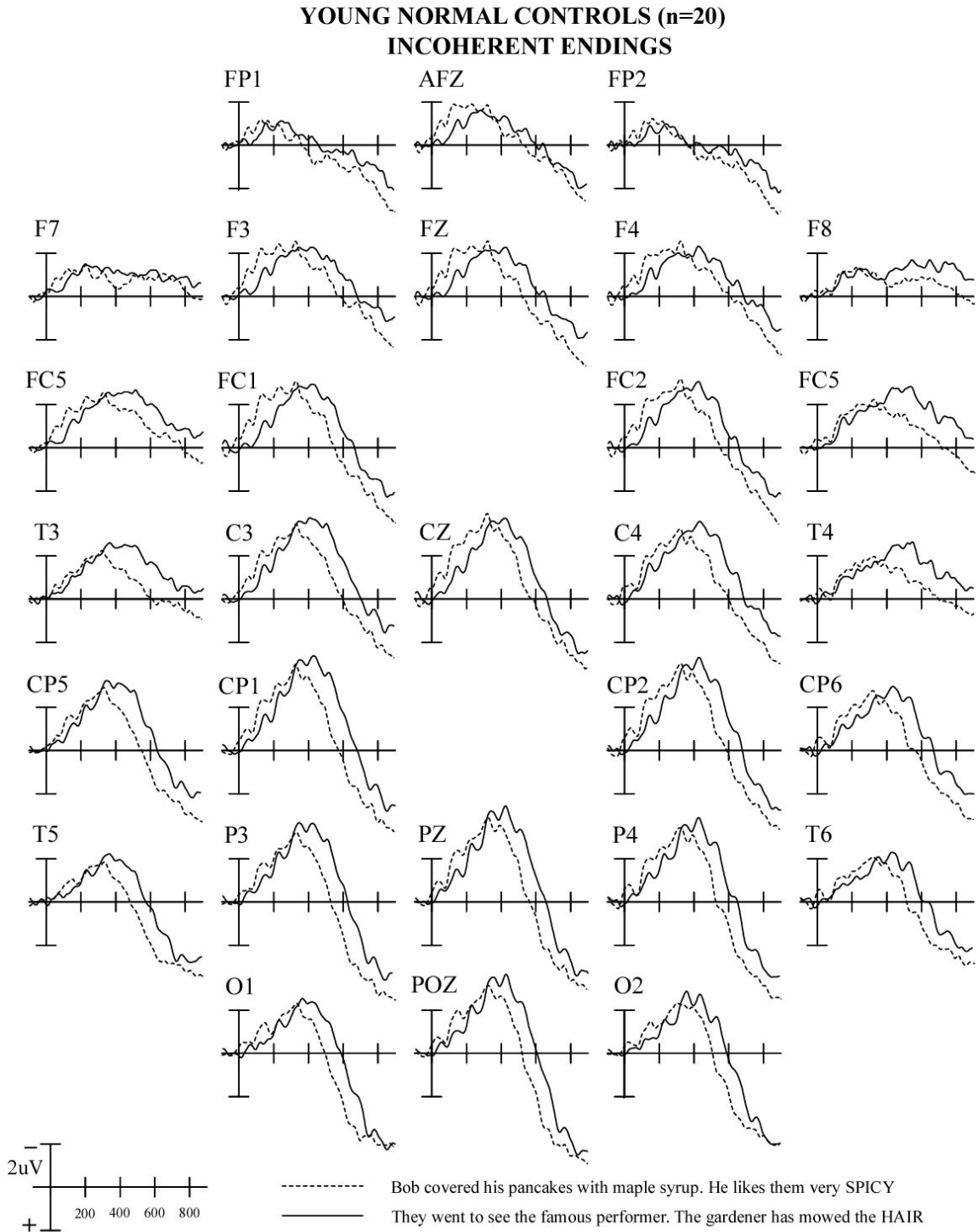


Figure 6 Grand Average ERP waveforms for the Young Controls in the Incoherent condition elicited by the discourse (dashed line) and sentence (solid line) contexts

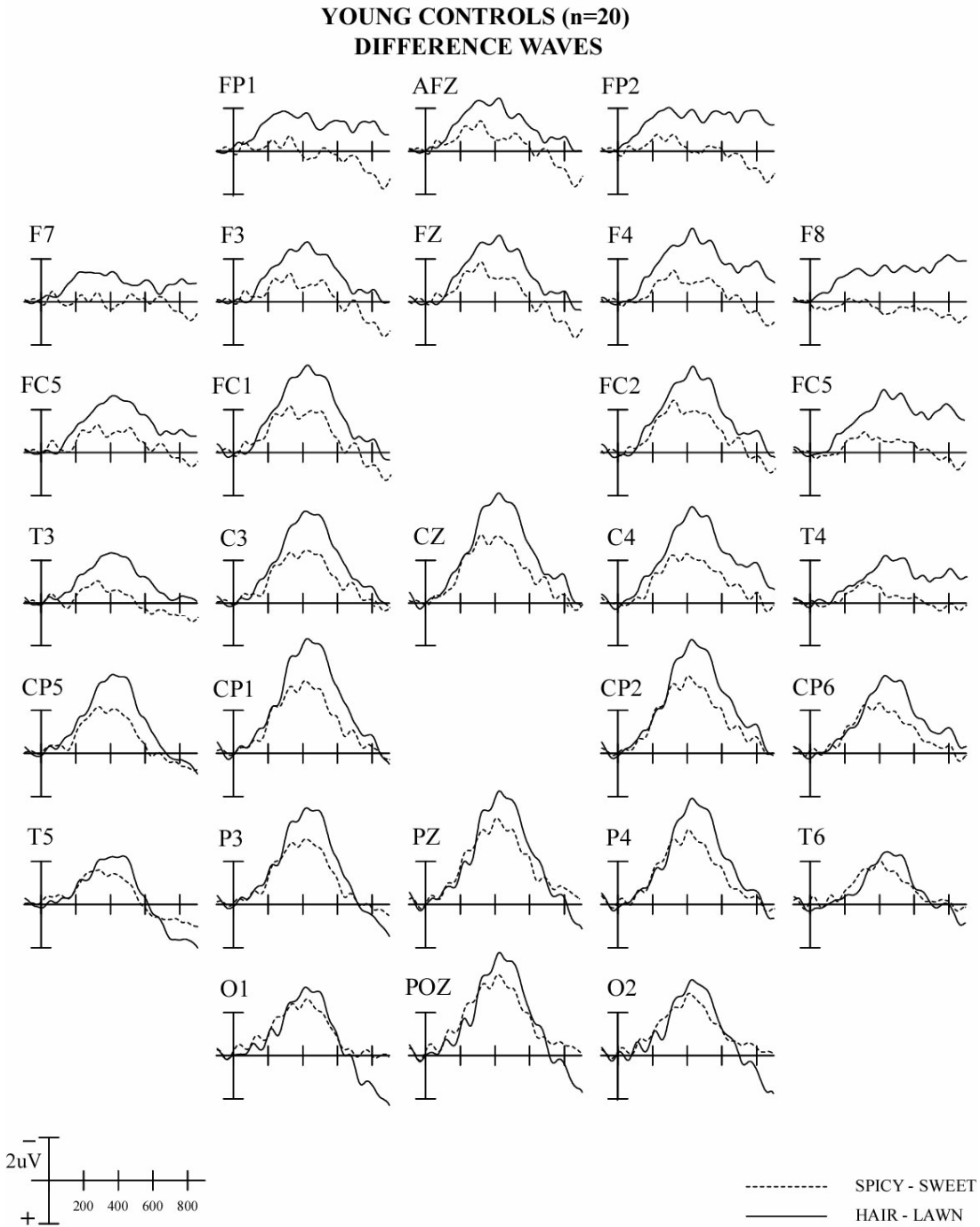


Figure 7 Difference waveforms for the Young Controls in the Discourse (dashed line) and Sentence (solid line) conditions. Difference waveforms were created by subtracting the ERPs elicited by the CWs in the coherent condition from those elicited in the incoherent condition

following the N400 (500 – 700 ms), there was both a main effect of Context with ERPs being overall negative in the Sentence and positive in the Discourse condition and a main effect of Location with overall positive ERPs at the posterior and negative ERPs at the anterior electrodes. Context and Location interacted such that at anterior sites, both discourse and sentence contexts elicited negativities, whereas at posterior sites, the discourse but not the sentence context elicited a positivity. Finally, in the latest window (700 – 1000 ms), there was a main effect of Location; ERPs were more positive-going at posterior than anterior electrode sites without differences between the two context conditions.

2.3.1.4 DIFFERENCE EFFECTS / ONSET ANALYSES

Difference waves were computed by subtracting the ERPs of the coherent from the incoherent endings for both the Discourse and Sentence conditions and are displayed in Figure 7. There was a significant main effect for the factor Context in the time window 300 – 500 ms ($F(1,19)=5.59$; $p=0.0289$) with a larger N400 effect for the Sentence than the Discourse condition. This effect did not interact with Electrode Site ($F(28,532)=2.01$; $p=0.1028$). In order to determine possible onset differences between the two conditions, ANOVAs were performed on the mean amplitude of the difference waves in consecutive 50 ms time windows starting at stimulus onsets. These differences did not reach significance until 400 – 450 ms ($F(1,19)=9.87$; $p=0.0054$). This window was then fractioned into 10ms time windows in order to precisely determine the onset differences which was obtained 400 – 410 ms after stimulus-onset ($F(1,19)=5.53$; $p=0.0296$).

2.3.2 Elderly Controls

2.3.2.1 OVERALL ANALYSES

For the Elderly Controls, overall rejection rates were 14.3% with 14.7% in the Discourse and 13.9% in the Sentence Condition. The results of the initial OMNIBUS ANOVA (F values and significance levels) investigating the effects of Context and Coherence in the five time windows are displayed in Table 12.

Table 12***F* values and significance levels of the OMNIBUS ANOVAs on the effects of Context and Coherence for the Elderly Controls**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|--------------------------------|--------|---------|-----------|-----------|-----------|------------|
| CONTEXT | 1,11 | 1.37 | 2.21 | <1 | 7.84* | 3.55# |
| CON x ELEC ⁺ | 28,308 | <1 | <1 | 1.18 | 1.91 | 1.9 |
| COH | 1,11 | 1.56 | 12.17** | 16.21** | 7.36* | 4.02# |
| COH x ELEC ⁺ | 28,308 | <1 | 3.55* | 10.30*** | 4.78** | 3.30* |
| CONT x COH | 1,11 | 2.63 | <1 | 7.25* | 2.83 | <1 |
| CONT x COH x ELEC ⁺ | 28,308 | 1.01 | <1 | <1 | <1 | 3.49** |

$p < 0.1$ $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$ + Greenhouse-Geisser adjusted p values

In the earliest time window between 0 and 100 ms, no significant effect was obtained. In the window between 100 and 300 ms, the only significant main effect is obtained for Coherence. ERPs are more negative in the Coherent than the Incoherent condition. This effect interacted with Electrode Site. In the N400 time window (300 – 500 ms), there was a main effect of Coherence with more negative ERPs in the Incoherent than the Coherent condition and an interaction between Coherence and Context; the effect of Coherence was more pronounced in the Sentence than the Discourse condition. Coherence significantly interacted with Electrode Site. In the window 500 – 700 ms, there was a main effect of Coherence with more positive ERPs in the Coherent than the Incoherent condition and an interaction between Coherence and Electrode Site. Coherence also interacted with Electrode Site. In the latest time window between 700 and 1000 ms, Coherence interacted with Electrode Site. Both main effects only showed a trends towards significance. Furthermore, the three-way interaction between Context, Coherence and Electrode Site was significant; at posterior electrodes, the coherent Sentence condition was less negative than all other conditions which appear to show now differences.

2.3.2.2 EFFECTS OF COHERENCE

ERP effects of Coherence are displayed in Figure 8 for the Sentence and in Figure 9 for the Discourse condition. The results of the ANOVAs (F values and significance levels)

for the effects of Coherence are displayed in Tables 13 and 14 for the Sentence and Discourse conditions, respectively.

2.3.2.2.1 SENTENCE CONDITION

Figure 8 displays the ERPs for the coherent and incoherent endings in the Sentence condition. No early differences and no clearly defined sensory components are obtained, and the waveforms start to diverge about 100 ms after the onset of the CW. An N400 is found in the Incoherent, but not the Coherent condition. This N400 in turn is followed by a positivity maximal over posterior electrodes and in the window between 700 and 1000 ms. This effect appears to be more pronounced in the Incoherent than the Coherent condition.

Table 13

***F* values and significance levels of the ANOVAs on the effect of Coherence in the Sentence Condition for the Elderly Controls**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|------------------|--------|---------|-----------|-----------|-----------|------------|
| COH | 1,11 | <1 | <1 | 10.68** | 24.61*** | <1 |
| LOCATION | 1,11 | 10.31** | 1.18 | <1 | 4.92* | 30.27*** |
| COH x LOC | 1,11 | <1 | 1.99 | 4.76* | 5.08* | <1 |
| COH x LOC x ELEC | 11,121 | <1 | <1 | 5.98** | 6.97*** | 2.08# |

$p < 0.1$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

+ Greenhouse-Geisser adjusted p values

In the window between 0 and 100 ms, only the main effect of Location was significant. ERPs were overall more negative at anterior than posterior electrodes. Despite the apparent difference between the Coherent and Incoherent conditions in the window 100 – 300 ms, statistical analyses do not reveal any significant effects in this time window. At around 400 ms after stimulus onset, a clear negative peak is observed at centro-posterior electrode sites for the incoherent relative to the coherent endings as indicated by the highly significant main effect for Coherence in the window 300 – 500 ms. The effect seems to be more prominent at posterior than anterior electrode sites, and the barely significant interaction between Coherence and Location ($F(1,11)=4.76$; $p=0.051$) indicates a tendency towards distributional

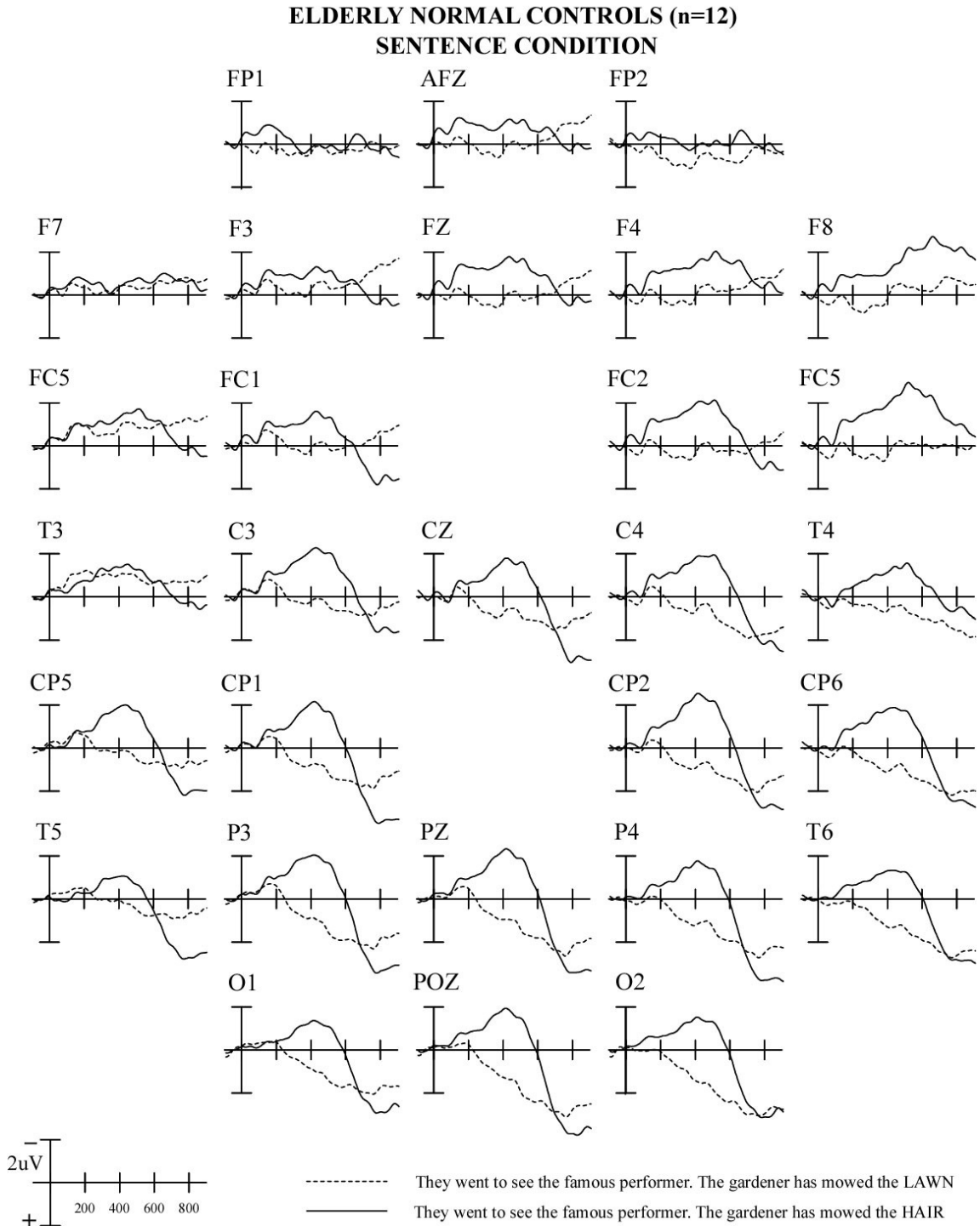


Figure 8 Grand Average ERP waveforms for the Elderly Controls to the coherent (dashed line) and incoherent (solid line) final words in the Sentence Condition

differences; the effect is more pronounced over posterior than anterior electrodes. The N400 effect is followed by a positivity between 500 and 1000 ms which is more pronounced in the later one of the two time windows in which it was investigated (500 – 700 ms; 700 – 1000 ms). In the window 500 – 700 ms, a main effect of Coherence was found with more negative ERPs in the Incoherent than the Coherent condition. Furthermore, ERPs were more negative at anterior than posterior electrodes as revealed by the main effect of Location. Both factors interacted with each other; the difference between the coherent and incoherent endings was more pronounced at posterior than anterior electrodes. Finally, in the latest time window (700 – 1000 ms), a main effect of Location was obtained. ERPs were overall more positive at posterior than anterior electrodes.

2.3.2.2.2 DISCOURSE CONDITION

Figure 9 shows that no clear N1-P2 complex can be distinguished for the coherent and incoherent CWs in the Discourse condition. The waveforms start to diverge at about 100 ms after stimulus onset and are more negative in the Incoherent than the Coherent condition. A negative deflection with a centro-posterior distribution and a peak at around 400 ms is found in the Incoherent, but not the Coherent condition and only at posterior but not anterior electrode sites. This negativity is followed by a positivity that is maximal between 700 and 1000 ms. It is more pronounced over posterior than anterior electrode sites, and no obvious differences between Coherent and Incoherent conditions can be observed at posterior but at anterior electrodes.

Table 14

***F* values and significance levels of the ANOVAs on the effect of Coherence in the Discourse Condition for the Elderly Controls**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|------------------|--------|---------|-----------|-----------|-----------|------------|
| COH | 1,11 | <1 | 4.95* | 3.65# | 4.29# | 6.73* |
| LOCATION | 1,11 | 16.58** | 2.67 | 1.63 | 6.89* | 28.28*** |
| COH x LOC | 1,11 | <1 | <1 | 3.27# | 1.31 | 1.86 |
| COH x LOC x ELEC | 11,121 | 1.04 | 1 | 2.37# | 1.88 | 2.12# |

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

+ Greenhouse-Geisser adjusted p values

In the window between 0 and 100 ms, no differences between coherent and incoherent CWs can be observed. Whereas, there was a main effect of Location; ERPs were more

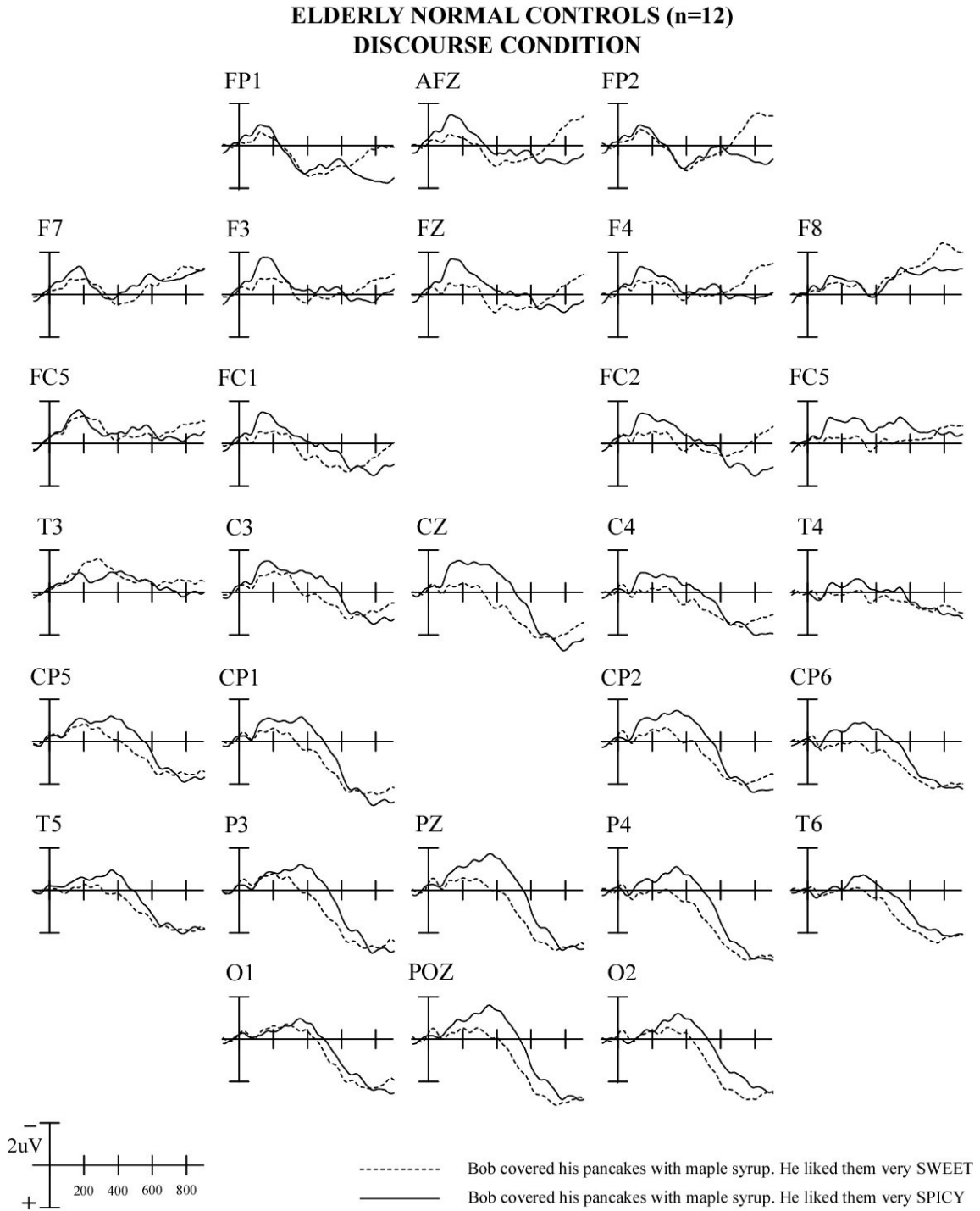


Figure 9 Grand Average ERP waveforms for the Elderly Controlsto the coherent (dashed line) and incoherent (solid line) final words in the Discourse Condition

negative at anterior than posterior electrode sites. In the window 100 – 300 ms, a main effect of Coherence was obtained, and ERPs were more negative in the Incoherent than the Coherent condition. This effect did not interact with Location. ERPs continue to be more negative in the Incoherent than the Coherent condition in the N400 time window between 300 and 500 ms. This is pronounced only at posterior but not anterior electrodes. The main effect of Coherence only approaches significance ($F(1,11)=3.65$; $p=0.08$) as does the interaction between Coherence and Location ($F(1,11)=3.27$; $p=0.09$). In order to omit a type II error, the effect of the N400 was further examined at the centro-posterior electrode sites at which it is largest (C3, C4, CP1, CP2, P3, P4, CZ, PZ, POZ). In this case, the main effect of Coherence proved to be significant ($F(1,11)=6.21$; $p=0.029$). The N400 is followed by a positivity between 500 and 1000 ms which reaches its maximum between 700 and 1000 ms. This positivity was investigated in two consecutive time windows (500 – 700 ms; 700 – 1000 ms). In the window 500 – 700 ms, a main effect of Location was found; coherent endings elicited more positive-going ERPs than incoherent endings. ERPs are more positive in the Incoherent than the Coherent condition, whereas the effect of Coherence only approaches significance ($F(1,11)=4.29$; $p=0.06$). In the late window (700 – 1000 ms), main effects of both Coherence and Location were obtained. ERPs were overall more positive-going in the Incoherent than the Coherent condition and at posterior than anterior electrodes; importantly, there are no differences between the Coherent and Incoherent conditions at posterior sites.

2.3.2.3 EFFECTS OF CONTEXT

The waveforms for the coherent and incoherent CWs in the Discourse and Sentence conditions are re-arranged in Figures 10 and 11 in order to display the effects of Context. Figure 10 displays a direct comparison of the ERPs in the Coherent condition for the sentence and discourse contexts and Figure 11 does so for the Incoherent condition.

2.3.2.3.1 COHERENT CONDITION

In Figure 10, the waveforms elicited by the coherent CWs in the Discourse and Sentence conditions are plotted. Like for the Young Controls, already right after the onset of the CW, ERPs are more negative in the Discourse than the Sentence condition. This effect appears to be more strongly pronounced at anterior than posterior electrodes. This pattern persists until about 300 ms after stimulus onset. Between 300 and 500 ms, i.e. in the N400 time window, there are no apparent differences between the conditions at posterior electrodes

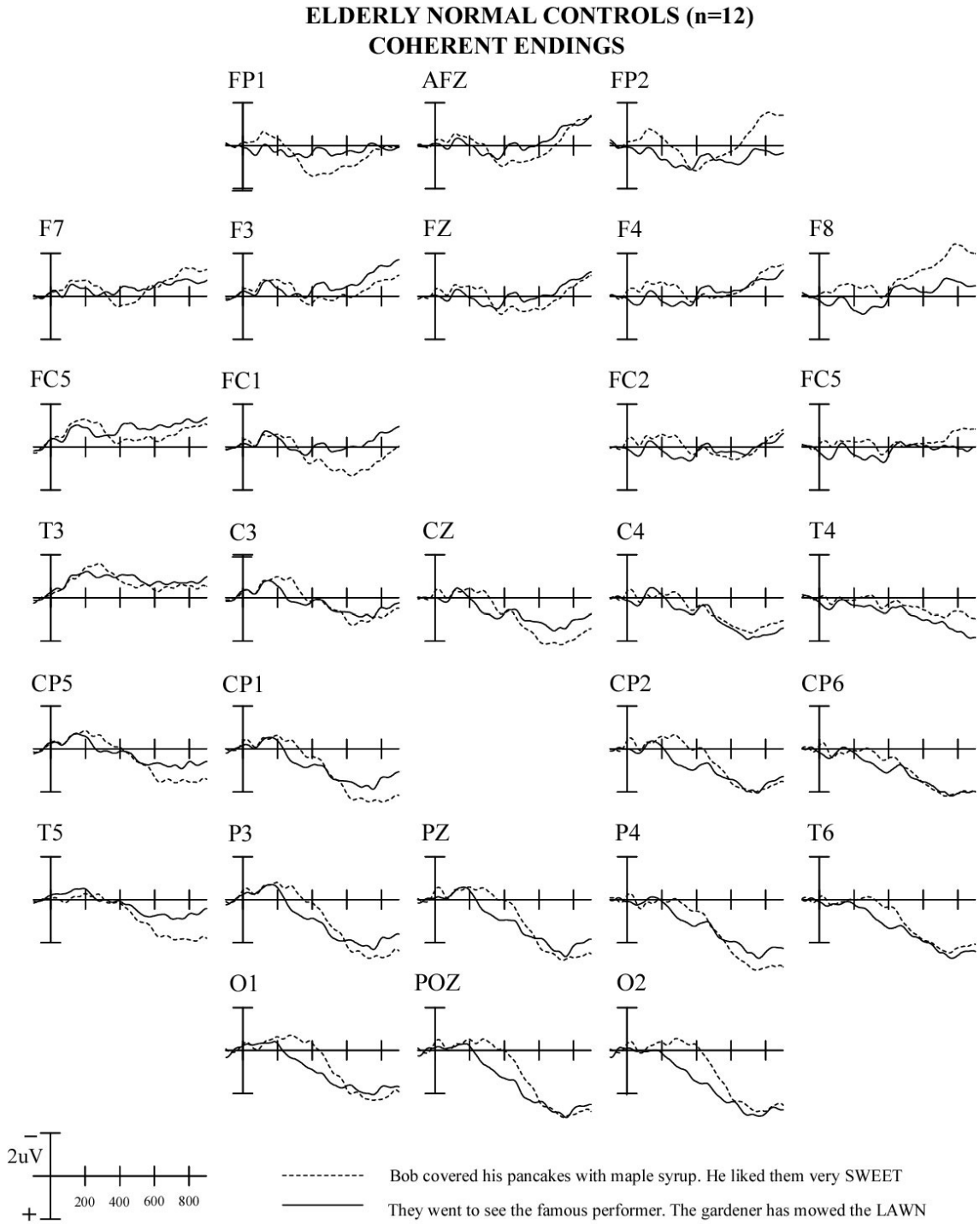


Figure 10 Grand Average ERP waveforms for the Elderly Controls in the Coherent condition elicited by the discourse (dashed line) and sentence (solid line) contexts

(i.e. at the N400 topography). In the late time windows, a positivity is obtain in both context conditions, it is more pronounced in the Discourse than the Sentence condition at posterior electrodes.

Table 15

***F* values and significance levels of the ANOVAs on the effect of Context in the Coherent condition for the Elderly Controls**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|--------------------------------|--------|---------|-----------|-----------|-----------|------------|
| CONTEXT | 1,11 | 9.1* | 12.6** | 3.01 | 3.03 | 2.47 |
| LOCATION | 1,11 | 3.86# | 1.06 | <1 | 10.064** | 21.01*** |
| CONT x LOC | 1,11 | 1.89 | 1.23 | <1 | <1 | 2.88 |
| CONT x LOC x ELEC ⁺ | 11,121 | <1 | <1 | <1 | 2 | 4.08* |

$p < 0.1$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

+ Greenhouse-Geisser adjusted p values

In the earliest window (0 – 100 ms), a main effect of context is obtained. ERPs are more negative in the Discourse than the Sentence condition. The trends towards significance of the main effect of Location ($F(1,11)=3.86$; $p=0.075$) implies a tendency towards more negative ERPs over anterior than posterior electrode sites. The main effect of context is the only significant effect in the window between 100 – 300 ms. ERPs remain more negative in the Discourse than the Sentence condition. In the N400 time window, none of the effects reach significance indicating no differences between the two context conditions. A positivity is observed between 500 and 1000 ms was investigated in two consecutive time windows (500 – 700 ms; 700 – 1000 ms). In both time windows, a significant main effect of Context reveals more positive ERPs in the Discourse than the Sentence condition. Only in the later window, the three-way interaction between Context, Location and Electrode reveals that the effect is more pronounced at posterior than anterior electrodes.

2.3.2.3.2 INCOHERENT CONDITION

Figure 11 displays the waveforms for the incoherent endings in the Discourse and Sentence conditions. Similar to the Coherent condition, the waveforms start to diverge immediately after the onset of the CW. This effect appears to be more pronounced at anterior than posterior electrodes. The ERPs elicited by the discourse context remain more negative than those elicited by the sentence context until about 300 ms after the onset of the CW. In

ELDERLY NORMAL CONTROLS (n=12)
INCOHERENT ENDINGS

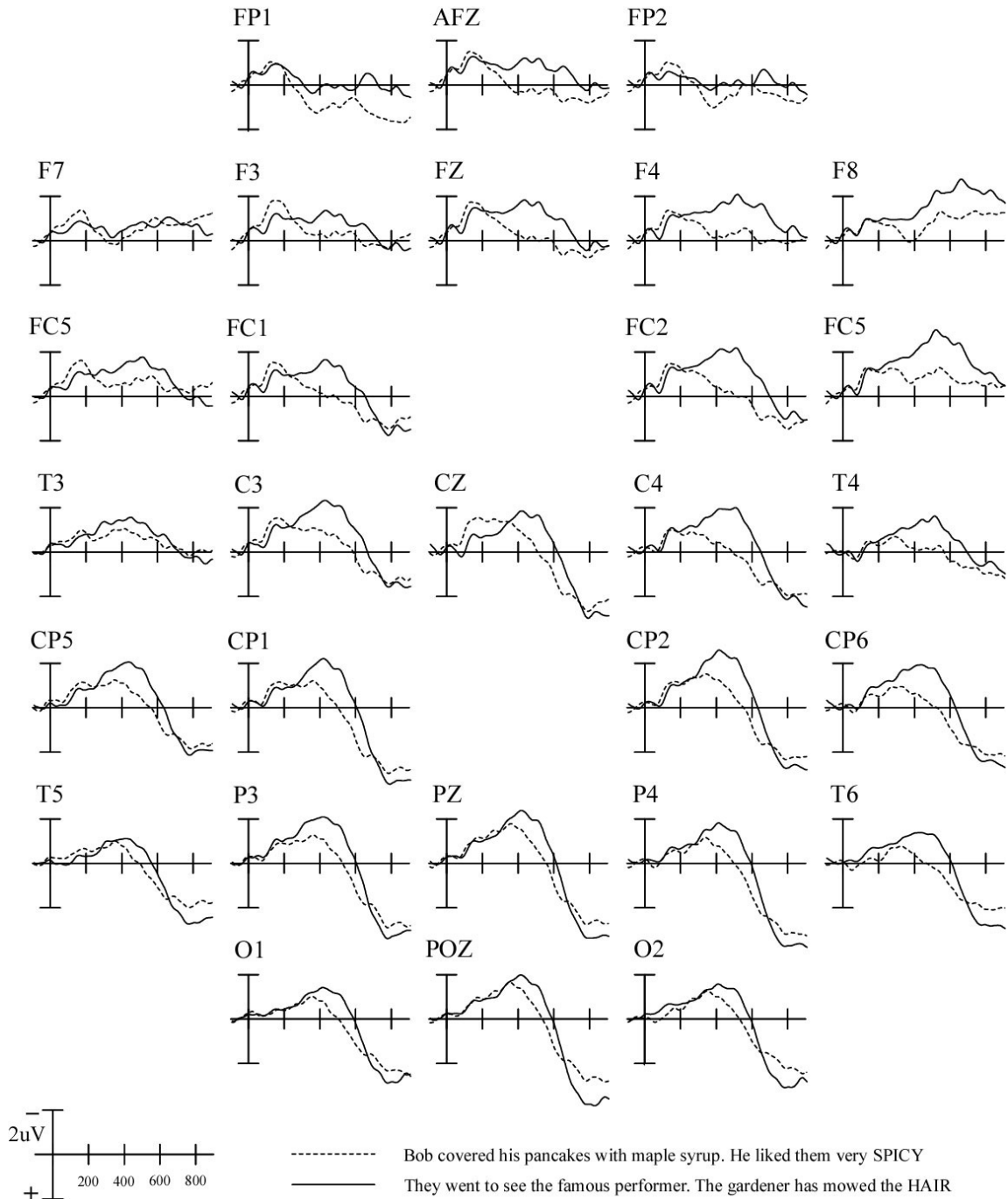


Figure 11 Grand Average ERP waveforms for the Elderly Controls in the Incoherent condition elicited by the discourse (dashed line) and sentence (solid line) contexts

both conditions, an N400 is elicited with a centro-posterior distribution. This N400 effect seems to be more prolonged in the Sentence than the Discourse condition. It is followed by a positivity which appears to be larger in the Discourse than the Sentence condition and more pronounced at posterior than anterior electrode sites.

Table 16

***F* values and significance levels of the ANOVAs on the effect of Context in the Incoherent Condition for the Elderly Controls**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|--------------------------------|--------|---------|-----------|-----------|-----------|------------|
| CONTEXT | 1,11 | <1 | <1 | 2.9 | 8.48* | 3.6# |
| LOCATION | 1,11 | 4.6# | <1 | 10.26** | 2.97 | 27.7*** |
| CONT x LOC | 1,11 | <1 | <1 | <1 | <1 | 2.98 |
| CONT x LOC x ELEC ⁺ | 11,121 | <1 | <1 | 1.93 | 4.54** | 2.61* |

$p < 0.1$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

+ Greenhouse-Geisser adjusted p values

In both early windows, no significant main effects were obtained. Only the barely significant effect of Location in the window 0 – 100 ms ($F(1,11)=4.6$; $p=0.055$) indicates a tendency towards more negative ERPs at anterior than posterior electrodes. In the N400 time window (300 – 500 ms), the only significant main effect was that of Location: ERPs were more negative at posterior than anterior (i.e. at the typical N400 location) electrodes, but they did not differ between the two context conditions. In the following window (500 – 700 ms), the main effect of Context indicates overall positive ERPs in the Discourse condition and overall negative ERPs in the Sentence condition. The three way interaction indicated that this difference is more strongly pronounced at posterior than anterior electrodes. In the latest window, the main effect of Location confirms that overall, ERPs are more positive over the posterior than the anterior electrodes.

ELDERLY NORMAL CONTROLS (n=12)
DIFFERENCE WAVES

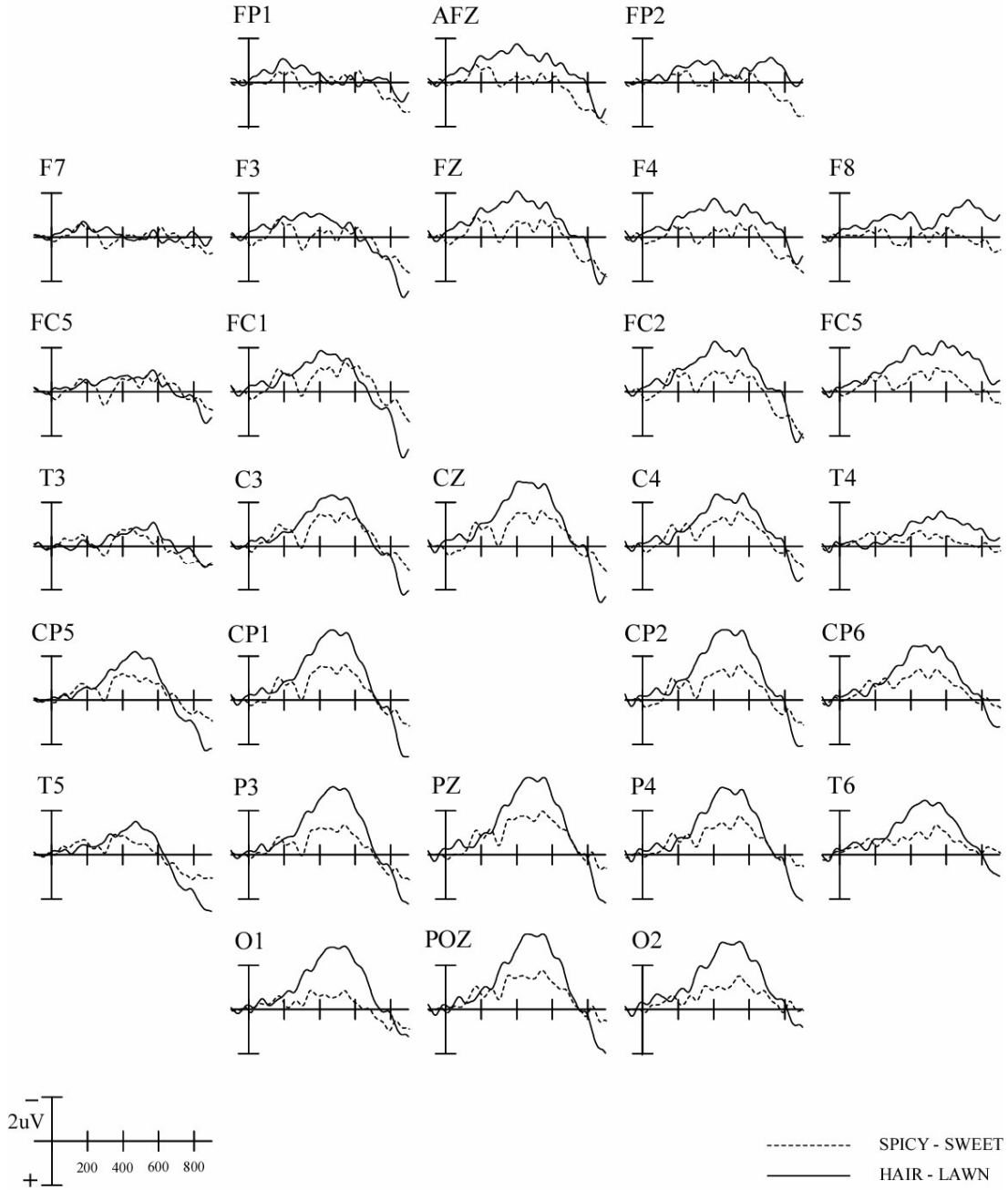


Figure 12 Difference waveforms for the Elderly Controls in the Discourse (dashed line) and Sentence (solid line) conditions. Difference waveforms were created by subtracting the ERPs elicited by the CWs in the coherent condition from those elicited in the incoherent condition

2.3.2.4 DIFFERENCE EFFECTS / ONSET ANALYSES

Difference waves were computed by subtracting the ERPs to the incoherent from those of the coherent endings for both the Discourse and Sentence conditions and are displayed in Figure 11. There was a significant main effect for the factor Context in the time window 300 – 500 ms ($F(1,11)=5.11$; $p=0.045$) with a larger N400 effect for the Sentence than the Discourse condition. This effect did not interact with Electrode Site ($F<1$). In order to determine possible onset differences between the two conditions, ANOVAs were performed on the mean amplitude of the difference waves in consecutive 50 ms time windows starting at stimulus onset. These differences did not reach significance until 300 – 350 ms ($F(1,11)=8.43$; $p=0.0143$). This window was then fractioned into 10ms time windows in order to precisely determine the onset differences which was obtained 300 – 310 ms after stimulus-onset ($F(1,11)=9.69$; $p=0.0098$).

2.3.3 High Comprehenders

2.3.3.1 OVERALL ANALYSES

Overall rejection rates were 11.3% with 9.6% in the Discourse and 13.0% in the Sentence Condition. The results of the initial 2 x 2 x 29 ANOVA (F values and significance levels) investigating the effects of Context and Coherence in the five time windows are displayed in Table 17.

Table 17

***F* values and significance levels of the OMNIBUS ANOVAs on the effects of Context and Coherence for the High Comprehenders**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 950 |
|--------------------------------|--------|---------|-----------|-----------|-----------|-----------|
| CONTEXT | 1,6 | 3.85# | 4.9# | 3.84# | 1.4 | 10.75* |
| CONT x ELEC ⁺ | 28,168 | 1.24 | <1 | <1 | 3.1# | 4.77* |
| COH | 1,6 | <1 | <1 | 4.48# | 22.37** | 2.48 |
| COH x ELEC ⁺ | 28,168 | 1.03 | 1.35 | 2.56# | 4.59* | 1.37 |
| CONT x COH | 1,6 | <1 | <1 | <1 | <1 | <1 |
| CONT x COH x ELEC ⁺ | 28,168 | 1.85 | 1.43 | 1.87 | <1 | 1.41 |

$p<0.1$ $p<0.05$ ** $p<0.01$ *** $p<0.001$

+ Greenhouse-Geisser adjusted p values

In the earliest time window between 0 and 100 ms, no significant effect was obtained. The main effect of Context approached significance ($F(1,6)=3.85$; $p=0.09$). In the window between 100 and 300 ms, the effect of Context is again only marginally significant ($F(1,6)=4.9$; $p=0.06$). In both time windows ERPs are more negative in the Discourse than the Sentence condition. In the N400 time window (300 – 500 ms), the effects of Context ($F(1,6)=3.84$; $p=0.09$) and Coherence ($F(1,6)=4.48$; $p=0.07$) again only approach significance as did the interaction between Coherence and Electrode Site ($F(28,168)=2.56$; $p=0.08$). In the window 500 – 700 ms, there was a highly significant main effect of Coherence with more negative ERPs in the Incoherent than the Coherent condition and an interaction between Coherence and Electrode Site. In the latest time window between 700 and 1000 ms, the only significant main effect was obtained for Context with more positive ERPs in the Discourse than the Sentence condition; that effect did interact with Electrode Site.

2.3.3.2 EFFECTS OF COHERENCE

Figure 13 displays the ERPs to the coherent and incoherent CWs for the Sentence condition and the Figure 14 for the Discourse condition. The results of the ANOVAs (F values and significance levels) for the effects of Coherence are displayed in Tables 18 and 19 for the Discourse and Sentence conditions, respectively. Note that due to clipping in one subject, ERPs could only be averaged until 950 ms after stimulus onset.

2.3.3.2.1 SENTENCE CONDITION

Figure 13 displays the ERPs for the coherent and incoherent endings in the Sentence condition. No sensory components are expressed, and no early differences are visible, and the waveforms start to diverge about 100 ms after the onset of the CW. ERPs are more negative in the Incoherent than the Coherent condition; this negativity has a clear centro-posterior distribution and reaches its peak at about 500 ms after stimulus onset. In the later time windows, ERPs remain more positive in the Coherent than the Incoherent condition.

Table 18

***F* values and significance levels of the ANOVAs on the effect of Coherence in the Sentence Condition for the High Comprehenders**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 950 |
|-------------------------------|-------|---------|-----------|-----------|-----------|-----------|
| COH | 1,6 | <1 | 1.79 | 3.74 | 8.66* | 3.32 |
| LOCATION | 1,6 | <1 | <1 | 5.52# | <1 | <1 |
| COH x LOC | 1,6 | <1 | 1.19 | 10.55* | 71.52*** | 1.35 |
| COH x LOC x ELEC ⁺ | 11,66 | <1 | <1 | 1.23 | 2.69 | <1 |

$p < 0.1$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

+ Greenhouse-Geisser adjusted p values

In the two early windows, none of the effects reached significance. In the window 300 – 500 ms, the interaction between Coherence and Location confirms that ERPs are more negative in the Incoherent than the Coherent condition and at posterior than anterior electrode sites. The barely significant effect of Location ($F(1,6)=5.52$; $p=0.057$) corroborates the fact that ERPs are overall more negative at posterior than anterior electrode sites. Post-hoc analyses reveal a significant main effect of Coherence at the posterior set of electrodes ($t=2.62$; $p=0.022$). In the window 500 – 700 ms, ERPs remain to be more negative in the Incoherent than the Coherent condition as indicated by the main effect of Coherence. The interaction between Coherence and Location indicates as similar distribution as in the previous window. Also here, post-hoc analyses reveal a significant main effect of Coherence at the posterior set of electrodes ($t=2.74$; $p=0.017$). In the latest window, none of the effects is significant.

2.3.3.2.2 DISCOURSE CONDITION

Figure 14 shows that also no clear N1-P2 complex can be distinguished for the coherent and incoherent CWs in the Discourse condition. Overall, the data are noisier than for the control groups and the waveforms start to diverge at about 100 ms after stimulus onset and are more negative in the Incoherent than the Coherent condition. A negative deflection with a centro-posterior distribution and a peak at around 600 ms is found in the Incoherent, but not the Coherent condition and only at posterior but not at anterior electrode sites. This negativity is followed by a positivity that is maximal between 700 and 1000 ms. It is more pronounced over posterior than anterior electrode sites, and differences between

HIGH COMPREHENDERS (n=7)
SENTENCE CONDITION

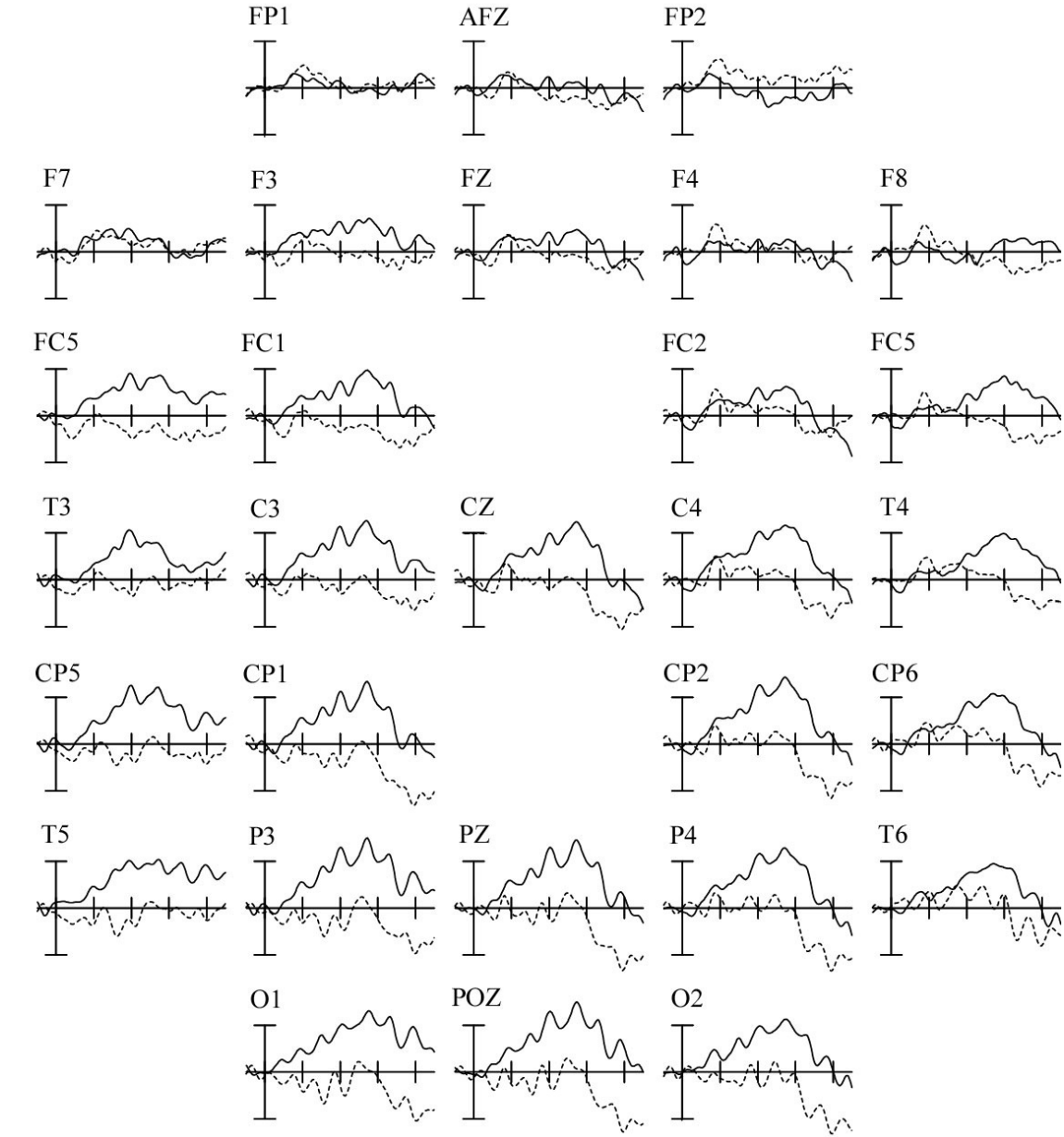


Figure 13 Grand Average ERP waveforms for the High Comprehenders to the coherent (dashed line) and incoherent final words in the Sentence Condition

Coherent and Incoherent conditions can be observed at posterior but not at anterior electrodes.

Table 19

***F* values and significance levels of the ANOVAs on the effect of Coherence in the Discourse Condition for the High Comprehenders**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 950 |
|------------------|-------|---------|-----------|-----------|-----------|-----------|
| COH | 1,6 | <1 | <1 | 1.18 | 3.1 | <1 |
| LOCATION | 1,6 | <1 | <1 | 1.23 | <1 | 4.43# |
| COH x LOC | 1,6 | 2.24 | 2.82 | 2.49 | 1.45 | <1 |
| COH x LOC x ELEC | 11,66 | <1 | 1.12 | <1 | <1 | <1 |

$p < 0.1$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

+ Greenhouse-Geisser adjusted p values

The effect of Coherence was larger in the window 500 – 700 ms ($-1.47 \mu\text{V}$) than in the window 300 – 500 ms ($-0.74 \mu\text{V}$); it interacted marginally with Electrode Site in the earlier window ($F(11,66)=2.44$; $p=0.08$) and significantly in the later one ($F(11,66)=2.44$; $p=0.045$). Post-hoc analyses reveal a significant main effect of Coherence at the posterior set of electrodes in both the time window 300 – 500 ms ($t=3.88$; $p=0.002$) and 500 – 700 ms ($t=2.96$; $p=0.011$) which is significantly larger in the later than the earlier window ($t=2.65$; $p=0.02$). No such effects are found in the window 700 – 100 ms.

2.3.3.3 EFFECTS OF CONTEXT

The waveforms for the coherent and incoherent CWs in the Discourse and Sentence conditions are re-arranged in Figures 15 and 16 in order to display the effects of Context. Figure 15 displays a direct comparison of the ERPs to the coherent CWs and Figure 16 for the incoherent CWs, respectively. The results of the ANOVAs (F values and significance levels) are summarized in Table 20 and 21 for the Coherent and Incoherent conditions, respectively.

**HIGH COMPREHENDERS (n=7)
DISCOURSE CONDITION**

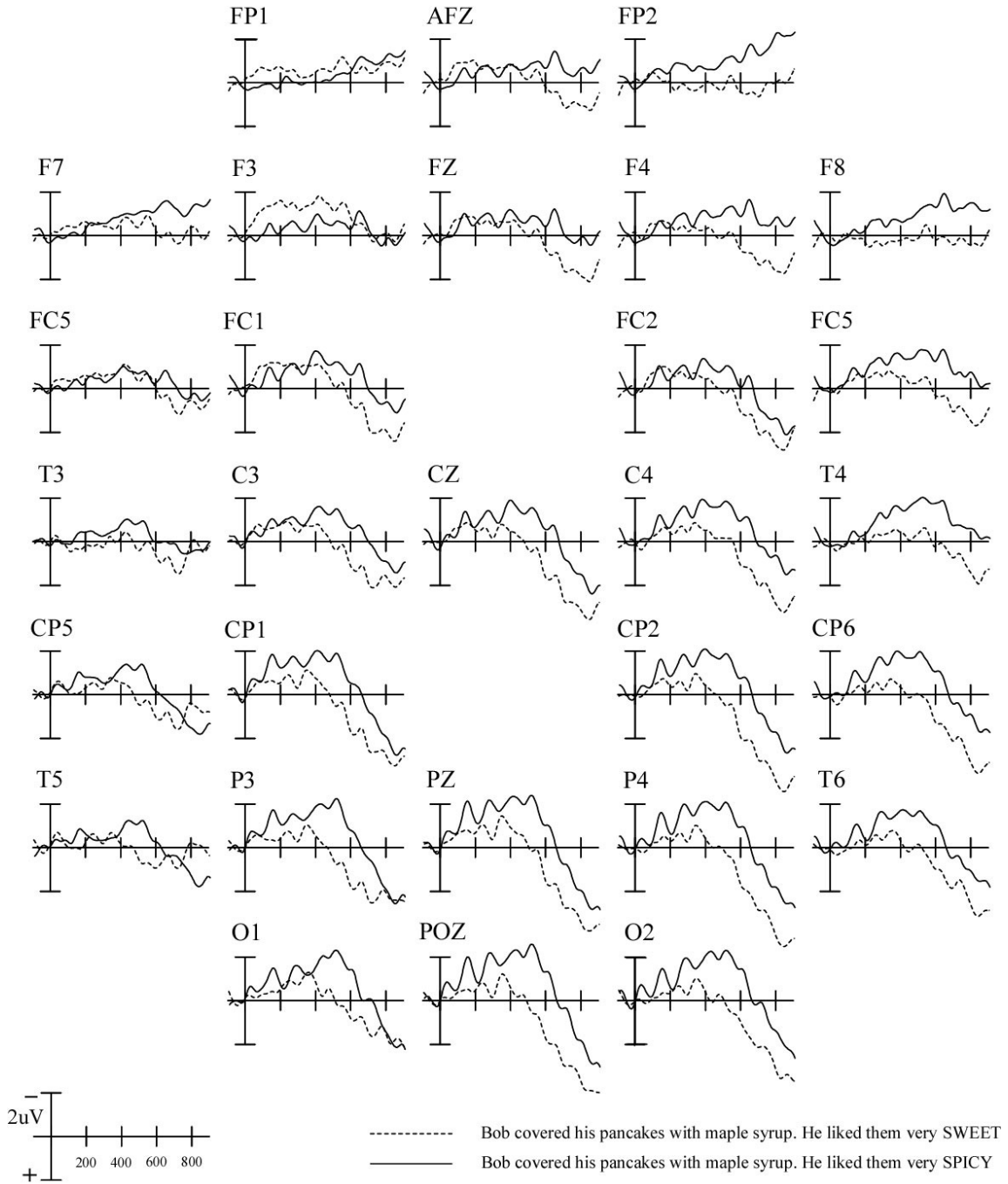


Figure 14 Grand Average ERP waveforms for the High Comprehenders to the coherent (dashed line) and incoherent final words in the Discourse Condition

2.3.3.3.1 COHERENT CONDITION

In Figure 15, the waveforms elicited by the coherent CWs in the Discourse and Sentence conditions are plotted. Already right after the onset of the CW, ERPs appear to be more negative in the Discourse than the Sentence condition over frontal electrodes. Following this early effect, the waveforms appear to be morphologically very similar in the two context conditions. It is not until about 700 ms after stimulus onset that the waveforms appear to be more positive in the Discourse than the Sentence conditions; this difference again does not have an obviously locally circumscribed distribution.

Table 20

***F* values and significance levels of the ANOVAs on the effect of Context in the Coherent condition for the High Comprehenders**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 950 |
|--------------------------------|-------|---------|-----------|-----------|-----------|-----------|
| CONTEXT | 1,6 | 1.31 | 1.63 | 1.16 | <1 | 1.35 |
| LOCATION | 1,6 | <1 | 1.4 | <1 | 1.29 | 3.63 |
| CONT x LOC | 1,6 | <1 | <1 | <1 | 3.03 | 2.21 |
| CONT x LOC x ELEC ⁺ | 11,66 | <1 | 2.12 | <1 | <1 | <1 |

$p < 0.1$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

+ Greenhouse-Geisser adjusted p values

In the earliest window (0 – 100 ms), no significant effect is obtained. Whereas, the effect does not have a clearly circumscribed topography. The marginally significant interaction between Context and Electrode ($F(11,66)=3.72$; $p=0.06$) appears to corroborate that there is a difference between the two context conditions. In the three following windows, again none of the effects is significant; nor did they interact with Electrode Site. In the latest window, ERPs appear to be more positive both at posterior than anterior electrodes and in the Discourse than the Sentence condition. Both Context ($F(11,66)=2.85$; $p=0.04$) and Location ($F(11,66)=3.32$; $p=0.04$) significantly interact with Electrode; this indicates that there are distributional differences between the two context conditions that do not have a topographically circumscribed distribution.

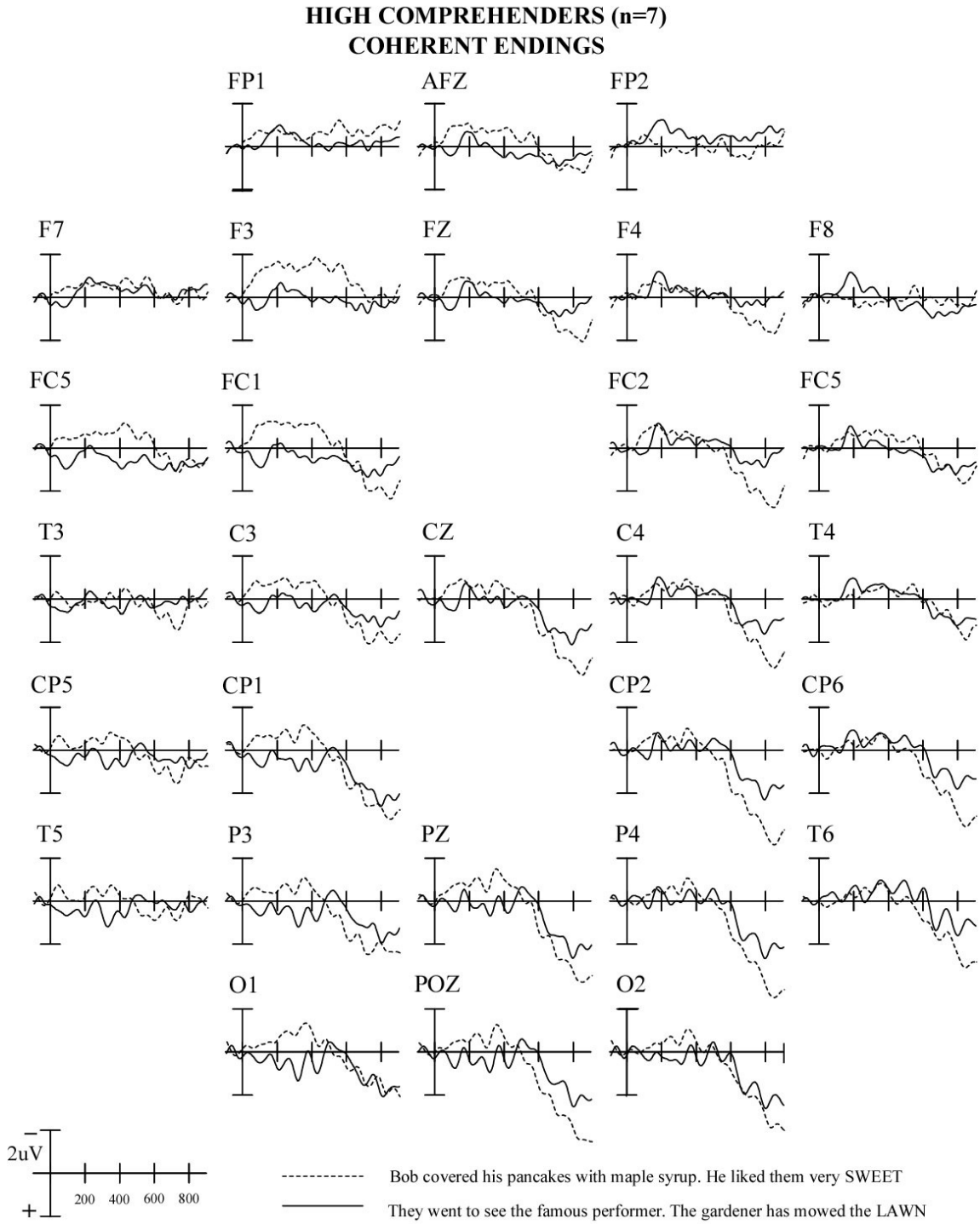


Figure 15 Grand Average ERP waveforms for the High Comprehenders in the Coherent condition elicited by the discourse (dashed line) and sentence (solid line) contexts

incoherent condition

Figure 16 displays the waveforms for the incoherent endings in the Discourse and Sentence conditions. Unlike in the Coherent condition, the waveforms do not appear to diverge immediately after stimulus onset. In both conditions, a negativity is obtained which is more pronounced at posterior than anterior electrode sites and which does not appear to differ between the two context conditions until about 500 ms after the onset of the stimulus. Starting at about 500 ms after stimulus onset, the waveforms appear to remain more negative in the Sentence than the Discourse condition.

Table 21

F values and significance levels of the ANOVAs on the effect of Context in the Incoherent Condition for the High Comprehenders

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 950 |
|--------------------------------|-------|---------|-----------|-----------|-----------|-----------|
| CONTEXT | 1,6 | 2.75 | <1 | <1 | <1 | 2.02 |
| LOCATION | 1,6 | 1.35 | 1.53 | 8.48* | <1 | <1 |
| LOC x ELEC ⁺ | 1,6 | <1 | <1 | <1 | 5.6# | 4.48# |
| CONT x LOC x ELEC ⁺ | 11,66 | 1.96 | 1.25 | <1 | 2.78# | 1.8 |

$p < 0.1$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

+ Greenhouse-Geisser adjusted p values

In both early windows, no significant main effects were obtained. In the time window 300 – 500 ms, the only significant main effect was that of Location: ERPs were more negative at posterior than anterior (i.e. at the typical N400 location) electrodes, but they did not differ between the two context conditions. In the following two windows (500 – 700 ms; 700 – 950 ms), the marginally significant interactions between Location and Electrode Site ($F(1,6)=5.6$; $p=0.055$ and $F(1,6)=4.48$; $p=0.078$) suggest that ERPs are overall more positive over the posterior than the anterior electrodes.

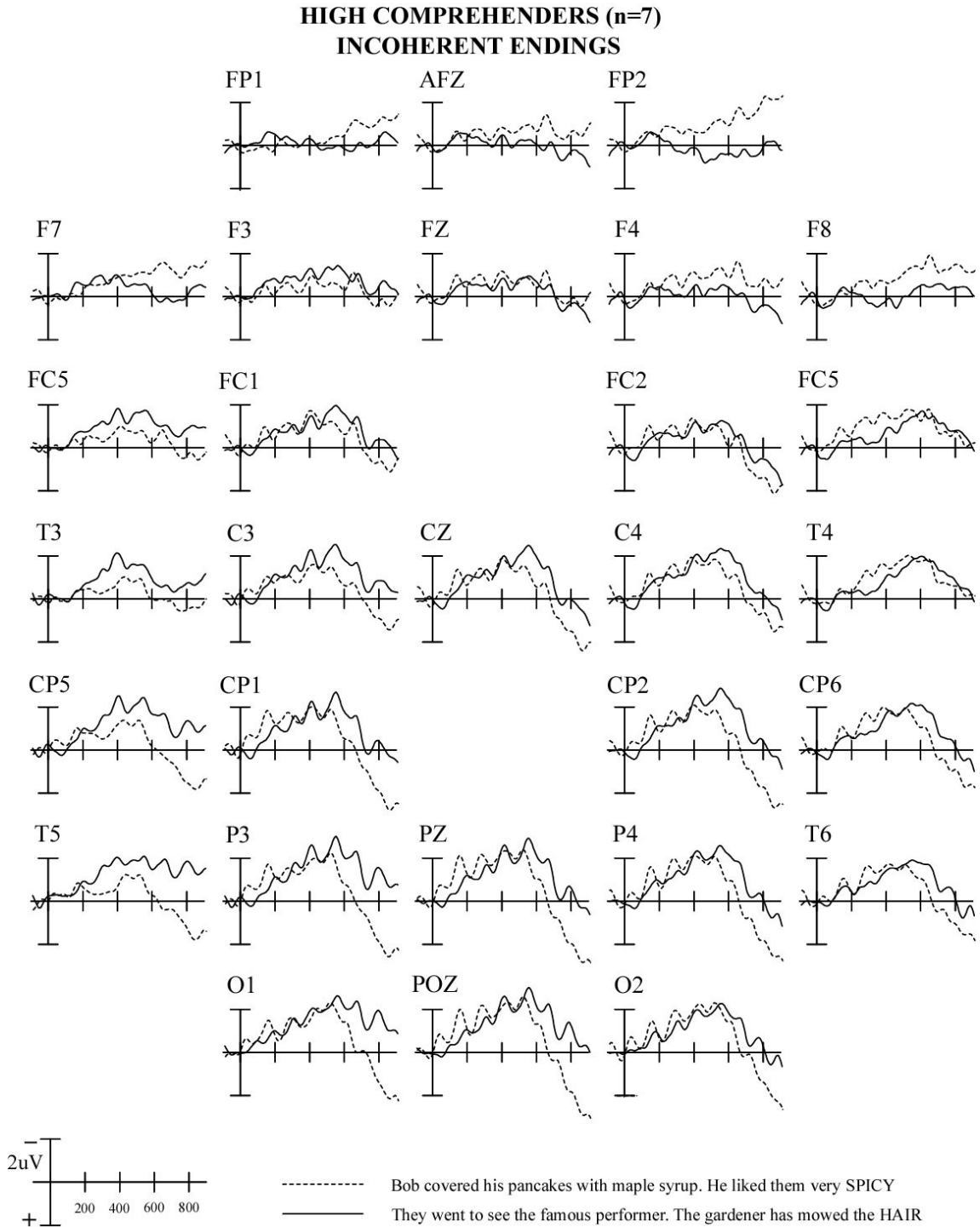


Figure 16 Grand Average ERP waveforms for the High Comprehenders in the Incoherent condition elicited by the discourse (dashed line) and sentence (solid line) contexts

**HIGH COMPREHENDERS (n=7)
DIFFERENCE WAVES**

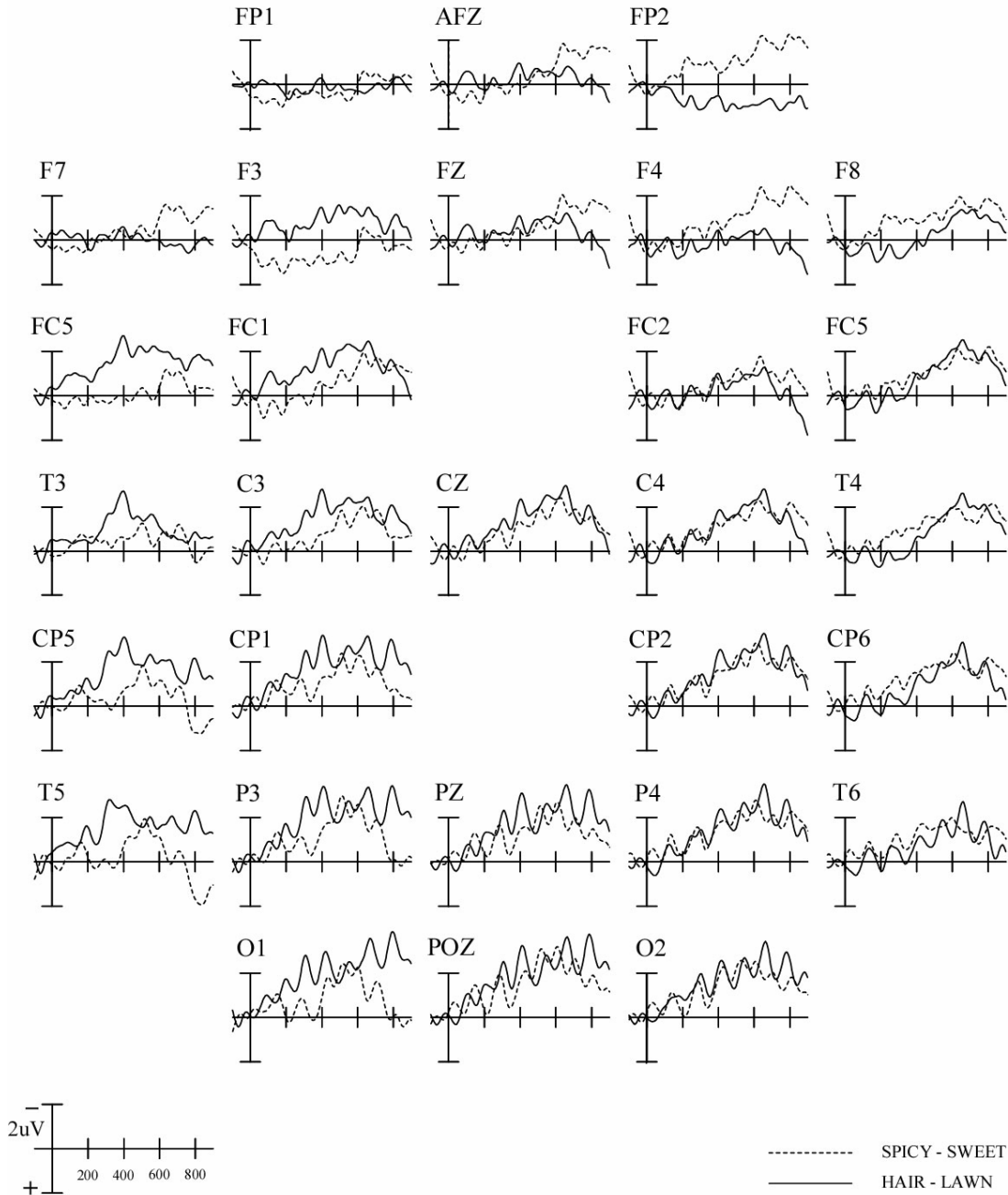


Figure 17 Difference waveforms for the High Comprehenders in the Discourse (dashed line) and Sentence (solid line) conditions. Difference waveforms were created by subtracting the ERPs elicited by the CWs in the coherent condition from those elicited in the incoherent condition

2.3.3.4 DIFFERENCE EFFECTS / ONSET ANALYSES

Difference waves were computed by subtracting the ERPs to the incoherent from the coherent endings for both the Discourse and Sentence conditions and are displayed in Figure 17. There was no effect for the factor Context in the time windows 300 – 500 ms and 500 – 700 ms ($F_s < 1$) indicating no differences in both time windows of the N400 between the Sentence and Discourse conditions. Thus, no further onset analyses were performed. Additional analyses investigated the potential difference in size of the N400 effects in the two windows in which it was investigated (300 – 500 ms & 500 – 700 ms); therefore, the factors Context (Sentence, Discourse) and Window (300 – 500 ms, 500 – 700 ms) were submitted to an ANOVA. In the Discourse, but not the Sentence condition, the effect of Context was highly more significant in the later than the earlier window ($t=3.89, p=0.002$) over the posterior set of electrodes.

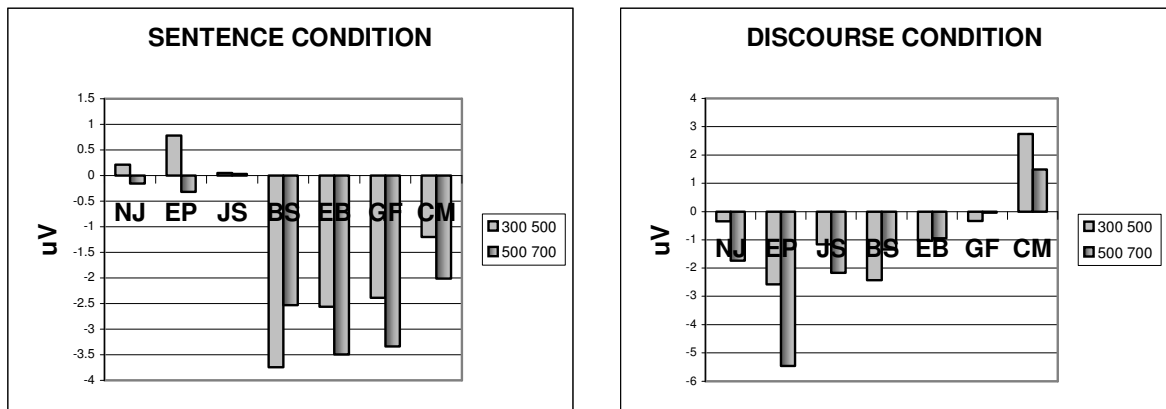


Figure 18 Single subjects difference effects for the High Comprehenders in the time windows 300 – 500 ms for the Sentence condition (left panel) and the Discourse condition (right panel).

2.3.4 Low Comprehenders

2.3.4.1 OVERALL ANALYSES

The results of the initial OMNIBUS ANOVA (F values and significance levels) investigating the effects of Context and Coherence in the five time windows are displayed in Table 22. Overall rejection rates were 21.2% with 18.3% in the Discourse and 24.1% in the Sentence condition.

Table 22

F values and significance levels of the OMNIBUS ANOVAs on the effects of Context and Coherence for the Low Comprehenders

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|--------------------------------|--------|---------|-----------|-----------|-----------|------------|
| CONTEXT | 1,4 | <1 | 1.05 | <1 | <1 | <1 |
| CONT x ELEC ⁺ | 28,112 | <1 | <1 | <1 | <1 | <1 |
| COH | 1,4 | 4.33 | 4.6# | <1 | 1.02 | <1 |
| COH x ELEC ⁺ | 28,112 | <1 | <1 | <1 | <1 | 1.09 |
| CONT x COH | 1,4 | <1 | <1 | 2.49 | 2.51 | 1.69 |
| CONT x COH x ELEC ⁺ | 28,112 | <1 | 1.65 | <1 | <1 | <1 |

$p < 0.1$ $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

+ Greenhouse-Geisser adjusted p values

In the overall analyses, no significant effects were obtained in any time window. In the following, I am going to report separate analyses for the effects of Coherence and Context.

2.3.4.2 EFFECTS OF COHERENCE

Figure 18 displays the ERPs to the coherent and incoherent CWs for the Sentence condition and the Figure 19 for the Discourse condition. The results of the ANOVAs (F values and significance levels) for the effects of Coherence are displayed in Tables 23 and 24 for the Sentence and Discourse conditions, respectively. Note that due to clipping in one subject, ERPs could only be averaged until 950 ms after stimulus onset.

2.3.4.2.1 SENTENCE CONDITION

Figure 19 displays the ERPs for the coherent and incoherent endings in the Sentence condition. Already very early on, ERPs diverge between the two conditions. ERPs are overall negative in the Coherent and overall positive in the Incoherent condition. Note however, that the baseline differs between the two conditions. In both conditions, a negative deflection can be seen between 300 and 700 ms over posterior electrode sites which does not appear to differ between the two conditions. However, coherent endings elicit more negative-going ERPs over anterior electrodes than do the incoherent endings. After about 800 ms, both conditions converge back to baseline.

Table 23

***F* values and significance levels of the ANOVAs on the effect of Coherence in the Sentence Condition for the Low Comprehenders**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|-------------------------------|-------|---------|-----------|-----------|-----------|------------|
| COH | 1,4 | 5.25 | <1 | <1 | 2.21 | <1 |
| LOCATION | 1,4 | 1.82 | 2.64 | <1 | <1 | 4.7# |
| COH x LOC | 1,4 | 2.3 | <1 | 4.08 | 6.87 | <1 |
| COH x LOC x ELEC ⁺ | 11,44 | <1 | <1 | <1 | <1 | <1 |

$p < 0.1$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

+ Greenhouse-Geisser adjusted p values

In the two early windows, none of the effects reached significance. ERPs are marginally more negative ($F(1,4)=6.7$; $p=0.06$) in the Coherent than the Incoherent condition in the window 500 – 700 ms, and marginally more negative over anterior than over posterior electrodes ($F(1,4)=4.7$; $p=0.09$) in the window 700 – 950 ms.

LOW COMPREHENDERS (n=5)

SENTENCE CONDITION

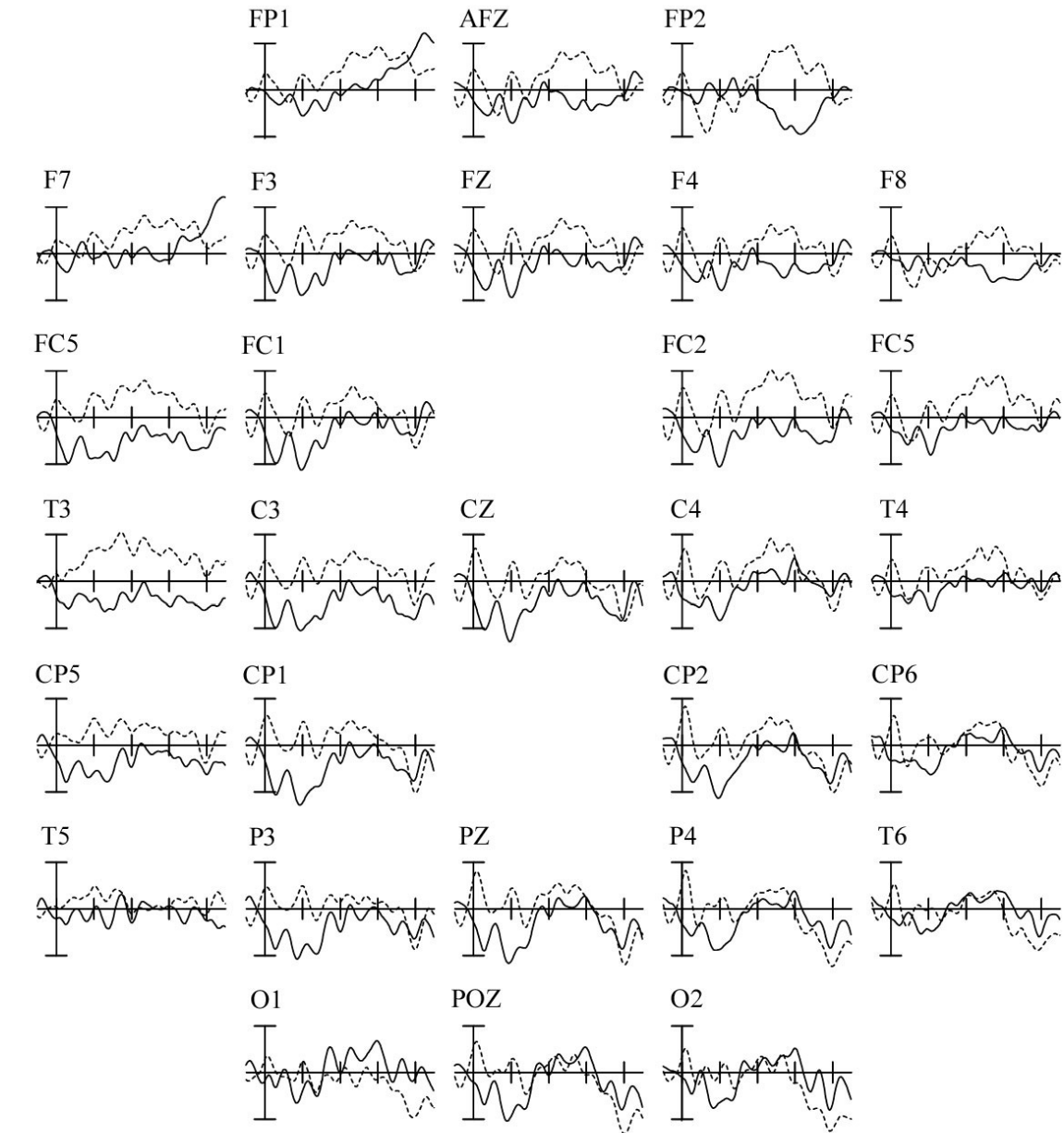


Figure 19 Grand Average ERP waveforms for the Low Comprehenders for to the coherent (dashed line) and incoherent final words in the Sentence Condition

2.3.4.2.2 DISCOURSE CONDITION

Figure 20 shows the ERPs elicited in the Discourse Condition. Unlike in the two control groups and the group of the High Comprehenders, no clearly defined components with respect to morphology and topography can be seen; coherent endings elicit slightly more negative-going ERPs than do incoherent endings, this is more so over anterior than over posterior electrodes. Statistical analyses do not indicate any significant differences; the results are displayed in Table 24.

Table 24

F values and significance levels of the ANOVAs on the effect of Coherence in the Discourse Condition for the Low Comprehenders

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|------------------|-------|---------|-----------|-----------|-----------|------------|
| COH | 1,4 | <1 | <1 | <1 | <1 | <1 |
| LOCATION | 1,4 | <1 | <1 | <1 | <1 | 1.07 |
| COH x LOC | 1,4 | <1 | 1.91 | 2.5 | 2.24 | 1.98 |
| COH x LOC x ELEC | 11,44 | <1 | <1 | <1 | <1 | <1 |

$p < 0.1$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

+ Greenhouse-Geisser adjusted p values

None of the statistical analyses indicate significant differences between the coherent and incoherent endings in the Discourse condition for the Low Comprehenders.

2.3.4.3 EFFECTS OF CONTEXT

The waveforms for the coherent and incoherent CWs in the Discourse and Sentence conditions are re-arranged in Figures 21 and 22 in order to display the effects of Context. Figure 21 displays a direct comparison of the ERPs to the coherent CWs in the Discourse and Sentence conditions and Figure 22 for the incoherent CWs, respectively. The results of the ANOVAs (*F* values and significance levels) are summarized in Table 25 and 26 for the Coherent and Incoherent conditions, respectively.

2.3.4.3.1 COHERENT CONDITION

In Figure 21, the waveforms elicited by the coherent CWs in the Discourse and Sentence conditions are plotted. No clear early differences can be seen between the Discourse and Sentence conditions. Already right after the onset of the CW, ERPs appear to be more.

**LOW COMPREHENDERS (n=5)
DISCOURSE CONDITION**

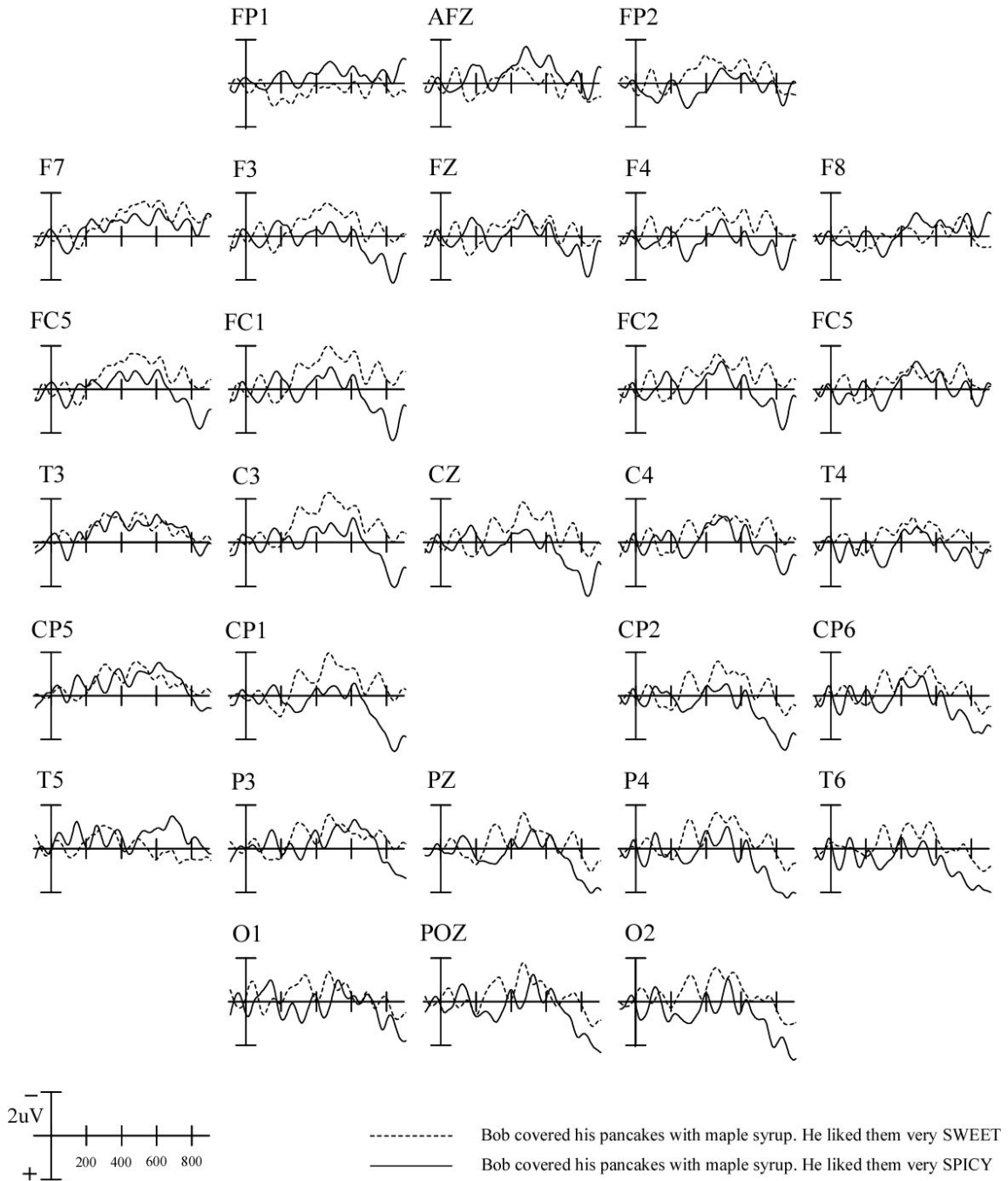


Figure 20 Grand Average ERP waveforms for the Low Comprehenders for the to the coherent (dashed line) and incoherent final words in the Discourse Condition

The waveforms appear to be morphologically very similar in the two context conditions. It is not until about 700 ms after stimulus onset that the waveforms appear to be more positive in the Discourse than the Sentence conditions; this difference again does not have an obvious locally circumscribed distribution.

Table 25
***F* values and significance levels of the ANOVAs on the effect of Context in the Coherent condition for the Low Comprehenders**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|--------------------------------|-------|---------|-----------|-----------|-----------|------------|
| CONTEXT | 1,6 | 1.31 | 1.63 | 1.16 | <1 | 1.35 |
| LOCATION | 1,6 | <1 | 1.4 | <1 | 1.29 | 3.63 |
| CONT x LOC | 1,6 | <1 | <1 | <1 | 3.03 | 2.21 |
| CONT x LOC x ELEC ⁺ | 11,66 | <1 | 2.12 | <1 | <1 | <1 |

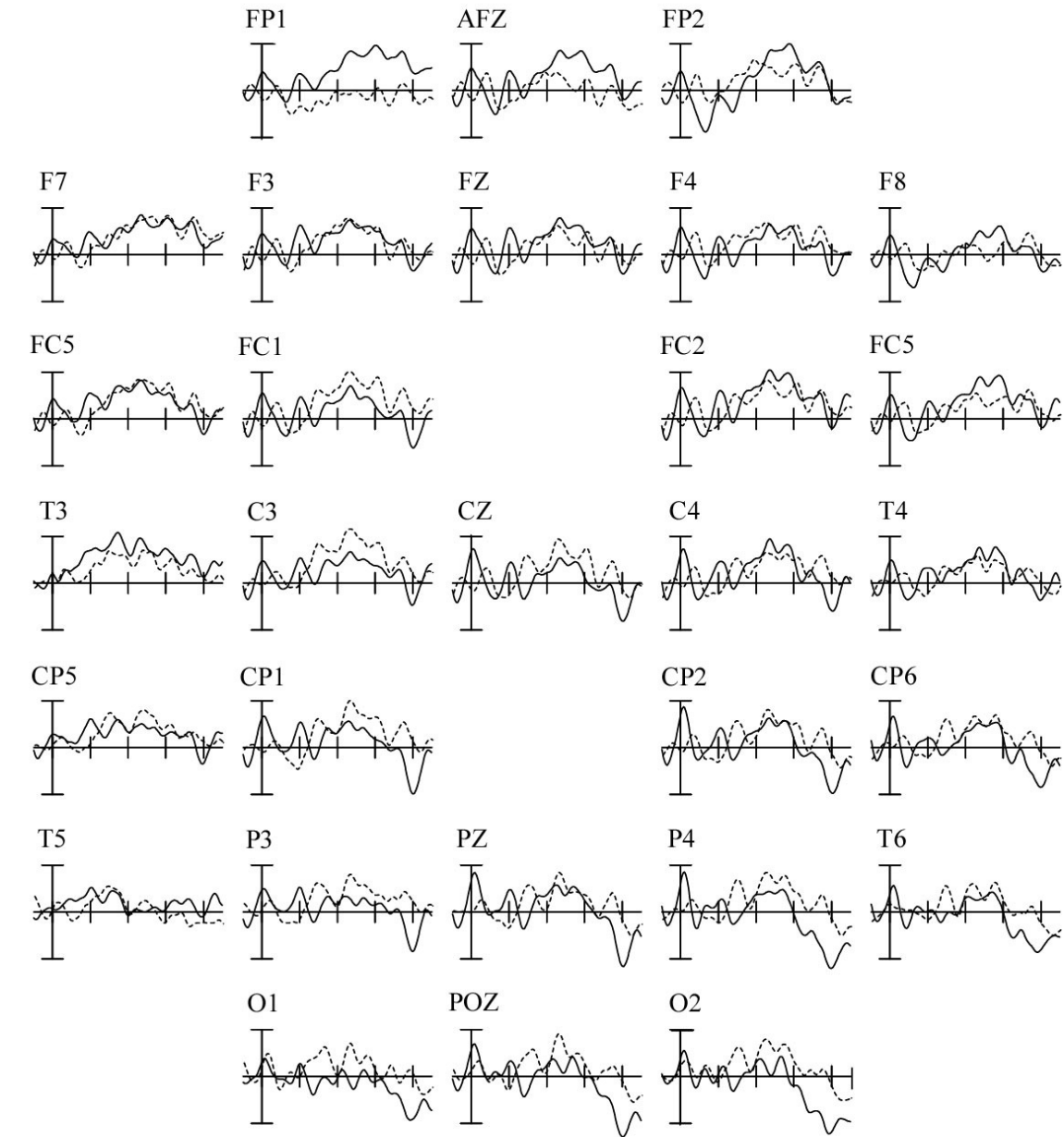
p<0.1 * p<0.05 ** p<0.01 ***p<0.001
 + Greenhouse-Geisser adjusted p values

Again, none of the statistical analyses reach significance. This supports the notion that there are no differences both with respect to amplitude and distribution for the coherent endings in the two context conditions.

2.3.4.3.2 INCOHERENT CONDITION

Figure 22 displays the waveforms for the Incoherent condition elicited in the Discourse and Sentence contexts. Unlike in the Coherent condition, the waveforms do appear to diverge immediately after stimulus onset; they are more positive in the Sentence than the Discourse condition. Following this early difference, waveforms appear to be morphologically similar, but no clear components can be distinguished with respect to morphology and topography. Over anterior sites, ERPs appear to be more negative in the Discourse than the Sentence condition. Results of the ANOVAs done in the Incoherent condition are displayed in Table 26.

**LOW COMPREHENDERS (n=5)
COHERENT ENDINGS**



----- Bob covered his pancakes with maple syrup. He liked them very SWEET
 _____ They went to see the famous performer. The gardener has mowed the LAWN

Figure 21 Grand Average ERP waveforms for the Low Comprehenders to the coherent final words in the Discourse (dashed line) and Sentence (solid line) Condition

LOW COMPREHENDERS (n=5)
INCOHERENT ENDINGS

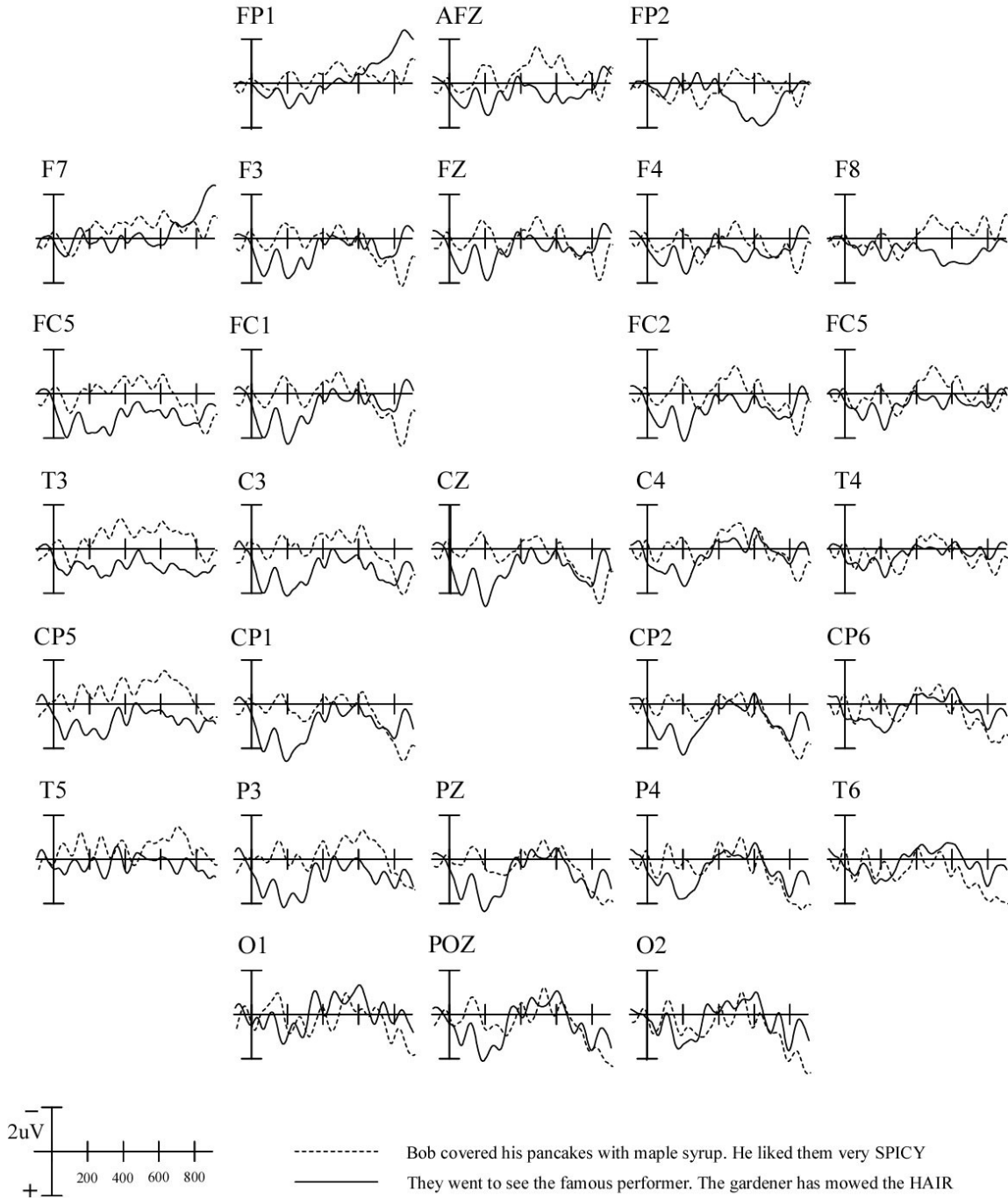


Figure 22 Grand Average ERP waveforms for the Low Comprehenders to the incoherent final words in the Discourse (dashed line) and Sentence (solid line) Condition

Table 26

***F* values and significance levels of the ANOVAs on the effect of Context in the Incoherent Condition for the Low Comprehenders**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|--------------------------------|-------|---------|-----------|-----------|-----------|------------|
| CONTEXT | 1,4 | <1 | <1 | <1 | <1 | <1 |
| LOCATION | 1,4 | 1.46 | <1 | <1 | <1 | 3.04 |
| CONT x LOC | 1,4 | <1 | 1.38 | <1 | <1 | <1 |
| CONT x LOC x ELEC ⁺ | 11,44 | <1 | <1 | <1 | <1 | <1 |

$p < 0.1$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

+ Greenhouse-Geisser adjusted p values

As for the coherent endings, no statistically significant differences are obtained for the incoherent endings.

2.3.4.4 DIFFERENCE EFFECTS / ONSET ANALYSES

Difference waves were computed by subtracting the ERPs elicited in the coherent from those of the incoherent endings for both the Discourse and Sentence conditions. They show the absence of clearly defined ERP components. There was no significant main effect for the factor Context in the time window 300 – 500 ms and 500 – 700 ms ($F_s < 1$) indicating no differences in both time windows of the N400 between the Sentence and Discourse conditions. Further onset analyses did not reveal any differences between the two conditions. The waveforms are displayed in Figure 24.

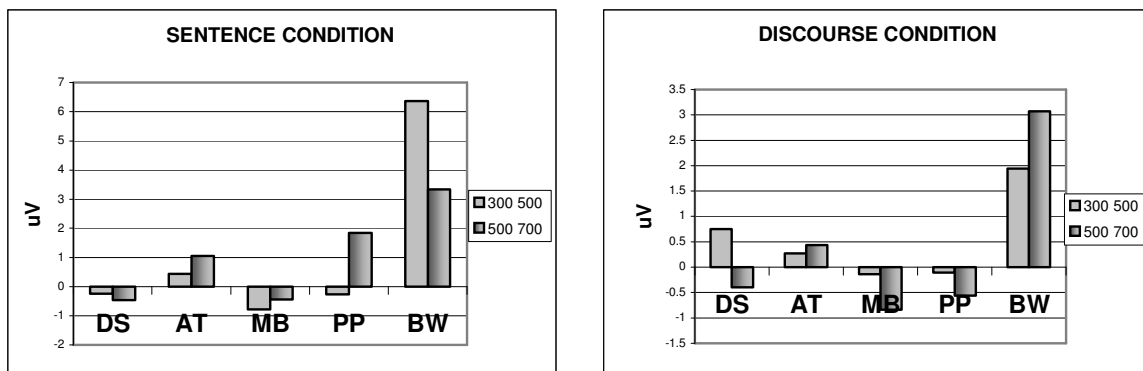


Figure 23 Single subjects difference effects for the High Comprehenders in the time windows 300 – 500 ms for the Sentence condition (left panel) and the Discourse condition (right panel).

LOW COMPREHENDERS (n=5)
DIFFERENCE WAVES

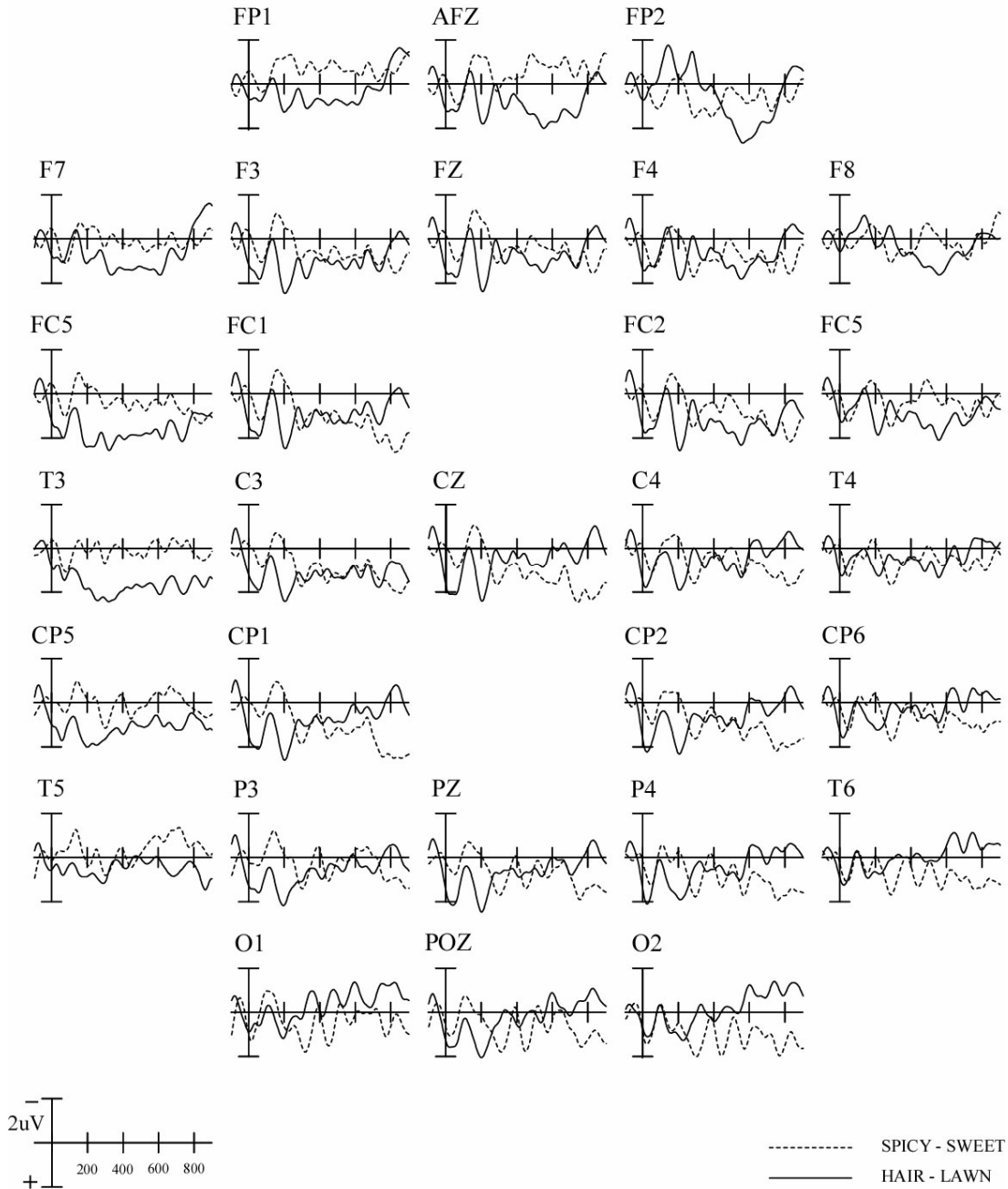


Figure 24 Difference waveforms for Low Comprehenders in the Discourse (dashed line) and Sentence (solid line) conditions. Difference waveforms were created by subtracting the ERPs elicited by the CWs in the coherent condition from those elicited in the incoherent condition

2.4 DISCUSSION

In our daily lives we constantly use language both actively and passively in a highly proficient manner. Most rarely however do we realize the enormous computational demands its complexity imposes on our brains nor the ease with which it masters them. Hardly ever do we converse by means of single sentences and even more rarely by means of single words. Most frequently, we utilize coherent discourse when engaged in conversations with other people. Despite the vast ubiquity of discourse in every day conversations, it has received surprising little attention in psycholinguistic research – at least compared to single words and single sentences. The devastating consequences of a breakdown of the language system can be observed in patients who suffer from aphasia as a consequence of brain damage in the left perisylvian area. Studies examining the comprehension deficits of aphasic patients for spoken language so far have focused primarily on single words or short sentences and thus far, the investigation of timing aspects of discourse comprehension in these patients has been largely neglected. Studies on discourse processing in aphasic patients have focused primarily on the production of discourse and less on timing aspects of comprehension. And no study so far has used ERPs to investigate discourse processing in aphasic patients.

The purpose of the ERP studies I conducted for my dissertation was to further elucidate temporal aspects of the nature of aphasic comprehension deficits. I wanted to contrast the hypotheses of an underlying activation vs. integration deficit by manipulating the amount and kind of context information that aphasic patients might utilize in order to aid comprehension in sentence and discourse contexts. Moreover, some light was supposed to be shed onto the cortical areas that subserve discourse processing, and the relative contributions of fronto-median and RH areas was to be investigated.

On more general grounds, I wanted to test the hypothesis of interactive vs. modular processing of discourse information. In the case of modular processing, the content of a local sentence would have to be processed before it can be integrated into a global context; thus, N400 effects should be delayed in a discourse relative to a sentence context; in the case of interactive processing, i.e. if local and global context are processed concurrently, no such timing differences should be observed.

Activation deficits have been proposed mainly in studies using priming between single words and have focused on phonological rather than semantic aspects of the input (e.g.

Milberg & Blumstein, 1981; Blumstein, et al., 1982; Milberg et al., 2003; Prather et al., 1997; Misiurski et al., 2005; Utman et al., 2001). Moreover, it has been proposed that aphasics rely more strongly on the semantic content of an utterance which they use in a heuristic way to aid comprehension (e.g. Zurif, Caramazza, & Myerson, 1972; Caramazza & Zurif, 1976; Milberg et al., 1995; Hagoort et al., 2003) In the present study, I used lexical association between words presented in sentence and discourse contexts to see whether this also holds for more natural processing conditions and if so, for how long these effects might last. Under the assumption of aphasia as an activation deficit, lexical-semantic relationships between the CWs and preceding content words should help patients in comprehension of the CWs. Because the effects of lexical association are relatively short-lived, this effect should be stronger in the sentence than the discourse condition: the N400 effects should be bigger in the Sentence than the Discourse condition.

Integration deficits have been proposed in ERP studies (Hagoort, 1989; Hagoort, 1997; Hagoort et al., 1996; Swaab et al., 1997, 1998) using both lexical priming, lexical ambiguity resolution and semantic violations. In these studies, however, ERPs were obtained from only seven electrodes, which makes it statistically easier to obtain significant results and harder to make claims about potential distributional differences of the effects. If comprehension deficits of aphasic patients are due to an integration deficit, the amount of context to be integrated should critically affect processing: thus, N400 effects should be delayed in the Discourse relative to the Sentence condition.

Both activation and integration deficits should vary as a function of the comprehension deficits examined with the BDAE.

Two groups of patients and two control groups were tested – a group of healthy young adults should establish a standard effect for the materials developed, and an age-matched control group should control for age-differences. I am going to discuss the results separately for each group of subjects.

2.4.1 Young Controls

Separate analyses investigated the differential effects of Coherence in the two context conditions as well as the effect of Context under the two coherence conditions. I am first going to discuss the effect of Coherence separately for the Sentence and Discourse conditions

and then, I am going to report the effects of Context for the Coherent and Incoherent conditions.

2.4.1.1 EFFECTS OF COHERENCE

2.4.1.1.1 SENTENCE CONDITION

No clear N1-P2 complex can be distinguished for the coherent and incoherent final words in the Sentence condition. This is consistent with findings from other ERP studies with connected speech (Holcomb & Neville, 1990; van Berkum, et al., 1999, 2003; Swaab et al., 1997, 1998). Early ERP components require longer separation from preceding materials in order to gain their maximum amplitudes. In the earliest time window, none of the effects reached significance which shows that subjects are not sensitive to semantic aspects of the sentence context at this early stage. The large and highly significant N400 effect has an early onset which is already expressed in the window 100 – 300 ms. It is maximal in the window 300 – 500 ms and has a centro-posterior maximum which indicates that subjects are sensitive to the anomalous semantic violations and replicates numerous previous studies (for a recent review see Friederici, 2004). The N400 is followed by a positivity which was maximal between 700 – 1000 ms over posterior electrode sites and which was significantly more positive for the incoherent than the coherent endings. This late positive complex (LPC) is most commonly interpreted as reflecting sentence-wrap-up processes as well as effects of memory (Rugg, 1990; Paller, Kutas, & McIsaac, 1995; Swick, 1998). The differential effects obtained for the coherent and incoherent endings suggest that coherent sentences are easier to wrap-up than incoherent ones. In other words, the integration of a coherent word into a sentence context is followed by a rather effortless wrap-up, whereas the failure of integration of an incoherent ending is followed by a more effortful wrap-up process.

2.4.1.1.2 DISCOURSE CONDITION

Like in the Sentence condition, no sensory ERP components can be distinguished which indicates no early sensitivity to the coherence of the discourse. Unlike in the Sentence condition however, early topographic differences are found for both conditions. Already right after the onset of the CW, ERPs are significantly more negative in both conditions over anterior than over posterior electrode sites in the window 0 – 100 ms. This effect is only found in the Discourse but not the Sentence condition and may be interpreted as an increased working memory load (Müntz, Schiltz, & Kutas, 1998) preceding the integration of a word

into a discourse context irrespective of its coherence with the overall context. A clear and highly significant N400 with a centro-posterior maximum is obtained. This indicates that subjects are also sensitive to semantic violations in a discourse context and that they can use the overall context to constrain a sentence that is unconstrained when presented in isolation. Both endings were rated equal with respect to both cloze probability and plausibility in the pretests, and ERP results show that subjects can use the discourse context that renders one ending as the best completion and one as a violation on a similar time scale as in a sentence context. The finding that coherent words are easily integrated into a discourse context is consistent with earlier ERP studies on discourse processing (van Berkum et al., 1999, 2003). Following the N400 effect, both conditions elicit a positivity that was investigated in two consecutive time windows. It is larger over posterior than anterior sites and in contrast to the Sentence condition, it does not differ between the coherent and incoherent endings. Since in linguistic contexts, the LPC most likely reflects sentence-wrap-up processes as well as effects of memory, the lack of a difference between the coherent and incoherent endings in the later time window suggests similar wrap-up and memory processes after both endings are integrated into the discourse context irrespective of their coherence.

2.4.1.2 EFFECTS OF CONTEXT

2.4.1.2.1 COHERENT CONDITION

Already right after the onset of the CWs, ERPs are bilaterally more negative over anterior electrodes in the Discourse condition. This difference persists until about 300 ms after stimulus onset. This effect does not have similarities with the Early Left Anterior Negativity (ELAN; for recent reviews see Friederici, 1997 and Friederici and Kotz, 2003) which has been described as reflecting automatic aspects of parsing in the case of syntactic violations. This very early, i.e. prelexical, effect might be interpreted as a more effortful retrieval of a word due to an increased working memory load in a discourse than a sentence context (e.g. Münte et al., 1998). In the time window of the N400, no differences are obtained between the two context conditions over the centro-posterior electrodes. This indicates that there are no differences for the lexical integration of a word into a sentence or a discourse context when it matches the respective context. Finally, in two later time windows between 500 and 1000 ms, the LPC is more pronounced in the Discourse than the Sentence condition. This late effect can be interpreted as an increased effort in wrapping up a discourse context

than a sentence context, even if the word that has to be integrated is coherent in the respective context. These results suggest that discourse information is more effortful to retrieve from working memory than sentence information; whereas, once it has been retrieved, it is as easily integrated. However, the wrap-up process following the integration process appears more effortful in a discourse than a sentence context.

2.4.1.2.2 *INCOHERENT CONDITION*

As for the coherent endings, a very similar pattern of results is obtained for the incoherent endings: again, right after the beginning of the CW, ERPs are bilaterally more negative in the Discourse than the Sentence condition. Whereas, for the incoherent endings, this is not confined to the anterior electrodes only. This difference persists again until about 300 ms after stimulus onset. In the N400 time window, ERPs are more negative over the posterior than the anterior electrodes, but there are no differences between the two Context conditions. This means that subjects are equally sensitive to a semantic violation in both contexts. There appears to be a difference in the offset of the effect between the two context conditions; therefore, the N400 time window was fractioned into an earlier (300 – 400 ms) and a later (400 – 500 ms) half. There was no effect of Context in the earlier half and a highly significant effect of Context in the later half. This indicates that there were no onset differences between the two conditions, but a more prolonged effect in the Sentence than the Discourse condition. This effect carries over into the window 500 – 700 ms. In the latest window, no differences between the two context conditions are obtained. This indicates similarly effortful wrap-up processes for incoherent endings in both sentence and discourse contexts; in other words, if a word does not match its context, for the wrapping up, it does not matter whether this context is a sentence or a discourse. Taken together, as for the coherent endings, a discourse context also poses more effortful retrieval for an incoherent word than does a sentence context. It is important to note that this happens prelexically, i.e. before the listener knows whether the word will match the context or not. Similarly, comparable integration processes are observed in the two contexts; the effect has a similar onset in both context conditions, but it is more prolonged in a sentence than a discourse context. And finally, after the process of integration, no differential wrap-up processes are obtained for the two context conditions. This means that once a word is difficult to integrate into a context, for the wrapping up, it does not matter whether this context is a single sentence or a discourse; they both require similar efforts.

2.4.1.3 GENERAL DISCUSSION

Young healthy adults are similarly sensitive to semantic violations in sentence and discourse contexts and do not show timing differences for the integration of CWs into either context. This is indicative of interactive processing of discourse context, i.e. local and global coherence are computed concurrently. However, a discourse context poses stronger demands on processing aspects both preceding and following the integration: a discourse context draws stronger processing demands on verbal working memory in which it has to be kept active or from which it has to be retrieved from – something that can not be differentially distinguished with the current paradigm. Moreover, it also poses stronger demands on the process involved in wrapping up the information: no matter whether a word is coherent or incoherent in a discourse context, it poses the same demands on the wrap-up process as a semantic violation. It is more difficult to retrieve from working memory and harder to wrap up irrespective of how well the CW fits its respective context. Because this effect is observed so early, i.e. before the subject can appreciate whether the word that is to be integrated is coherent with the context or not, this is in line with the discourse models described by Albrecht & O'Brien (1993), Albrecht & Mason, 1994; Myers, O'Brien & Albrecht & Mason (1994) and O'Brien & Albrecht (1992), which state that there is constant mapping of global and local coherence. This finding is inconsistent with the minimal hypothesis (McKoon & Ratcliff, 1992) which states that discourse information is only activated in the case of a break of local coherence; in the present case, discourse information is already activated before the subject can know whether the respective word is coherent or not. Also the results of the wrap-up effect contradict the minimal hypothesis because it does not differ between the coherent and incoherent endings. If the subject was sensitive to breaks between local and global coherence, one would expect differential wrap-up effects between the coherent and incoherent discourse endings.

2.4.2 Elderly Controls

As for the Young Controls, I am going to separately discuss the effects of Coherence for the two context conditions and the effects of Context for the Coherent and Incoherent conditions.

2.4.2.1 EFFECTS OF COHERENCE

2.4.2.1.1 SENTENCE CONTEXT

The Elderly Adults show a qualitatively similar pattern of results in the Sentence Condition as the Young Adults. Also here, no clear sensory components and no early effects of Coherence are obtained. A highly significant N400 effect is obtained which is maximal over posterior electrodes indicates that the Elderly Adults are sensitive to semantic violations in the sentence context. In the time windows following the N400, ERPs are significantly more positive over posterior than over anterior electrodes, and the interaction with Coherence only approaches significance; this indicates a tendency towards a slightly more difficulty for wrapping up the incoherent than the coherent ending of a sentence.

2.4.2.1.2 DISCOURSE CONDITION

In the Discourse condition, the Elderly Adults also do not show early effects of Coherence. When considering the entire set of electrodes, the N400 effect only approaches significance; therefore, additional analyses examined the effect over the posterior electrodes where it is maximal. In this case, the effect is significant which extends the validity of previous results from van Berkum et al. (1999, 2003) to an elderly subject group as well. Like the Young Adults, the Elderly Adults can use discourse context in order to constrain a sentence which is unconstrained when presented in isolation. Two causes might be responsible for this smaller effect: first, there are only 12 subjects in the group, which yields a poorer signal-to-noise ratio, and elderly subjects usually tend to have smaller ERPs than young subjects. And second, in four of the twelve subjects, the incoherent endings elicited P600-like rather than N400-like ERP effects. The P600 is commonly associated with repair aspects of syntactic processing and more generally with revision (for an overview see Kaan & Swaab, 2002, 2003); this might be interpreted as the elderly subjects being maybe less susceptible to semantic aspects of the discourse context which they appear to revise rather than integrate. Recently, Federmeier & Kutas (2005) have shown that elderly adults are impaired in their ability to use context to facilitate lexical integration.

2.4.2.2 EFFECTS OF CONTEXT

2.4.2.2.1 COHERENT CONDITION

Like the Young Adults, the Elderly Adults show early bilateral effects of Context over the anterior electrodes for the coherent endings suggesting more difficult retrieval of discourse information from working memory. No differences are found in the time window and location where the N400 is usually obtained, thus, in both conditions, words are equally easily integrated. Unlike for the Young Adults, in the two latest time windows, ERPs differ with respect to Location but not with respect to Context. This suggests equally effortful or effortless wrapping up of both sentence and discourse contexts – if they are coherent.

2.4.2.2.2 INCOHERENT CONDITION

Unlike for the coherent endings and unlike for the Young Adults as well, the Elderly Adults do not show significant effects of Context for the incoherent endings. Visual inspection of the waveforms however indicates that both context conditions elicit more negative-going ERPs. In this case, the sentence context appears to draw comparable demands on working memory retrieval as the discourse context. The N400 is larger over the posterior than over the anterior electrodes, i.e. at the usually observed location. It does not differ between the two context conditions, which indicates equally effortful integration of a CW into a sentence and a discourse context. The N400 effect is more sustained in the Sentence than the Discourse condition, as indicated by the significant effect of Context in the window 500 – 700 ms. In the wrap-up phase, ERPs are more negative over the posterior electrodes, and more so in the Discourse than the Sentence condition, which replicates the findings for the Young Controls and indicates that the wrap-up process is more effortful in a discourse than a sentence context..

2.4.2.3 GENERAL DISCUSSION

The effects for the Elderly Adults are qualitatively similar to those for the Young Adults. They are equally sensitive to semantic violations in both sentence and discourse contexts, which are resolved on comparable time scales as indicated by the lack of onset differences of the effects in both contexts and integrates previous findings on discourse processing in young subjects and semantic integration in elderly adults (van Berkum et al., 1999, 2003; Federmeier & Kutas, 2005). This is again indicative of interactive rather than

modular processing of discourse information. ERP effects are overall less strong for the Elderly than for the Young Adults which is observed in healthy aging (e.g. Federmeir et al., 2003).

2.4.3 High Comprehenders

ERPs are overall noisier for the patients than for both control groups. The disadvantageous signal-to-noise ratio is due to a smaller group size ($n=7$) than in the control groups; application of an algorithm to correct for oculomotor artifacts yielded rejection rates comparable to the controls. The concession to resort to use this correction was made in order to avoid inducing a dual-task situation for the patients in which they not only would have to do the language comprehension task but also perform a go/no-go task with respect to withholding blinking in certain periods and exert it in others. Like for the two control groups, I am going to discuss the effects of Coherence and Context separately also for the High Comprehenders

2.4.3.1 EFFECTS OF COHERENCE

2.4.3.1.1 SENTENCE CONDITION

The group of the High Comprehenders does not show early sensory components and also no early effects of Context in the Sentence condition. Visual inspection of the waveform suggests that not the onset, but the peak of the N400 effect is delayed in the Sentence condition. This is confirmed statistically with the main effect of Context being significant in the later (500 – 700 ms) but not the earlier window (300 – 500 ms), in which it interacts with Location. Furthermore, the effect of Coherence is significantly larger in the later than the earlier time window. The High Comprehenders are sensitive to semantic violations in a sentence context, but they do not come to fully appreciate it until a later point in time.

Due to clipping in one of the subjects, data could be averaged only until 950 ms after stimulus onset; thus, the window necessary to capture the entire wrap-up process might simply be too short. Overall morphology of the waveforms in the late time windows is different from the control groups with an opposite pattern between the two conditions.

2.4.3.2 DISCOURSE CONDITION

In the Discourse Condition, there is also no early effect of Coherence. However, there are also no early differences in distribution as for the other subject groups. There is an N400-like component, which is delayed; i.e. it reaches its maximum in the window 500 – 700 ms. Importantly, this, effect is not smaller than in the Sentence condition, but it is significantly delayed. This is consistent with the view of an underlying integration deficit as it has been proposed by Hagoort et al. (1996) and Swaab et al. (1997, 1998). These authors find delayed N400 effects only for the Low, but not the High Comprehenders in sentence contexts. The current results extend the previous findings by showing that if the to be integrated information exceeds the level of a single sentence, High Comprehenders run into similar processing deficits as Low Comprehenders. In the present case, the High Comprehenders are sensitive to semantic violations in a discourse context, however at a certain cost. Again, not enough data points could be averaged in order to make conclusive statements about the wrap-up process following the integration.

2.4.3.3 EFFECTS OF CONTEXT

2.4.3.3.1 *COHERENT CONDITION*

No early effects of Context could be found in the Coherent condition, which indicates that the High Comprehenders do not show the early effects that appear to tax working memory processes in the two healthy control groups. This raises the question whether the early prelexical appreciation of the discourse context is necessary for later successful and timely integration of lexical information in a discourse context. Also, they do not appear to differentially wrap-up sentence and discourse contents.

2.4.3.3.2 *INCOHERENT CONDITION*

ERPs do not differ between the incoherent endings in the Discourse and Sentence conditions. However, in the N400 time window, ERPs are overall more negative over the posterior than the anterior electrodes; this means that the N400 that is elicited in both contexts has the typical centro-posterior distribution. As in the Coherent condition, no early frontal differences are found between the two context conditions which suggests that they do not susceptible to the increased demands on working memory in the Discourse condition.

2.4.3.4 GENERAL DISCUSSION

In terms of the nature of the underlying deficit, the obtained tendency towards a delay of the N400 effect is consistent with the view that comprehension deficits are due to an integration rather than an activation deficit (e.g. Hagoort, 1993; Hagoort et al. 1996; Swaab et al., 1997). Moreover, they seem to profit from lexical-semantic relationships, and more so in a sentence than a discourse context, which is consistent with the view that they can make use of semantic information to aid comprehension. However, with the present results, it can no be distinguished whether the patients profit from the semantic relationship in the Coherent condition or whether they suffer from the semantic violation in the Incoherent condition. In other words, the question about whether they heuristically use semantic information to aid processing can not be conclusively answered.

With respect to the brain areas involved in discourse processing, the present results rather speak for an involvement of bilateral medial frontal than for right hemisphere involvement. All patients are more strongly impaired in processing the discourse than the sentence contexts which speaks against the idea that the right hemisphere is primarily involved in processing of discourse. Patients whose lesions encompass not only lateral but also medial prefrontal areas show stronger impairments in the discourse condition.

Most of the High Comprehenders for whom lesion information was available show lesion sites that extended into inferior frontal gyrus and encompassed Broca's area, (cf. Figure 1), moreover it was mainly those patients with lesions in Broca's area who show larger effects in the earlier than the later time window (patients BS, EB, CM; cf. Figure 18). Thus, the data obtained here do not comply with the hypothesis of Broca's area as being the seat of semantic integration (e.g. Hagoort, 2005; Hagoort et al., 2004), but see also van Petten & Luke, 2006). Even though the inferior frontal gyrus - and especially Broca's area - has undoubtedly an important role in language processing, it does not seem to be crucially involved in the generation of the N400. The differential timing of the effects in the two context conditions in the two time windows suggests that the High Comprehenders integrate information in sentence and discourse contexts on different time scales and the relative delay in the Discourse condition indicates that this group of patients processes discourse information in a modular rather than an interactive fashion. Discourse processing has shown to draw stronger demands on verbal working memory processes for the two healthy control groups, and the impairment in discourse processing in this group of patients appear to reflect

the fact that their brain damage encompasses lateral prefrontal areas which are crucially involved in verbal working memory (for an overview see e.g. Owen, 2000). Though, I might want to argue that the underlying problem in the Discourse condition is more one of a working memory deficit than one of a linguistic processing deficit. This is further corroborated by the absence of the early frontal effects in the Discourse relative to the Sentence condition which appear to tax the increased demands on working memory for the retrieval of discourse information for the two control groups. With respect to the brain areas involved in discourse processing,

2.4.4 Low Comprehenders

For the Low Comprehenders, the data have an overall lower signal to noise ratio than for the other subject groups. In this group of patients, this is not only because of the rather small group size ($n=5$), but also because of the relatively high rejection rates (18.3% in the Discourse and 24.1% in the Sentence condition) - despite the application of an eye-correction procedure.

2.4.4.1 EFFECTS OF COHERENCE

2.4.4.1.1 SENTENCE CONDITION

The Low Comprehenders show the opposite pattern of results from all other subject groups: ERPs are more negative for the coherent than for the incoherent endings over anterior electrodes and they do not differ over the posterior electrodes. However, as can be seen from the single subject data in Figure XXX, two of the five Low Comprehenders (BW, DS) show a reversed pattern: they have more negative ERPs in the Coherent than the Incoherent condition. This somewhat surprising effect might be interpreted such that the N400 does not vary as a continuous linear function of integration difficulty; rather it might reflect integration difficulty up to a certain degree, but that once integration becomes impossible, its amplitude decreases again. Rather than being absent, the difference between the Coherent and Incoherent conditions has been averaged out.

Moreover, the baseline is not completely flat and there are differences between the two conditions. Using a longer pre-stimulus baseline did not alter the results fundamentally; however, using a post-stimulus baseline (0 – 50 ms) as suggested by T.S. yields results

pointing in the right direction, but that would artificially distort them. Thus, I decided not to use a different baseline for one subject group in condition in one experiment.

The overall pattern of results implies that the underlying processing is fundamentally different from that of the other subject groups as must be the brain areas contributing to the effect. There are no conclusive studies that systematically investigate the effects of lesion location on volume conduction and the resulting altered topography of evoked potentials. The next step will be to investigate how topographic maps of the evoked potentials differ from those of the control groups and how that related to both location and extent of lesions. These findings contradict those of Swaab et al. (1997) who found significant N400 effects in both the 300 – 500 ms epoch and the 500 – 700 ms epoch. However, these authors recorded from only seven electrodes, which entails an increased likelihood of finding statistically significant differences.

2.4.4.1.2 DISCOURSE CONDITION

ERPs obtained in the discourse condition have no morphological similarity with the typically obtained N400; this is indicative of the Low Comprehenders' failure to integrate the CWs in the discourse context and their inability to use lexical associations between the CW and the final word of the first sentence to aid comprehension. Rather than being equally impaired by a violation and a semantic match, the Low Comprehenders appear to be unable to process discourse information. Unlike for the High Comprehenders, this appears to be due to a lexical rather than a working memory deficit.

2.4.4.2 EFFECTS OF CONTEXT

2.4.4.2.1 COHERENT CONDITION

Statistical analyses do not reveal significant effects for the coherent endings. Unlike for the control groups, no early differences reflecting the retrieval and activation of verbal working memory are obtained, and neither are the late effects reflecting the post-integration wrap-up process. The group of the Low Comprehenders does not show signs of early appreciation of discourse context crucial for later successful integration.

2.4.4.2 *INCOHERENT CONDITION*

Like for the coherent endings, no differences are found between the incoherent endings in both context conditions. This indicates that they are not differentially sensitive to violations of sentence and discourse contexts.

2.4.4.3 GENERAL DISCUSSION

The Low Comprehenders show fundamentally different effects of processing from all other groups of subjects. They can clearly not profit from lexical-semantic relationships to aid comprehension in both sentence and discourse contexts. In the Sentence condition, they do not show clear sensitivity to semantic violations, but rather opposing patterns are obtained for certain individuals. This does neither confirm nor contradict the idea of an integration deficit; a larger sample of patients would have helped to further elucidate the pattern, but unfortunately, the financial situation of the lab did not allow to test any more patients.

In the Discourse condition, however, they do not show signs of either successful or impaired integration, which rises the possibility that the N400 might not be a continuous linear function of integration difficulty but rather a curvilinear one: its amplitude gradually increases as integration difficulty increases, and once it becomes impossible, the amplitude decreases again.

2.4.5 General Discussion

The purpose of this experiment was to further elucidate timing aspects of discourse processing in healthy and aphasic individuals by means of the N400 component of the evoked potential. The effect sizes in the two time windows in which potential delays of the N400 were examined are summarized in Figure 25. Both groups of healthy adults show immediate influence of discourse context on lexical integration on a local sentence level, and they show no signs of a delay of the N400 in either sentence or discourse context, and they neither show differences in the onset of the effects; moreover, the effect is significantly larger in the earlier than the later time window. This is clear evidence for interactive rather than modular processing of discourse information (e.g. Marslen-Wilson & Tyler, 1987; McClelland & Elman, 1986; MacDonald et al., 1994; Jackendoff, 1999;). However, a discourse context poses stronger demands on the processes preceding and following integration: it is more difficult to retrieve discourse from working memory and it poses comparable demands on the

wrap-up and repair process as does a semantic violation in a sentence context irrespective of whether it is coherent or not.

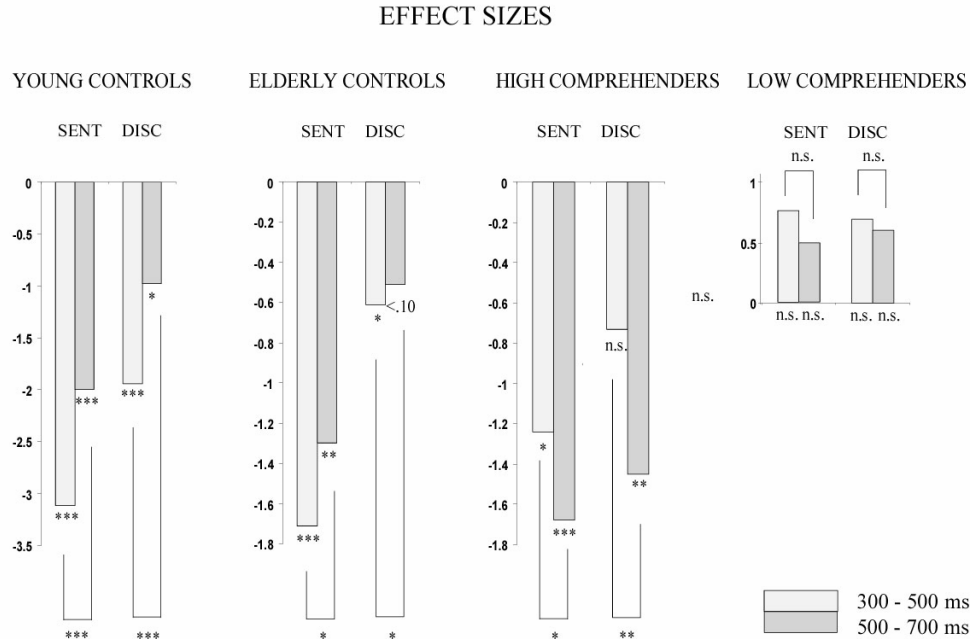


Figure 25 Sizes of the difference ERP effects in both context conditions over the centro-posterior set of electrodes in the two time windows 300–500 ms and 500–700 ms. Significance levels are given both for the effects within each condition and for the difference between the two time windows

The High Comprehenders show significant delays of N400 effects in both context conditions which is indicative of an integration rather than an activation deficit as the underlying problem of their comprehension problems. Also, they appear to be able to use lexical-semantic information to aid processing – and this more so in a sentence than a discourse context. Most High Comprehenders have lesions in the inferior frontal gyrus encompassing Broca’s area which suggests that Broca’s area is not crucially involved in the process of lexical integration as indexed by the N400 component. The Low Comprehenders do not show differential effects in integrating coherent and incoherent sentence endings indicating that they are equally impaired in processing both semantic violations and semantic fits and that they do not appear to profit from lexical-semantic relationships. Moreover, they do not show electrophysiological evidence for successful processing of discourse information.

Both groups of patients do not appear to be able to automatically access discourse information prelexically which appear to be crucial for successful and on-time integration of

discourse information. In sum, both the ability to use lexical information and to integrate lexical information into contexts of increasing processing demand varies as a function of the severity of the patients' comprehension deficits.

With the current paradigm, it can not be conclusively decided whether the High Comprehenders profit from lexical-semantic relations or whether they suffered from the semantic anomalies. Thus, a second experiment was conducted that used the same paradigm, but without relationships between single words determining the overall fit of the CWs.

3 EXPERIMENT 2:

HIGH AND LOW CLOZE PROBABILITY

INSENTENCE AND DISCOURSE CONTEXTS

The aim of this experiment was to further elucidate the comprehension deficits of the patients who showed an impairment in processing semantic anomalies the previous experiment. The same design was employed; however, in the present experiment, the CWs varied with respect to Cloze Probability in the respective contexts. It was not the content of single words but the overall content that determined the overall fit of the CWs. The two factors Context (Sentence, Discourse) and Cloze Probability (High, Low) were crossed; thus, processing was examined under more natural processing conditions, i.e. in the absence of crude semantic violations. This manipulation allows to determine whether the processing impairments observed in the previous experiment can be eliminated or aggravated by the lack of semantic relationships and violations.

Moreover, the general findings of Experiment 1 should be replicated.

3.1 HYPOTHESES

Hypothesis 1: profit from semantic relationships

If the patients profited from the lexical-semantic relationships between the Coherent CWs, the N400 effects should be smaller and later in Experiment 2 than in Experiment 1.

Hypothesis 2: impairment from semantic violations

However, if the patients suffered from the lexical-semantic violations in Experiment 1, the N400 effects should be larger and earlier in Experiment 2 than in Experiment 1.

3.2 METHODS

3.2.1 Subjects

Four groups of subjects participated in the Experiment: two control groups and two groups of aphasic patients.

3.2.1.1 CONTROL GROUPS

3.2.1.1.1 *YOUNG CONTROLS*

Participants were 20 native speakers (13 female; age range 18-33 years, mean age 20.71 years) and were recruited from the University of California at Davis population. All were native speakers of American English and right handed and none had any current or prior neurological or psychiatric impairments or any hearing problems. None of the participants in the ERP study participated in any of the pretests. Participants gave informed consent before the experiment and were compensated with payment (\$10/hour) or course credit.

3.2.1.1.2 *ELDERLY CONTROLS*

The same group of Elderly Controls as in Experiment 1 participated

3.2.1.2 APHASIC PATIENTS

The same group of Aphasic Patients as in Experiment participated.

3.2.2 **Materials**

As in the previous experiment, the critical words (CWs) to which ERPs were obtained were the final words of auditorily presented sentence pairs. In contrast to the previous experiment, the matching of the CWs into the respective context was not achieved by means of a respective semantic match / mismatch but by means of a high / low cloze probability in the respective context. In other words, it was not by means of the contribution of the semantics of single words that made the CW fit into its context but the overall content of the respective context. And as a result, the absence of semantic violations rendered all sentences plausible, so that the N400 effects could not be attributed to differences in plausibility. The factors Context (discourse vs. sentence, i.e. global vs. local) and Cloze Probability (high vs. low) were crossed. In the discourse condition, the local cloze probability was always low and it was rendered globally high or low by means of the preceding sentence. In the Sentence condition, local cloze probability was determined by the context of the second sentence alone in absence of any global context. Cloze probability was manipulated by terminating a highly constricting sentence with the best completion or a word that had a very low cloze probability

and which was yet plausible. In order to quantify the degree of semantic relatedness between the critical words, the method of Latent Semantic Analysis (LSA)⁸ was used. The Near Neighbors procedure was used to confirm the absence of semantic proximity between the final words of both sentences in the discourse condition. The mean cos value for the high cloze condition was 0.013 and for the low cloze condition, it was 0.003. That difference was not significant ($F(1,1)=1.3099$; $p=0.2548$).

Table 1

Examples of stimulus pairs for the discourse and sentence conditions used in Experiment 2. Critical words (CWs) to which ERPs were obtained are printed in CAPITALS.

| DISCOURSE | |
|-------------------|---|
| cloze probability | |
| high | Joel's office is forty miles away. He does not like the long COMMUTE. |
| low | Joel's office is forty miles away. He does not like the long CURTAINS. |
| SENTENCE | |
| cloze probability | |
| high | We had to wait in line at the station. While skiing, Randy broke his LEG. |
| low | We had to wait in line at the station. While skiing, Randy broke his NOSE |

3.2.2.1 PRETESTS

3.2.2.1.1 CLOZE PROBABILITY TEST

The sentence materials were submitted to a series of five pretests. First, the second sentences of both types of scenarios were submitted to a cloze probability test. For the discourse condition, this was done to establish that there was no difference in the predictability of the final word from the local sentence context. Both endings should be equally likely without the context of the preceding sentence. For the sentence condition, it should be established that the high cloze ending was indeed the best completion and that the low cloze ending would not come up more than in 25% of all cases.

⁸ The online version of LSA was used (<http://lsa.colorado.edu/>)

Sentences were presented in written form and random order with the final word omitted. Subjects were instructed to complete the sentences with the one word that came to their mind first. An initial set of 143 sentence pairs was created and presented to 20 undergraduate students from the University of California at Davis participating for a course requirement. Rejection criterion for the discourse scenarios was a value for cloze probability of higher than 30% and for the sentence scenarios it was a value lower than 50% for the high and higher than 25% for the low cloze endings. The cloze probability test lead to the rejection of nine items altogether; five were discourse scenarios and four were sentence scenarios. The results of the cloze probability test are given in Table 2.

Table 2
Mean cloze probability in percentage. Values in brackets refer to standard deviations

| | DISCOURSE | SENTENCE |
|-----------------|-------------|--------------|
| high cloze (SD) | 4.5 (8.16) | 82.08 (17.9) |
| range | 0 – 30 | 50 – 100 |
| low cloze (SD) | 2.16 (5.15) | 1.9 (4.32) |
| range | 0 – 25 | 0 – 25 |

For the discourse scenarios, the cloze probability test revealed an over all low cloze probability with no difference for the high and low cloze endings (post hoc contrast: $t=1.23$, $p>0.5$). For the sentence scenarios, it revealed indeed a high cloze probability for the high and a low cloze probability for the low cloze endings (post hoc contrast: $t=42.2$, $p=0$). These results indicate that the materials meet the desired criteria for cloze probability.

3.2.2.1.2 *PLAUSIBILITY TESTS*

Following the cloze procedure, the sentence pairs were submitted to a plausibility test. This was done in order to establish that there was no difference in plausibility for any of the conditions.

Subjects were given the complete concluding sentence and were asked to rate their plausibility on a scale from 1 – 5. Rejection criteria was a value smaller than 2.5. The two versions of the same sentence were distributed over two lists. An additional 75 implausible filler items were added to each list in order to provide a broader bandwidth of responses. Forty

undergraduate native speakers of the University of California at Davis participated in return for course credit.

The initial procedure led to the revision of 32 items, (four in the discourse condition). These items were submitted to a second plausibility test together with another 32 filler items. Twenty subjects participated, all in exchange for course credit. The plausibility tests led to the rejection of another seven items, one of which was in the discourse condition. The results are given in Table 3.

Table 3
Mean plausibility rating in percentage. Values in brackets refer to standard deviations

| | DISCOURSE | SENTENCE |
|----------------|-------------|-------------|
| high cloze(SD) | 4.65 (0.24) | 4.64 (0.28) |
| range | 3.7 – 5 | 3.9 – 5 |
| low cloze (SD) | 4.58 (0.24) | 4.52 (0.31) |
| range | 3.9 – 5 | 3.5 – 4.9 |

The plausibility procedure did not reveal significant differences in plausibility ratings for both the discourse scenarios ($t=0.33$, $p>0.5$) and the sentence scenarios ($t=1.221$, $p>0.5$).

3.2.2.1.3 COHERENCE TESTS

3.2.2.1.3.1 Coherence Test I

As in the previous Experiment, following the plausibility procedure, the remaining items were submitted to a final pretest in order to test the coherence of the sentence pairs. This was done in order to assess the relationship between the two sentences in a pair. In other words, it should be established that the discourse scenarios were indeed coherent in the sense that the conclusion formed a continuation of the context given by the premise and that there was no such relationship between the sentences of the sentence scenarios.

In the coherence test, both versions of the sentence pairs were presented in written form in two opposing columns and subjects were asked to rate whether the sentence pairs were coherent or not in the sense that the second sentence provided a continuation of the context introduced by the first one. If they thought they were coherent, they should indicate which one of the sentence pairs they thought was more coherent. Subjects were 25

undergraduate students of the University of California at Davis receiving credit for a course requirement. The coherence test did not lead to the elimination of any item.

3.2.2.1.3.2 Coherence Test 2

Following this initial coherence procedure, the qualitative results were further corroborated by a quantitative measure. The two versions of a sentence pair were distributed over two separate lists that were given to a total of 30 subjects. Subjects were asked to rate the coherence of the sentence pairs on a scale from 1 (“not coherent at all”) to 5 (“very coherent”). An ANOVA yielded significant main effects for both factors (context: $F(1,1)=842.63$; $p<0.000$; cloze: $F(1,1)=98.54$; $p<0.000$) as well as an interaction between them ($F(1,2)=50.14$; $p<0.000$). Post-hoc tests revealed a highly significant difference in the discourse ($t=15.21$; $p<0.000$), but not the sentence condition ($t=-0.45$; $p=0.654$). Thus, the coherence procedure confirms that the discourse scenarios were rated overall coherent with the high cloze versions being rated as significantly more coherent than the low cloze versions. The sentence scenarios were not rated as coherent. None of the items was discarded due to the coherence procedure. Altogether, for the discourse condition, the coherence test revealed overall high for the high cloze and a low coherence ratings for the low cloze pairs. For the sentence condition, the coherence test revealed overall low coherence ratings for both the high and low cloze endings, thus confirming that the sentence materials met the coherence criteria.

Table 4

Mean ratings of the coherence of the sentence pairs on a scale 1 – 5. Values in brackets refer to standard deviations

| | DISCOURSE | SENTENCE |
|-----------------|-------------|-------------|
| high cloze (SD) | 4.61 (0.59) | 1.50 (0.54) |
| range | 4 – 5 | 1 – 2 |
| low cloze (SD) | 2.91 (0.89) | 1.54 (0.44) |
| range | 2 – 5 | 1 – 3 |

3.2.2.1.4 SUMMARY OF RESULTS

The results of the series pretests with 135 subjects are displayed in Table 5; they confirm that the materials indeed matched the desired criteria:

The cloze procedure revealed that the high and low cloze endings of the discourse scenarios were equally likely when presented in isolation. This rules out that differences in the ERP to the final words of the discourse scenarios could be attributed to differences in cloze probability for the respective endings. For the sentence scenarios, it was confirmed that the high cloze ending was indeed the best completion and that the low cloze endings did not come up in more than 20% of all cases.

The plausibility test revealed no differences in plausibility for the high and low cloze endings of both the discourse and the sentence condition, ruling out that this could account for possible differences in the ERPs.

Finally, the two coherence tests revealed that the discourse scenarios were indeed coherent, in the sense that the second sentence provided a meaningful continuation of the context introduced by the first sentence and that the high cloze ending was considered indeed more coherent than the low cloze one. For the sentence scenarios, it was confirmed that there was no such relationship between the two sentences.

Table 5
Summary of Stimulus characteristics

| | cloze probability (in %) | plausibility (1 – 5) | lexical frequency (log) | duration (in ms) |
|------------------|-----------------------------|-------------------------|----------------------------|---------------------|
| DISCOURSE | | | | |
| high cloze | 4.5 | 4.65 | 3.52 | 492 |
| low cloze | 2.16 | 4.58 | 3.19 | 535 |
| SENTENCE | | | | |
| high cloze | 82.08 | 4.64 | 4.06 | 430 |
| low cloze | 1.9 | 4.52 | 3.55 | 471 |

3.2.2.2 SELECTED MATERIALS

Of the initially created 143 scenarios, 16 were eliminated after the series of pretests. Another four items were randomly deleted leaving a total of 120 scenarios, 60 in the Discourse and 60 in the Sentence condition. The final words were matched with respect to

written lexical frequency (Francis & Kučera, 1982), number of letters, phonemes and syllables.

3.2.2.2.1 SENTENCE CONDITION

There were no differences with respect to written lexical frequency (Francis & Kučera, 1982) and duration. The mean log lexical frequency for the high and low cloze final words were 4.06 and 3.55 (range 0 – 6.78 and 0 – 6.46, respectively), and the mean duration of the high and low cloze final words were 438 and 482 ms (range 212 – 719 and 298 – 752, respectively), neither of these differences were significant with $F_s < 1$, respectively. The mean number of letters for the high and low cloze final words was 5.01 and 5.16 (range 3 – 8 and 3 – 11, respectively), the mean number of phonemes was 3.87 and 6.16 (range 2 – 7 and 2 – 10, respectively), the mean number of syllables was 1.44 and 1.5 (range 1 – 3 and 1 – 3, respectively), none of these differences were significant, all $F_s < 1$. The mean number of words in the first sentence of the sentence scenarios was 7.78 (range 6 – 11), and their mean duration was 2142 ms (range 1585 – 3280). The mean number of words in the first sentence of the sentence scenarios was 7.88 (range 4 – 12), and the mean duration was 2134 ms (range 1295 – 3240) for the high and 2157 ms (range 1385 – 3685) for the low cloze versions, respectively.

3.2.2.2.2 DISCOURSE CONDITION

There were no differences with respect to written lexical frequency (Francis & Kučera, 1982) or duration. The mean log lexical frequency for the high and low cloze probability final words in the discourse scenarios were 3.52 and 3.19 (range 0 – 5.34 and 0 – 5.74, respectively). The mean duration of the high and low cloze final words were 533 and 542 ms (range 336 – 807 and 325 – 838, respectively), neither of these differences were significant with all $F_s < 1$. The mean number of letters for the high and low cloze final words was 6.18 and 5.91 (range 3 – 11 and 4 – 10, respectively), the mean number of phonemes was 4.7 and 4.65 (range 2 – 9 and 2 – 8, respectively), the mean number of syllables was 1.82 and 1.66 (range 1 – 3 and 1 – 3, respectively), none of these differences were significant, all $F_s < 1$. The mean number of words in the first sentences of the discourse scenarios was 8.81 (range 4 – 17), and their mean duration was 2730 ms (range 1267 – 4467). The mean number of words in the second sentences of the discourse scenarios was 7.78 (range 6 – 11), and the mean duration was 1901 ms (range 1091 – 3498) for the high and 1930 ms (range 1106 – 3331) for

the low Cloze versions. The scenarios were evenly distributed over 4 blocks with high and low cloze versions of the same scenarios always separated by one intervening block. Each block contained equal numbers of discourse- and sentence scenarios and high and low cloze endings, respectively. Each block started with two start-up items which were items that either did not pass any of the pretests or were randomly discarded from the original list after the pretests. In addition to the four experimental blocks, a practice session was created in order to make subjects familiar with the experimental procedure.

3.2.2.2.3 RECORDING OF THE MATERIALS

Materials were recorded by an experienced male speaker and directly recorded onto the hard disc of a computer using a SCHOEPS® Colette modular microphone and a USB PreAmplifier. The materials were sampled at 48.000 Hz and 24 bit.

3.2.3 EEG Experiment

3.2.3.1 PROCEDURE

The same EEG recording procedure as in Experiment 1 was used.

3.2.3.2 EEG RECORDING

The same EEG recording setup as for the Elderly Controls and the patients in Experiment 1 was used for all subject groups.

3.2.3.3 SOUND DELIVERY

The same sound delivery system as for the Elderly Controls and the patients in Experiment 1 was used for all subject groups.

3.2.3.4 HEARING ASSESSMENT

The same hearing assessment parameters as in Experiment 1 were used.

3.2.3.5 OCULAR ARTIFACT REDUCTION FOR THE PATIENT GROUPS

The same ocular artifact reduction procedure as in Experiment 1 was used.

3.2.3.6 DATA ANALYSIS AND DATA REDUCTION

The same data analysis and data reduction parameters as in Experiment 1 were used.

3.3 RESULTS

Repeated measures of variance ANOVAs were performed on the mean amplitude of the ERPs to the CWs in five epochs: two early epochs (0 – 100 ms and 100 – 300 ms), the N400 epoch (300 – 500 ms), and two late epochs (500 – 700 and 700 – 1000 ms), relative to a 100 ms pre-stimulus baseline. An initial $2 \times 2 \times 29$ OMNIBUS ANOVA was performed with the following within-subject factors: Context (Discourse, Sentence), Cloze Probability (High, Low), and Electrode Site (29 sites). All analyses were done over artifact free or artifact corrected trials and included Subjects as a random factor. In the case of a significant interaction with Electrode Site, further analyses were performed containing the additional factor Location (Anterior: FP1, FP2, F3, F4, F7, F8, FC1, FC2, FC5, FC6, AFZ, FZ; Posterior: CP1, CP2, CP5, CP6, P3, P4, T5, T6, O1, O2, PZ, POZ). This was done to test for apparent anterior-posterior differences in the distribution of the ERP effects. Two sets of planned pair wise comparisons were performed. The first set of analyses compared the effects of Cloze Probability within the Discourse and Sentence conditions: One set of analyses compared high and low cloze probability CWs for the Discourse and one for the Sentence condition, respectively. The other set of analyses compared the effects of Cloze Probability: One compared the sentence and discourse contexts for the High Cloze Probability conditions, and one for the Low Cloze Probability condition. Finally, in order to compare the onset of the effects in the Discourse and Sentence conditions, additional analyses on the mean amplitude of the N400 effects (the difference waves) was performed in consecutive 50 ms time windows. For evaluating effects with more than one degree of freedom in the numerator, the Greenhouse-Geisser correction was used to compensate for inhomogeneous variances and covariances across treatment levels (Greenhouse & Geisser, 1959). The respective adjusted p -values will be reported. Because of the within-subjects design, subjects were presented both the coherent and incoherent versions of the sentence pairs; therefore, a first set of ANOVAs examined the possible effects of repetition. The high and low cloze probability versions of the same pair were separated by one intervening block, such that each version of the pair appeared in either the first or the second half of the experiment. In this set of ANOVAs, the factor Order (1st half, 2nd half) was included. Note however, that only the sentence pairs, but not the CWs themselves were repeated. For none of the four subject groups, the factor Order interacted with any other experimental factor (all $F_s < 1$) and was hence neglected. All further analyses reported here were performed on the entire data set.

3.3.1 Young Controls

3.3.1.1 OVERALL ANALYSES

Overall rejection rates were 21.17% (Discourse 18.69%, sentence 22.10%). Results of the omnibus ANOVAs investigating the effects of Context and Cloze Probability in the five time windows (F values and significance levels) are displayed in Table 6.

Table 6

F values and significance levels of the OMNIBUS ANOVAs on the effects of Context and Cloze Probability for the Young Controls

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|----------------------------------|--------|----------|-----------|-----------|-----------|------------|
| CONTEXT | 1,19 | 21.03*** | 14.60** | 9.65** | 1.90 | <1 |
| CONT x ELEC ⁺ | 28,532 | 4.31** | 4.67** | 4.02** | 4.19** | 21.74*** |
| CLOZE | 1,19 | <1 | 21.05*** | 32.80*** | 4.60* | <1 |
| CLOZE x ELEC ⁺ | 28,532 | <1 | 7.07*** | 26.97*** | 4.19** | 3.02* |
| CONT x CLOZE | 1,19 | <1 | <1 | 6.78* | 1.83 | 2.01 |
| CONT x CLOZE x ELEC ⁺ | 28,532 | <1 | <1 | 2.82* | 1.59 | 1.85 |

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

⁺ Greenhouse-Geisser adjusted p values

In the earliest time window between 0 and 100 ms, the only significant main effect was obtained for Context; ERPs were more negative in the Discourse than in the Sentence condition. This factor interacted with Electrode Site. In the window between 100 and 300 ms, significant main effects were obtained both for Cloze Probability with more negative ERPs in the low than the High Cloze Probability condition and for Context with more negative ERPs in the Discourse than the Sentence condition. Both Context and Cloze Probability interacted with Electrode Site, but not with each other. In the N400 time window (300 – 500 ms), there was a main effect of Cloze Probability with more negative ERPs in the Low than the High Cloze Probability condition and an interaction between Cloze Probability and Context; the effect of Cloze Probability was more pronounced in the Discourse than in the Sentence condition. Both Cloze Probability and Context significantly interacted with Electrode Site. In the window 500 – 700 ms, a main effect of Cloze Probability was found with more positive ERPs in the High than the Low Cloze Probability condition; this factor interacted with

Electrode Site. Context interacted with Electrode Site as well. In the latest time window between 700 and 1000 ms, the only significant effects were interactions between Electrode Site and both Cloze Probability and Context.

3.3.1.2 EFFECTS OF COHERENCE

The results of the ANOVAs (F values and significance levels) for the effects of Cloze Probability are displayed in Tables 7 and 8 for the Sentence and Discourse conditions, respectively.

3.3.1.2.1 SENTENCE CONDITION

Figure 1 shows the ERPs elicited by the high and low cloze probability endings in the Sentence condition. No clear N1-P2 complex can be distinguished, and the waveforms start to diverge at around 100 ms after the onset of the CW, with ERPs being more negative in the Low than the High Cloze Probability condition. An N400 is obtained in the Low but not the High Cloze Probability condition. This N400 has a very clear centro-posterior distribution. It is followed by a positive-going wave that appears to be more pronounced at posterior than anterior electrode sites.

Table 7

F values and significance levels of the ANOVAs on the effect of Cloze Probability in the Sentence Condition for the Young Controls

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|-------------------------------|--------|---------|-----------|-----------|-----------|------------|
| CLOZE | 1,19 | <1 | 4.44* | 4.73* | 1.06 | 3.24 |
| LOCATION | 1,19 | 3.10 | 12.88** | 12.37** | 14.25** | 4.65* |
| CLOZE x LOC | 1,19 | <1 | 1.70 | 12.75** | <1 | <1 |
| CLOZE x LOC x EL ⁺ | 11,209 | <1 | 3.15* | 3.96* | <1 | <1 |

p<0.05 ** p<0.01 ***p<0.001

⁺ Greenhouse-Geisser adjusted p values

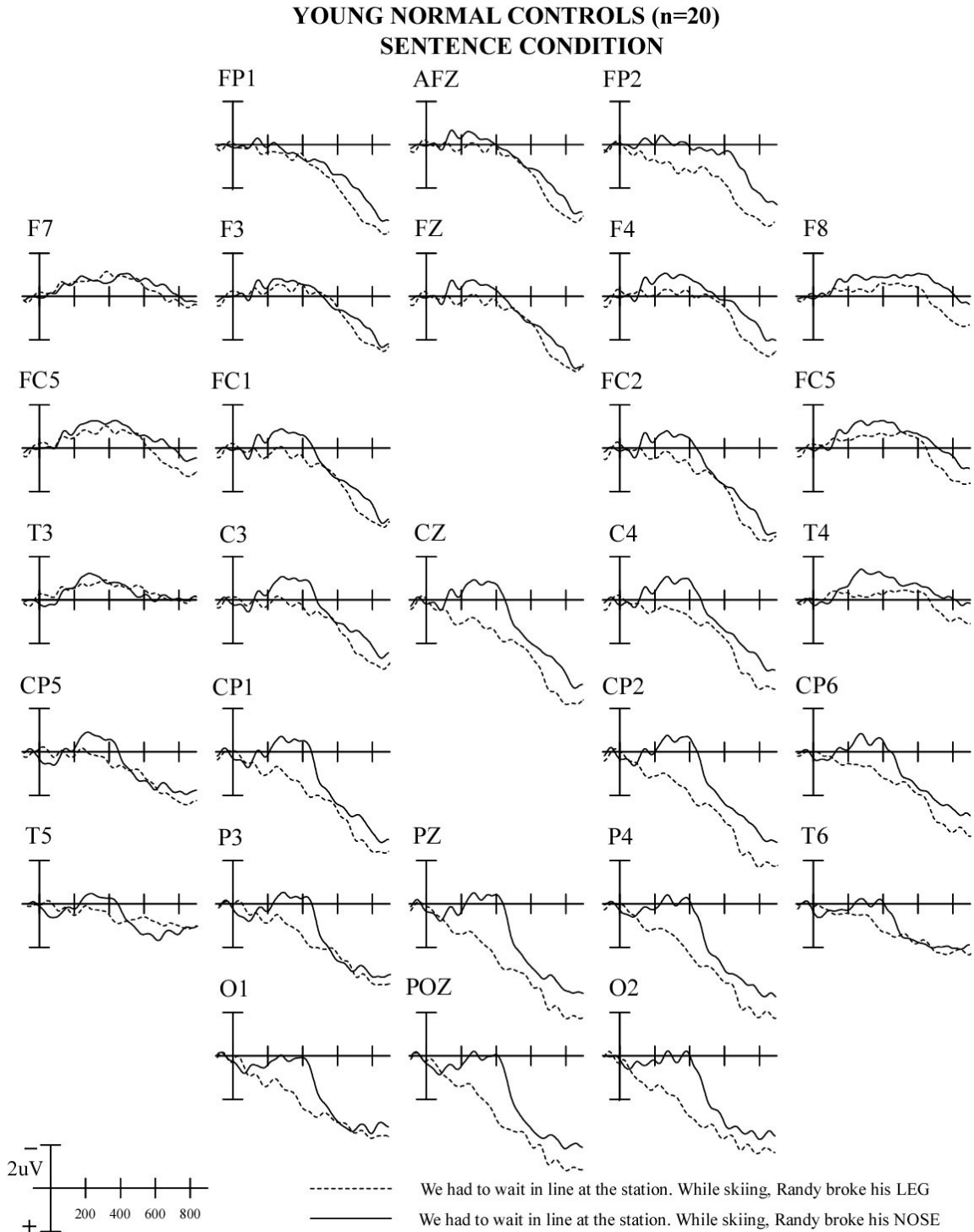


Figure 1 Grand Average ERP waveforms for the Young Controls to the high (dashed line) and low cloze probability (solid line) final words in the Sentence Condition

As in the previous experiment, none of the effects reached significance in the earliest time window. Analyses in the window 100 – 300 ms revealed a main effect of Cloze Probability with more negative ERPs in the low than the High Cloze Probability condition and a main effect of Location with more negative ERPs at anterior than posterior electrodes. The N400 effect was examined in the window 300 – 500 ms after stimulus onset. Main effects of Cloze Probability and Location as well as an interaction between Cloze Probability and Location were obtained: overall, ERPs were more negative in the low than the High Cloze Probability condition and at posterior than anterior electrode sites. The difference between the low and high cloze endings was more pronounced at posterior electrode sites, thus confirming the typical topographic distribution of the effect. The positivity following the N400 effect is more pronounced at posterior than anterior electrode sites in both late time windows, and this does not differ between the low and high cloze endings. All in all, the effects from Experiment 1 can be replicated.

3.3.1.2.2 DISCOURSE CONDITION

Figure 2 shows that no clear N1-P2 complex can be distinguished for the low and high cloze CWs in the Discourse condition. Already right after the beginning of the CW, ERPs are more negative over the anterior than over the posterior electrodes. The waveforms start to diverge at about 100 ms after stimulus onset. A broad negative deflection with a centro-posterior distribution and a peak at around 400 ms is found in the Low, but not the High Cloze Probability condition. This negativity is followed by a positivity that is maximal between 700 and 1000 ms. It is more pronounced over posterior than anterior electrode sites, and no obvious differences between High and Low Cloze Probability conditions can be observed.

Table 8

***F* values and significance levels of the ANOVAs on the effect of Cloze Probability in the Discourse Condition for the Young Controls**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|---------------------------------|--------|----------|-----------|-----------|-----------|------------|
| CLOZE | 1,19 | <1 | 24.48*** | 66.00*** | 8.98** | <1 |
| LOCATION | 1,19 | 15.19*** | 6.15* | 5.38* | 32.68*** | 49.31*** |
| CLOZE x LOC | 1,19 | <1 | 6.90* | 31.26*** | 2.68 | 2.58 |
| CLOZE x LOC x ELEC ⁺ | 11,209 | <1 | 5.48*** | 15.87*** | 3.23* | 2.96* |

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$ + Greenhouse-Geisser adjusted p values

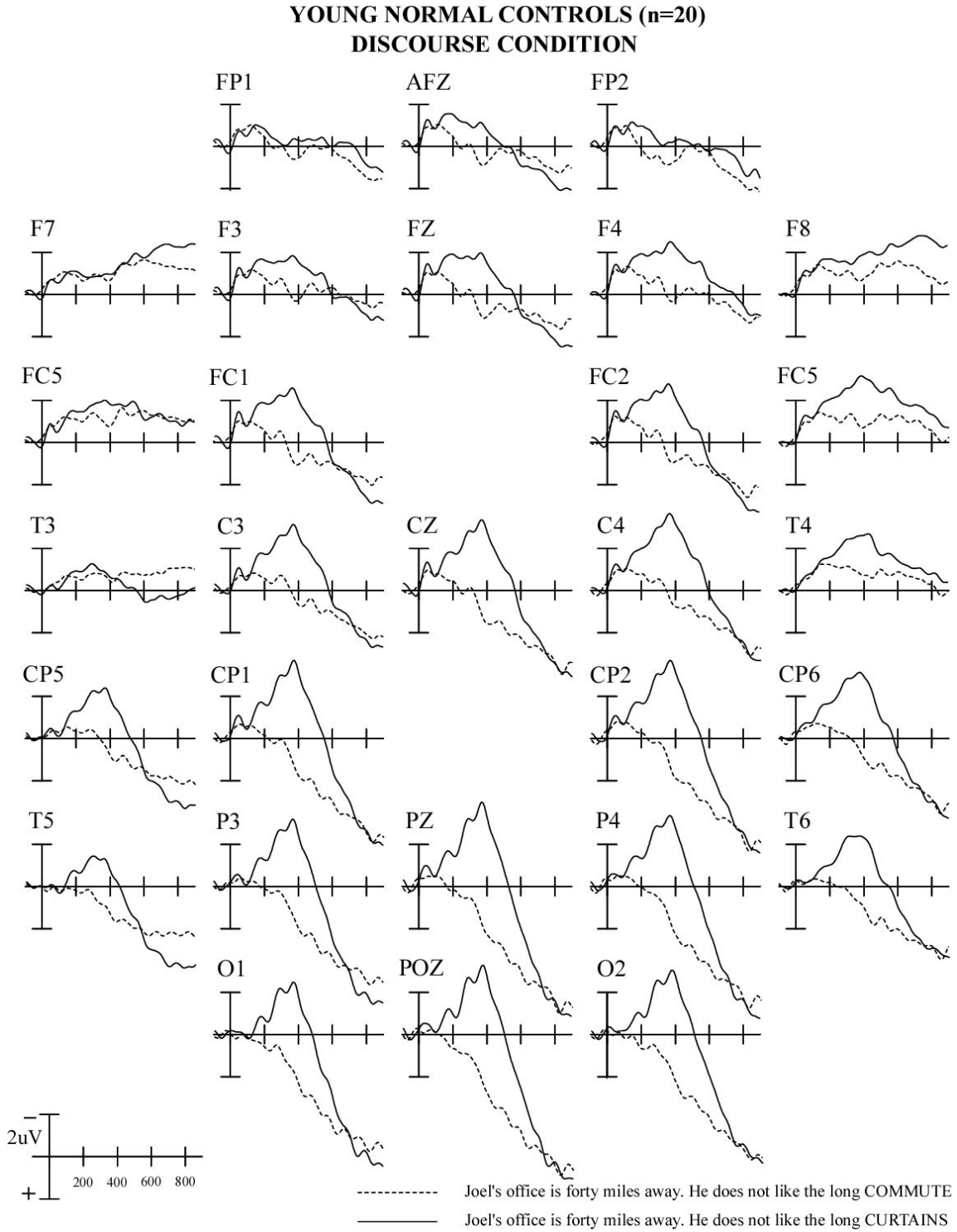


Figure 2 Grand Average ERP waveforms for the Young Controls to the high (dashed line) and low cloze probability (solid line) final words in the Discourse Condition

In the window between 0 and 100 ms, a main effect of Location was obtained with overall more negative ERPs at anterior than posterior electrode sites. As in Experiment 1, the waveforms for the high and low cloze CWs do start to diverge at around 100ms after stimulus onset. Analyses in the window 100 – 300 ms reveal a main effect of Cloze Probability with more negative ERPs in the Low than the High Cloze Probability condition and a main effect for Location with more negative ERPs at anterior than posterior electrode sites. The N400 effect was investigated in the window 300 – 500 ms after stimulus onset. A significant main effect of Cloze Probability was obtained with more negative ERPs in the Low than the High Cloze Probability condition. Furthermore, the significant main effect of Location indicated more negative ERPs at posterior than anterior electrodes. The interaction between Cloze Probability and Location shows that the effect of Cloze Probability was more pronounced at posterior than anterior electrodes. The positivity following the N400 was investigated in two consecutive windows. In the window 500 – 700 ms, two main effects were found. The main effect of Cloze Probability indicates that ERPs were more positive in the High than the Low Cloze Probability condition, and the main effect of Location indicates that ERPs were more positive at posterior than anterior electrodes. In the latest time window, a significant main effect of Location is obtained; ERPs are overall more positive at posterior than anterior electrode sites. No differences are found for the effect of Cloze Probability. Also for the Discourse condition, the results from Experiment 1 could be replicated.

3.3.1.3 EFFECTS OF CONTEXT

In Figures 3 and 4, the waveforms of Figures 1 and 2 are rearranged in order to display the effects of Context in the two Cloze Probability conditions. The results of the ANOVAs (*F* values and significance levels) are summarized in Table 9 and 10 for the High and Low Cloze Probability conditions, respectively.

3.3.1.3.1 HIGH CLOZE CONDITION

Figure 3 shows the ERPs in the High Cloze condition for both the Discourse and the Sentence contexts. Right after stimulus onset, ERPs are more negative in the Discourse than the Sentence condition and over anterior than posterior electrodes. This difference vanishes in the N400 time window where no apparent differences between the two context conditions can be seen. ERPs continue to be negative in both context conditions; over frontal sites, ERPs are

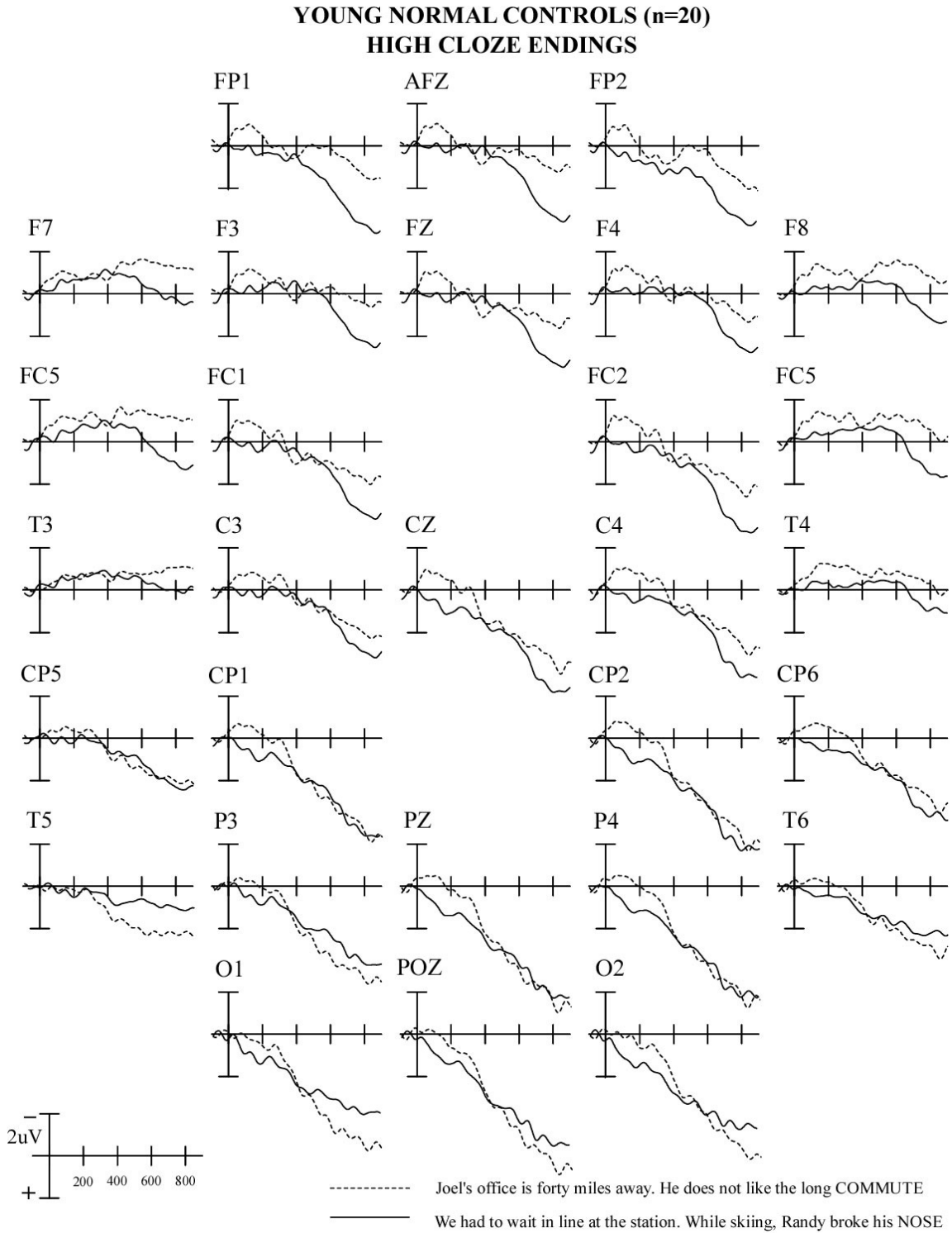


Figure 3 Grand Average ERP waveforms for the Young Controls to the High Cloze Probability final words for the discourse (dashed line) and sentence (solid line) contexts

more positive in the Sentence than the Discourse condition, and no apparent differences can be seen over posterior electrodes.

Table 9

F values and significance levels of the ANOVAs on the effect of Context in the High Cloze Probability Condition for the Young Controls

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|--------------------------------|--------|---------|-----------|-----------|-----------|------------|
| CONTEXT | 1,19 | 8.40** | 5.39* | <1 | <1 | 1.64 |
| LOCATION | 1,19 | 9.23** | 28.83*** | 41.03*** | 36.37*** | 21.52*** |
| CONT x LOC | 1,19 | <1 | <1 | <1 | 6.98* | 33.78*** |
| CONT x LOC x ELEC ⁺ | 11,209 | 2.78* | 1.98 | <1 | 1.15 | 2.27 |

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

⁺ Greenhouse-Geisser adjusted p values

In the two early time windows, there was both a main effect of Context with more negative-going ERPs for the Discourse than the Sentence condition and a main effect of Location with more negative-going ERPs at anterior than posterior sites which replicates the findings from Experiment 1. In the N400 time window (300 – 500 ms), there was a main effect for Location with more positive ERPs at posterior than anterior electrodes, but no effect of Context. In the both late windows, a qualitatively similar patterns of results was obtained: there was a main effect of Location with more positive-going ERPs at posterior than anterior electrodes and an interaction between Context and Location. ERPs were more positive in the Sentence than the Discourse condition at anterior but not posterior electrode sites.

3.3.1.3.2 LOW CLOZE CONDITION

Figure 4 shows the Grand Average ERPs elicited by the discourse and the sentence contexts in the Low Cloze Probability Condition. Already right after stimulus onset, ERPs appear more negative in the Discourse than the Sentence condition and also over anterior than posterior electrodes. ERPs continue to be more negative in the Discourse than the Sentence condition until about 650 ms after stimulus onset. Thereafter, they are more positive in the Discourse than the Sentence condition but only over posterior and not anterior electrodes.

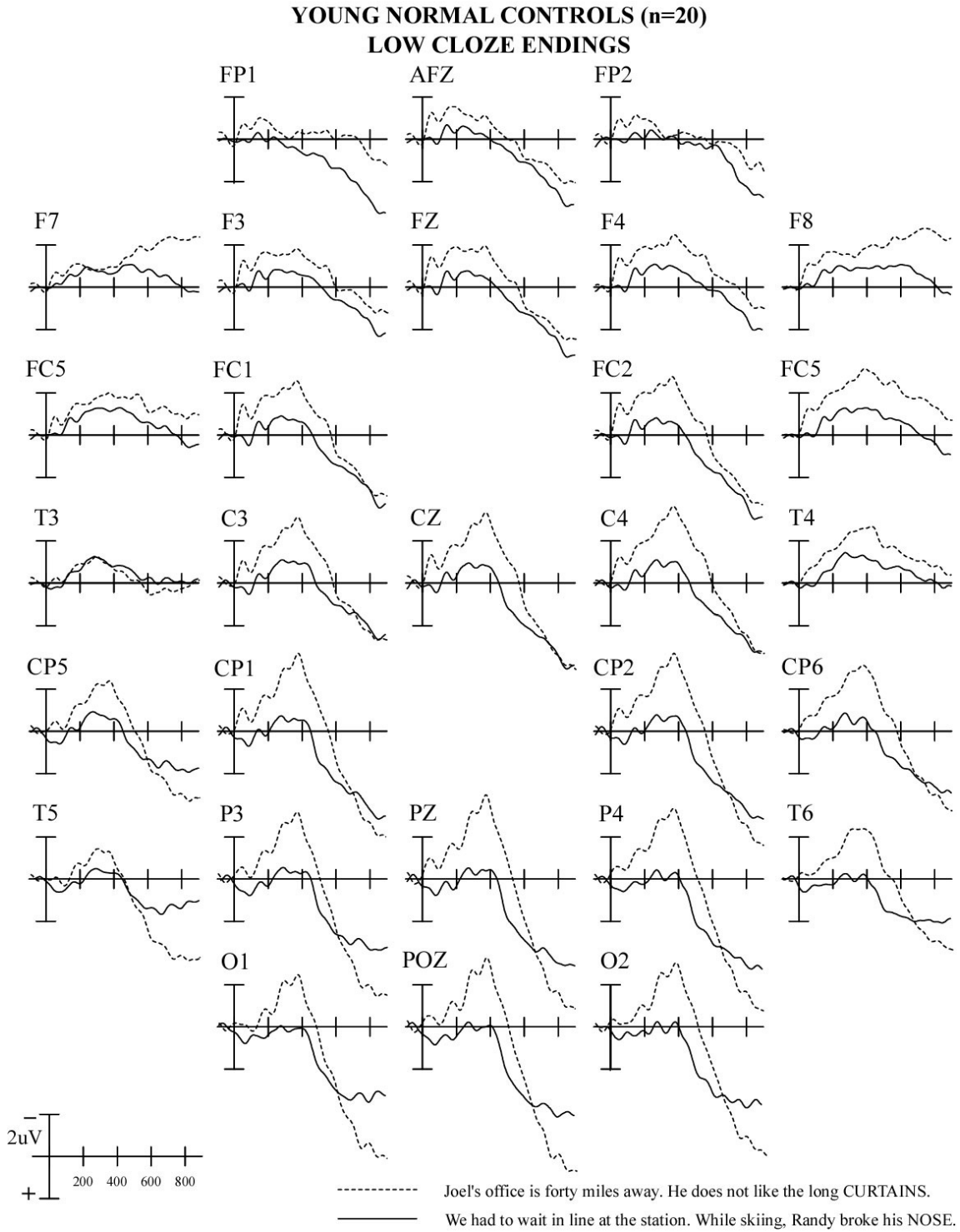


Figure 4 Grand Average ERP waveforms for the Young Controls to the Low Cloze Probability final words for the discourse (dashed line) and sentence (solid line) contexts

Table 10**F values and confidence levels of the ANOVAs on the effect of Context in the Low Cloze Probability Condition for the Young Controls**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|--------------------------------|--------|---------|-----------|-----------|-----------|------------|
| CONTEXT | 1,19 | 14.15** | 14.17** | 20.66*** | 4.15 | <1 |
| LOCATION | 1,19 | 5.54* | 1.53 | <1 | 15.64*** | 22.16*** |
| CONT x LOC | 1,19 | <1 | 2.11 | 6.10* | 1.78 | 54.31*** |
| CONT x LOC x ELEC ⁺ | 11,209 | 5.64** | 3.84* | 7.69*** | 2.22 | 4.78*** |

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$ ⁺ Greenhouse-Geisser adjusted p values

In the very early window (0 – 100 ms), there was a main effect of Context with more negative ERPs in the Discourse than the Sentence condition and a main effect of Location with more negative ERPs at anterior than posterior sites. In the window between 100 and 300 ms, the only significant effect is a main effect of Context with more negative ERPs in the Discourse than the Sentence condition. In the N400 time window (300 – 500 ms), there was a main effect of Context with again more negative ERPs in the Discourse than the Sentence condition. Context interacted with Location indicating a larger difference between Discourse and Sentence conditions at posterior than anterior electrodes, i.e. at the typical N400 topography. In the window following the N400 (500 – 700 ms), there was only a main effect of Location with overall more positive ERPs at posterior than anterior electrodes. Finally, in the latest window (700 – 1000 ms), a main effect of Location and an interaction between Context and Location was obtained. ERPs were overall more positive at posterior than anterior electrode sites. Furthermore, ERPs were more positive in Discourse than the Sentence condition at the posterior electrode sites and the reversed pattern was observed at anterior sites.

3.3.1.4 DIFFERENCE EFFECTS / ONSET ANALYSES

Difference waves were computed by subtracting the ERPs of the high from the low cloze endings for both the Discourse and Sentence conditions. There was a significant main effect for the factor Context in the time window 300 – 500 ms ($F(1,20)=7.32$; $p=0.0136$) with the N400 effect being more negative for the Discourse than the Sentence condition. This effect interacted with Electrode Site ($F(28,532)=3.41$; $p=0.021$). In order to determine possible onset differences between the two conditions, ANOVAs were performed on the

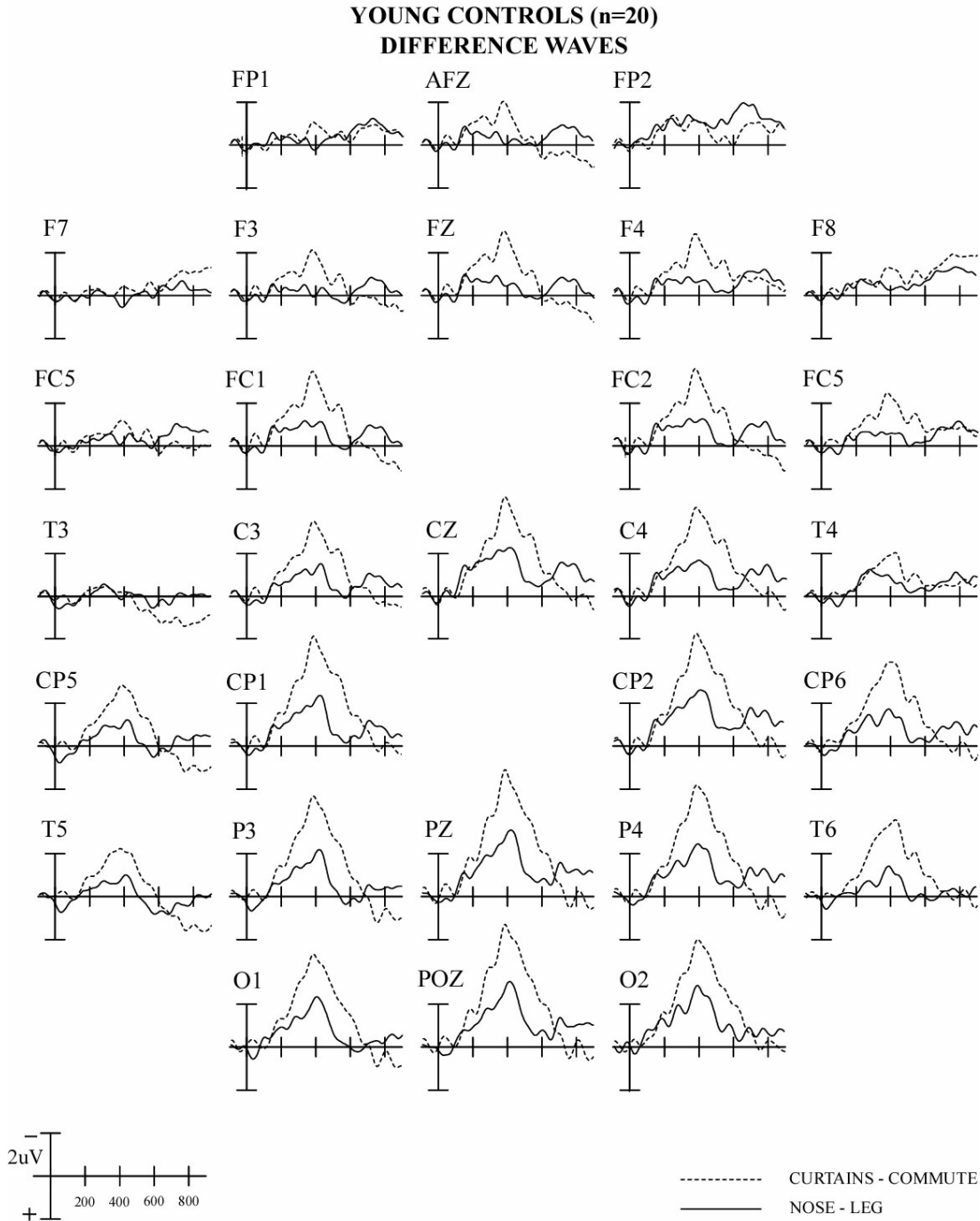


Figure 5 Difference waveforms for the Young Controls in the Discourse (dashed line) and Sentence (solid line) conditions. Difference waveforms were created by subtracting the ERPs elicited by the CWs in the coherent condition from those elicited in the incoherent condition

mean amplitude of the difference waves in consecutive 50 ms time windows starting at stimulus onset.. These differences did not reach significance until 350 – 400 ms ($F(1,19)=9.55$; $p=0.0058$). This window was then fractioned into 10ms time windows in order to precisely determine the onset differences which was obtained 350 – 360 ms after stimulus-onset ($F(1,19)=8.36$; $p=0.0090$).

3.3.2 Elderly Controls

3.3.2.1 OVERALL ANALYSES

Results of the omnibus ANOVAs investigating the effects of Context and Cloze Probability in the five time windows (F values and significance levels) are displayed in Table 11. Overall rejection rates were 15.2% (Discourse 15.1%, sentence 15.3%).

Table 11

F values and significance levels of the OMNIBUS ANOVAs on the effects of Context and Cloze Probability for the Elderly Controls

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|----------------------------------|--------|----------|-----------|-----------|-----------|------------|
| CONTEXT | 1,11 | 32.49*** | 33.56*** | 13.55** | <1 | <1 |
| CONT x ELEC ⁺ | 28,308 | 2.99* | 3.44* | 8.31*** | 2 | 7.19*** |
| CLOZE | 1,11 | 2.33 | 11.64** | 67.41*** | <1 | 6.33* |
| CLOZE x ELEC ⁺ | 28,308 | <1 | 4.86* | 25.84*** | 11.05*** | 2.47 |
| CONT x CLOZE | 1,11 | <1 | <1 | 12.51** | 1.08 | <1 |
| CONT x CLOZE x ELEC ⁺ | 28,308 | 1 | 1.25 | 5.15 | 1.45 | 1.14 |

* $p<0.05$ ** $p<0.01$ *** $p<0.001$

⁺ Greenhouse-Geisser adjusted p values

In the earliest time window between 0 and 100 ms, the only significant main effect was obtained for Context; ERPs were more negative in the Discourse condition than in the Sentence condition. This factor interacted with Electrode Site. In the window between 100 and 300 ms, significant main effects were obtained both for Cloze Probability with more negative ERPs in the low than the High Cloze Probability condition and for Context with more negative ERPs in the Discourse than the Sentence condition. Both Context and Cloze Probability interacted with Electrode Site, but not with each other. In the N400 time window, the main effects of Context and Cloze Probability were highly significant; ERPs were overall

more negative in the Discourse than the Sentence condition and for low than high cloze endings. Both factors interacted with each other and with Electrode Site. In the window between 500 – 700 ms, the only significant effect was the interaction between Cloze Probability and Electrode Site. In the latest time window between 700 and 1000 ms, the only significant effects were the main effect of Cloze Probability with more positive ERPs in the Low than the High cloze condition and the interaction between Electrode Site and Context.

3.3.2.2 EFFECTS OF COHERENCE

The results of the ANOVAs (*F* values and significance levels) for the effects of Cloze Probability are displayed in Tables 12 and 13 for the Sentence and Discourse conditions, respectively.

3.3.2.2.1 SENTENCE CONDITION

Figure 6 shows the ERPs elicited in the high and low cloze endings in the Sentence condition. No clear sensory components (N1 & P2) can be distinguished, and the waveforms start to diverge at around 150 ms after the onset of the CW, with more negative ERPs the Low than the High Cloze Probability condition. An N400 is obtained in the Low but not the High Cloze Probability condition. This N400 has a very clear centro-posterior distribution. Even though the absolute voltage values are positive even for the Low Cloze Probability condition, the pattern of differences complies with standard N400 effects. The N400 is followed by a positive-going wave which is maximal between 700 and 1000 ms and which appears to be more pronounced at posterior than anterior electrode sites.

Table 12

***F* values and significance levels of the ANOVAs on the effect of Cloze Probability in the Sentence Condition for the Elderly Controls**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|-------------------------------|--------|---------|-----------|-----------|-----------|------------|
| CLOZE | 1,11 | <1 | 9.77** | 21.16*** | <1 | 4.82* |
| LOCATION | 1,11 | 1.12 | 9.21* | 8.11* | 18.97** | 14.46** |
| CLOZE x LOC | 1,11 | <1 | 1.15 | 23.46*** | 13.82** | 3.71# |
| CLOZE x LOC x EL ⁺ | 11,121 | <1 | 3.35* | 7.79*** | 2.49# | 1 |

$p < 0.10$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

⁺ Greenhouse-Geisser adjusted *p* values

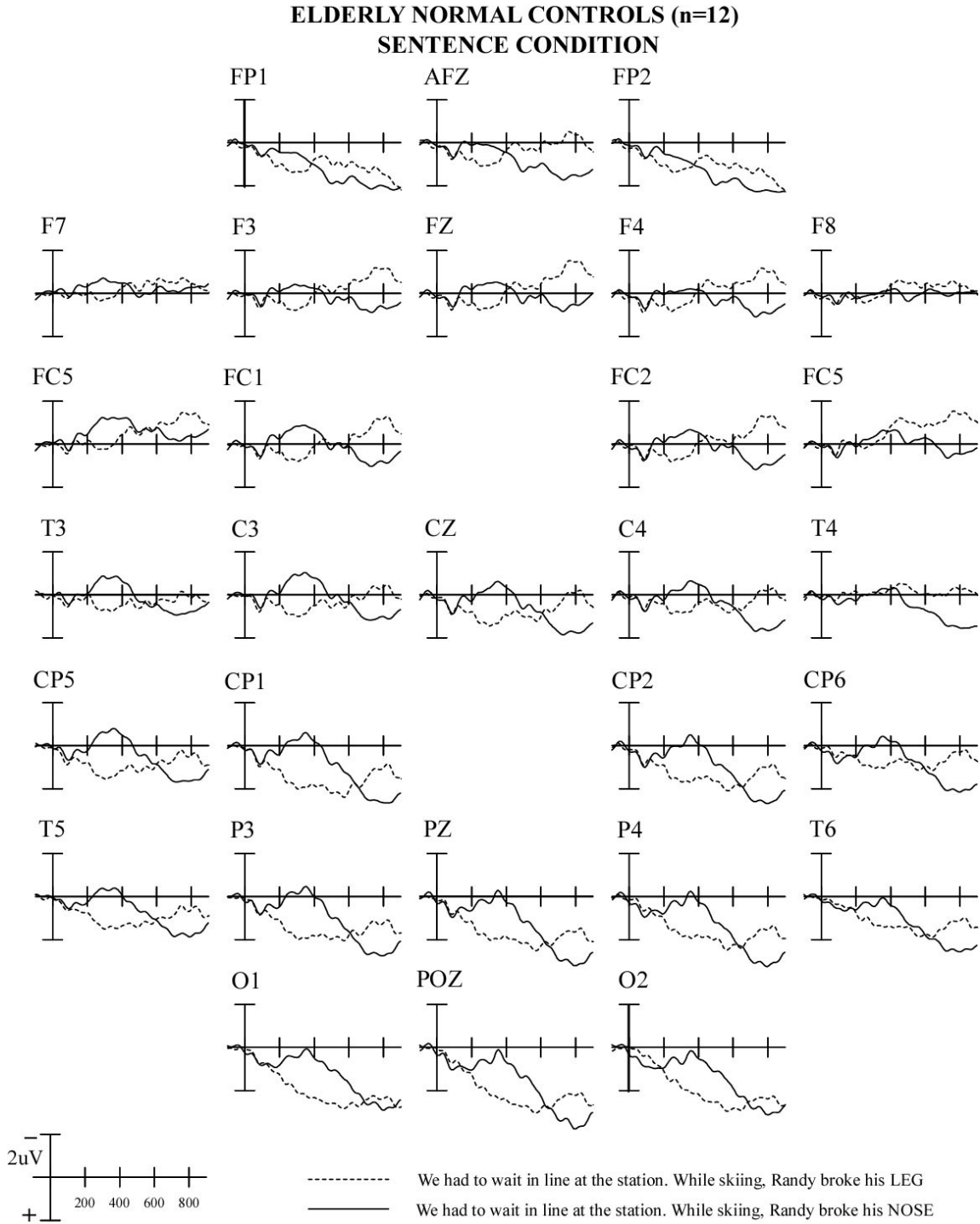


Figure 6 Grand Average ERP waveforms for the Elderly Controls to the high (dashed line) and low cloze probability (solid line) final words in the Sentence Condition

None of the effects reached significance in the earliest time window. Analyses in the window 100 – 300 ms revealed a main effect of Cloze Probability with more positive ERPs in the High than the Low Cloze Probability condition and a main effect of Location with more positive ERPs at posterior than anterior electrodes. In the N400 time window, significant main effects were obtained for the factors Cloze Probability and Location as well as an interaction between the two. This confirms statistically that ERPs were more negative for the low than the high cloze endings and overall more positive over posterior than anterior electrodes. The difference between the high and low cloze endings was more pronounced over posterior than anterior electrodes. Between 500 – 700 ms, the main effect of Location indicates that ERPs are more positive over posterior than anterior electrodes and the interaction between Cloze Probability and Location indicates that over posterior electrodes, the difference between the low and high cloze endings is positive and that over anterior electrodes, it is negative. Finally, in the latest window, both main effects are significant; ERPs are more positive in the High Cloze Probability condition than in the Low Cloze Probability condition and over posterior than over anterior electrodes. The marginally significant interaction between Cloze and Location ($F(1,11)=3.71;p=0.069$) indicates that the difference between the high and low cloze endings is larger over the posterior than the anterior electrodes.

3.3.2.2.2 DISCOURSE CONDITION

Figure 7 shows that no clear N1-P2 complex can be distinguished for the low and high cloze CWs in the Discourse condition. No early differences can be seen between the two conditions; however, ERPs are overall more negative of the anterior than over the posterior electrodes. The waveforms start to diverge at about 100 ms after stimulus onset. An N400 is found in the Low, but not the High Cloze Probability condition. This negativity is followed by positivity. It is maximal between 700 and 1000 ms and more strongly pronounced over posterior electrodes, where no differences appear between the two conditions.

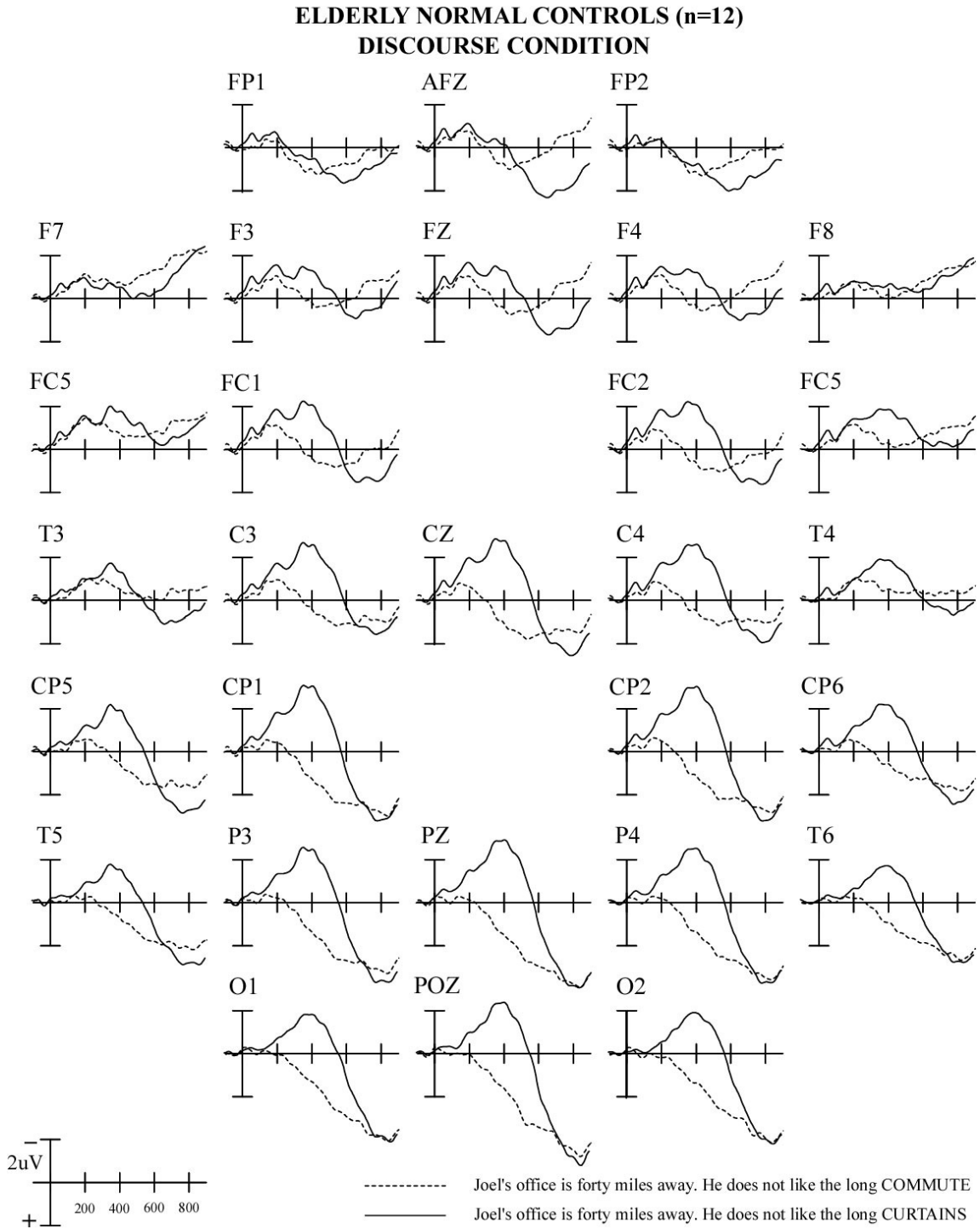


Figure 7 Grand Average ERP waveforms for the Elderly Controls to the high (dashed line) and low cloze probability (solid line) final words in the Discourse Condition

Table 13

***F* values and significance levels of the ANOVAs on the effect of Cloze Probability in the Discourse Condition for the Elderly Controls**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|------------------------------|--------|---------|-----------|-----------|-----------|------------|
| CLOYE | 1,11 | 2.23 | 9.26* | 58.33*** | 4.64# | 2.52 |
| LOCATION | 1,11 | 3.61# | 2.16 | <1 | 11.34** | 38.42*** |
| CLOZE x LOC | 1,11 | <1 | 2.66 | 32.55*** | 17.46** | <1 |
| CLOZ x LOC x EL ⁺ | 11,121 | <1 | 6.6*** | 29.47*** | 6.19*** | 2.79# |

<0.10 * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

⁺ Greenhouse-Geisser adjusted p values

In the window between 0 and 100 ms, the main effect of Location barely reached significance ($F(1,11)=3.61$; $p=0.08$); overall, ERPs were slightly more negative over anterior than over posterior electrodes. Between 100 – 300 ms, the effect of Cloze Probability is already significant; low cloze endings elicit more negative ERPs than do high cloze endings. The three-way interaction between Cloze Probability, Location and Electrode Site indicates overall distributional differences of this effect. In the window 300 – 500 ms, the effect of Cloze Probability remains highly significant; it interacts with the factor Location which confirms that the effect is overall stronger over posterior than over anterior electrodes. In the window 500 – 700 ms, the effect of Cloze Probability barely fails to reach significance ($F(1,11)=4.64$ $p=0.0543$); in this window, ERPs remain to be more positive in the Low than the High Cloze Probability condition. Furthermore, ERPs are overall significantly more positive over posterior than anterior electrodes, and the difference between the high and the low cloze endings is significantly stronger over the posterior than the anterior electrodes. Finally, in the latest window, the only significant effect is that of Location; ERP are more negative over the posterior than over the anterior electrodes with no differences between the two cloze conditions.

3.3.2.3 EFFECTS OF CONTEXT

In Figures 8 and 9, the waveforms of Figures 6 and 7 are rearranged in order to display the effects of Context in the two conditions of Cloze Probability. The results of the

ANOVAs (F values and significance levels) are summarized in Table 14 and 15 for the High and Low Cloze Probability conditions, respectively.

3.3.2.3.1 HIGH CLOZE CONDITION

As can be seen in Figure 8, already right after stimulus onset, there appears to be a difference between the two context conditions. ERPs are more negative in the Discourse than the Sentence condition. This difference is apparent until about 350 ms after stimulus onset. In the latency range of the N400, no apparent differences can be observed between the two context conditions over posterior electrodes while ERPs appear to be slightly more positive in the Sentence than the Discourse condition over anterior sites. Starting at about 700 ms, ERPs continue to be more positive in the Discourse than the Sentence conditions over posterior electrodes. No such differences and overall negative potentials are obtained over anterior sites.

Table 14

F values and significance levels of the ANOVAs on the effect of Context in the High Cloze Probability Condition for the Elderly Controls

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|--------------------------------|--------|---------|-----------|-----------|-----------|------------|
| CONTEXT | 1,19 | 10.08** | 32.49*** | <1 | <1 | <1 |
| LOCATION | 1,19 | <1 | 9.11* | 10.99** | 24.98*** | 23.54*** |
| CONT x LOC | 1,19 | <1 | <1 | 8.91* | <1 | 10.43** |
| CONT x LOC x ELEC ⁺ | 11,209 | 4.09* | 3.25* | <1 | 1.35 | 2.36\$ |

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

⁺ Greenhouse-Geisser adjusted p values

In both early time windows, there was a main effect of Context with more negative-going ERPs for the Discourse than the Sentence condition. In the window 100 – 300 ms, there was also a main effect of Location with overall more negative ERPs over anterior than posterior electrodes. In the N400 time window, no differences were found between the two context conditions. Whereas, the main effect of Location indicates that ERPs were more positive over the posterior than the anterior electrodes. Context and Location interacted such that over posterior electrodes, the difference between the Discourse and Sentence condition

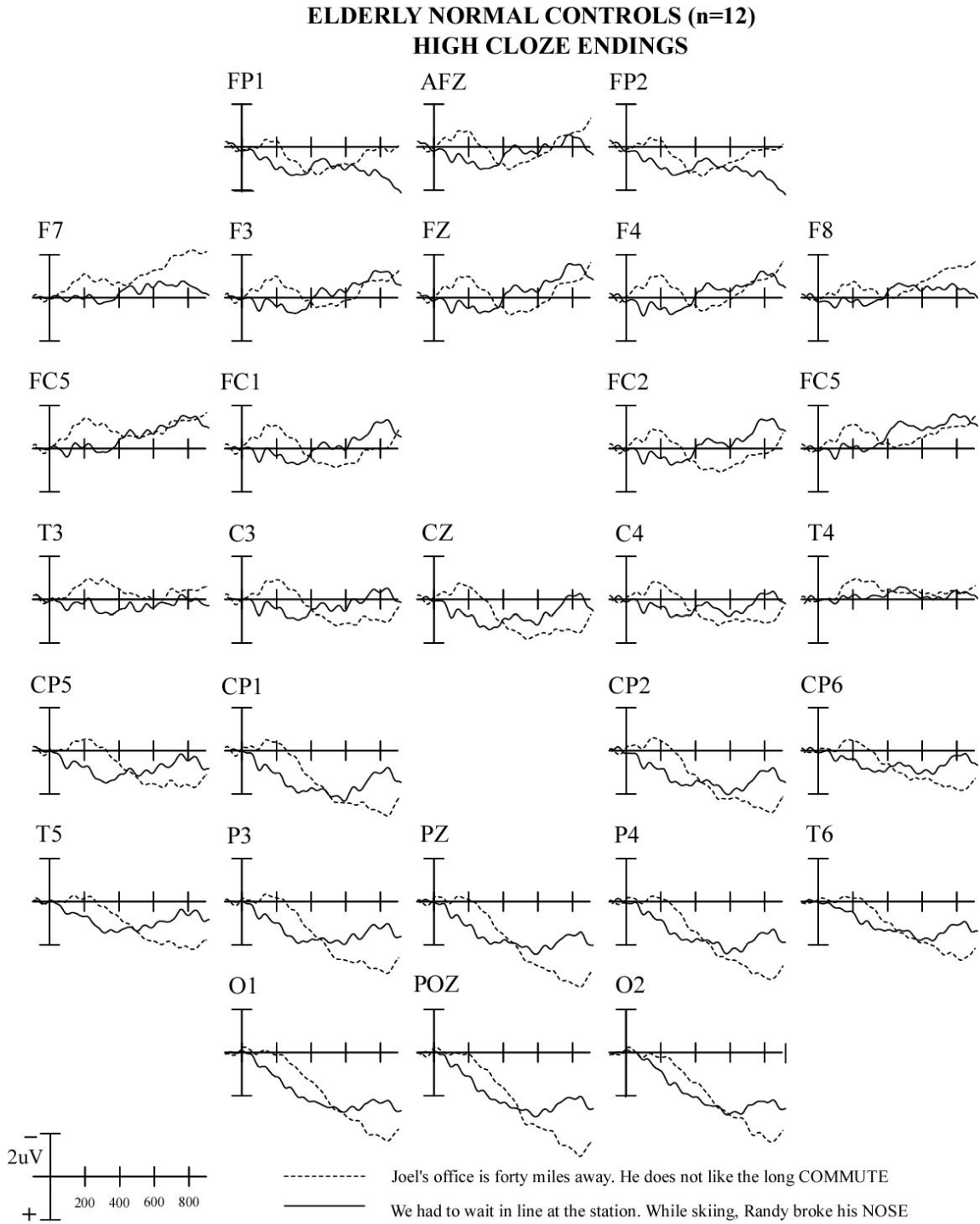


Figure 8 Grand Average ERP waveforms for the Elderly Controls to the High Cloze Probability final words for the discourse (dashed line) and sentence (solid line) contexts

was almost zero ($0.1357\mu\text{V}$), whereas over anterior electrodes, it was negative ($-0.6202\mu\text{V}$). In both late windows, ERPs were overall positive over posterior and negative over anterior electrodes as indicated by the significant main effect of Location. In the latest window, Location and Context interacted such that a difference between the two context conditions was obtained over posterior but not over anterior electrodes.

3.3.2.3.2 LOW CLOZE CONDITION

As can be seen in Figure 9, immediate differences appear to show between the two context conditions. This appears to be more strongly pronounced over the anterior than over the posterior electrodes. In both contexts, an N400 is obtained which is much larger in the Discourse than the Sentence condition; it also has a broader scalp distribution and extends more into frontal sites. The N400 is followed by a positivity which is larger over the posterior than the anterior electrodes, and no apparent differences between the two context conditions can be seen over posterior but over anterior sites.

Table 15

F values and confidence levels of the ANOVAs on the effect of Context in the Low Cloze Probability Condition for the Elderly Controls

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 1000 |
|--------------------------------|--------|---------|-----------|-----------|-----------|------------|
| CONTEXT | 1,19 | 15.62** | 21.62*** | 20.57*** | 1.59 | <1 |
| LOCATION | 1,19 | 6.16* | 1.67 | 1.46 | 4.85* | 24.7*** |
| CONT x LOC | 1,19 | <1 | 4.53 | 27.4*** | 3.2 | 8.8* |
| CONT x LOC x ELEC ⁺ | 11,209 | 3.79* | 6.07*** | 7.71*** | 1.56 | 3.96** |

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

⁺ Greenhouse-Geisser adjusted p values

In the two early windows, ERPs are significantly more negative in the Discourse than the Sentence Condition. Furthermore, in the earliest window, a main effect of Location confirms overall more negative ERPs over anterior than posterior electrodes. The N400 is more negative in the Discourse than the Sentence Condition and has a broader distribution as indicated by the main effect of Context and the interaction between Context and Location. The positivity following thereafter is larger over posterior than over anterior electrodes. In the latest window, the interaction between Context and Location indicates that the difference

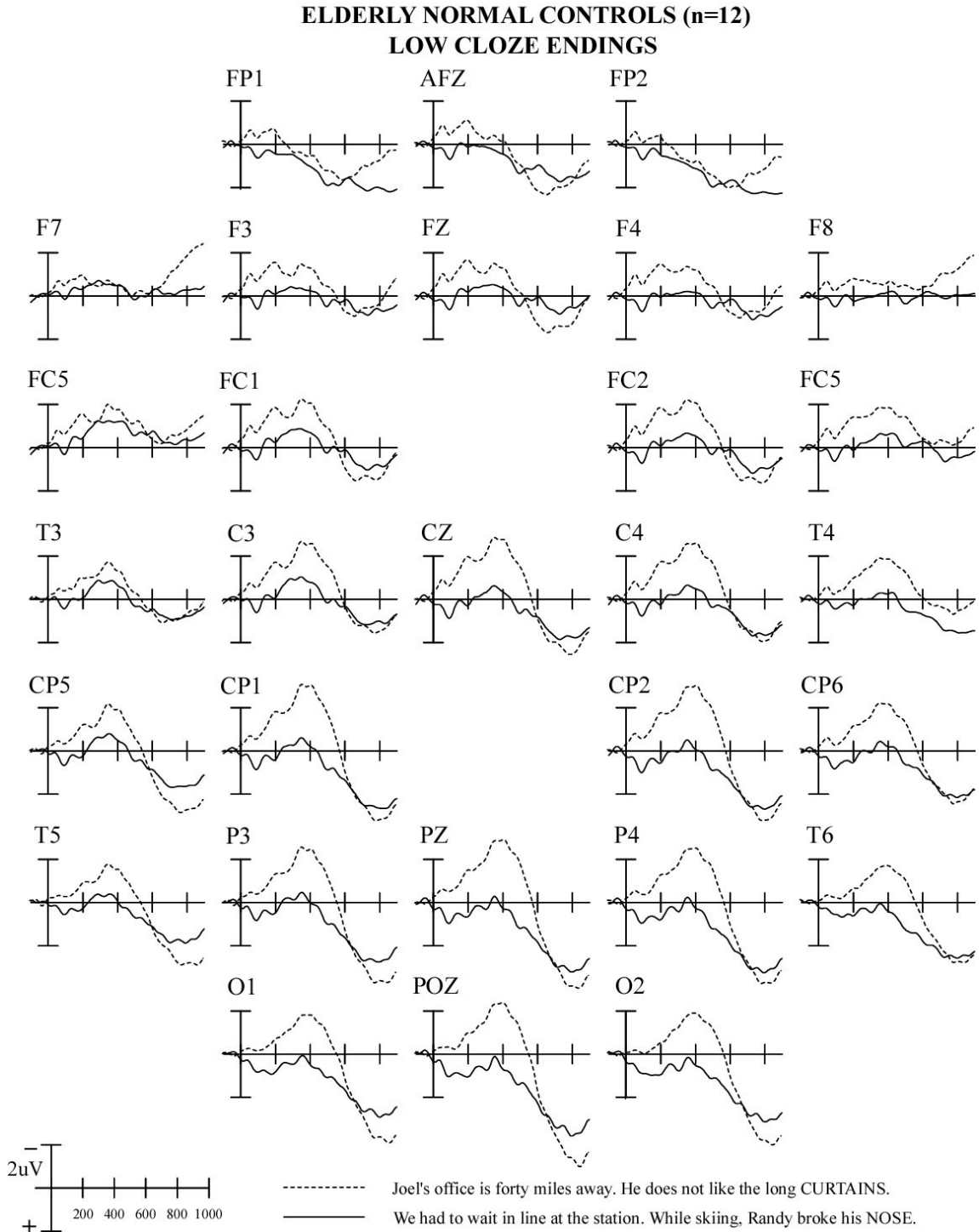


Figure 9 Grand Average ERP waveforms for the Elderly Controls to the Low Cloze Probability final words for the discourse (dashed line) and sentence (solid line) contexts

between the Discourse and the Sentence Condition is overall positive over posterior and negative over anterior electrodes.

3.3.2.4 DIFFERENCE EFFECTS / ONSET ANALYSES

Difference waves were computed by subtracting the ERPs of the high from the low cloze endings for both the Discourse and Sentence conditions (see Figure 10). There was a significant main effect for the factor Context in the time window 300 – 500 ms ($F(1,11)=4.85$; $p=0.0498$) with the N400 effect being more negative for the Discourse than the Sentence condition. This effect did not interact with Electrode Site ($F(28,308)=1.41$; $p=0.08$). In order to determine possible onset differences between the two conditions, ANOVAs were performed on the mean amplitude of the difference waves in consecutive 50 ms time windows starting at the onset of the stimulus. These differences did not reach significance until 350 – 400 ms ($F(1,11)=6.05$; $p=0.0371$). This window was then fractioned into 10ms time windows in order to precisely determine the onset differences which was obtained in the window 380 – 390 ms after stimulus-onset ($F(1,11)=4.99$; $p=0.0471$).

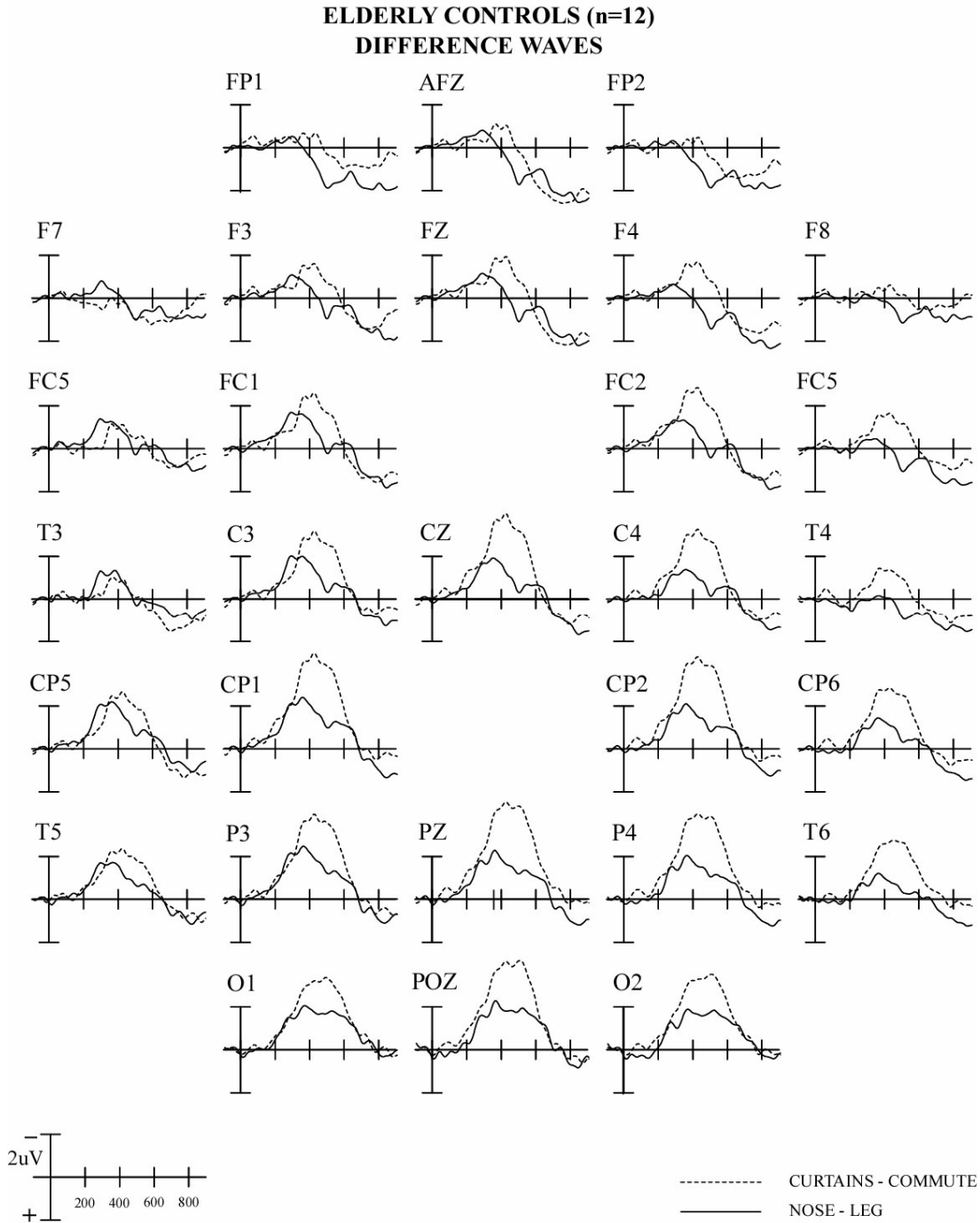


Figure 20 Difference waveforms for the Elderly Controls in the Discourse (dashed line) and Sentence (solid line) conditions. Difference waveforms were created by subtracting the ERPs elicited by the CWs in the coherent condition from those elicited in the incoherent condition

3.3.3 High Comprehenders

3.3.3.1 OVERALL ANALYSES

Overall rejection rates were 20.3% with 19.9% in the Discourse and 20.7% in the Sentence Condition. The results of the initial OMNIBUS ANOVA (F values and significance levels) investigating the effects of Context and Cloze Probability in the five time windows are displayed in Table 16.

Table 16
 F values and significance levels of the OMNIBUS ANOVAs on the effects of Context and Cloze Probability for the High Comprehenders

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 950 |
|---------------------------------|--------|---------|-----------|-----------|-----------|-----------|
| CONTEXT | 1,6 | 4.01# | 5.85* | 15.43** | 10.09* | <1 |
| CONT x ELEC ⁺ | 28,168 | <1 | <1 | <1 | <1 | <1 |
| CLOZE | 1,6 | 4.34# | <1 | 2.39 | 6.6* | <1 |
| CLOZ x ELEC ⁺ | 28,168 | 2.02 | <1 | 4.91* | 2.84# | <1 |
| CONT x CLOZE | 1,6 | <1 | <1 | <1 | 1.29 | <1 |
| CONT x CLOZ x ELEC ⁺ | 28,168 | 1.49 | 1.85 | <1 | <1 | <1 |

$p < 0.1$ $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

⁺ Greenhouse-Geisser adjusted p values

In the earliest time window between 0 and 100 ms, both main effects of Context ($F(1,6)=4.01$; $p=0.09$) and Cloze Probability ($F(1,6)=4.34$; $p=0.08$) approach significance. This shows the tendency that ERPs are more negative both in the Discourse than the Sentence condition and in the incoherent than the coherent condition. In the window 100 – 300 ms, the effect of Context is the only significant one, ERPs are more negative in the Discourse than the Sentence condition. In the N400 time window (300 – 500 ms), ERPs continue to be more negative in the Discourse than the Sentence condition. The effect of Cloze Probability interacts with Electrode Site, and ERPs are more negative in the Low than the High Cloze Probability condition and at posterior than anterior electrodes. In the window 500 – 700 ms, there was a significant main effect of Context with more positive ERPs in the High than the Low Cloze Probability condition as well as for Coherence; ERPs remain more negative in the

Discourse than the Sentence condition. Finally, in the latest window, no significant effects are obtained.

3.3.3.2 EFFECTS OF COHERENCE

The results of the ANOVAs (F values and significance levels) for the effects of Cloze Probability are displayed in Tables 17 and 18 for the Sentence and Discourse conditions, respectively. Note that due to clipping in one subject, ERPs could only be averaged until 950 ms after stimulus onset.

3.3.3.2.1 SENTENCE CONDITION

Figure 11 displays the ERPs for the high low cloze endings in the Sentence condition. No early differences and no sensory components are visible, and the waveforms start to diverge about 100 ms after the onset of the CW. A negative deflection is evoked in the Low, but not the High Cloze condition; it has a clear centro-posterior distribution and reaches its peak at around 500 ms after stimulus onset. In the later time windows, no differences can be seen between the high and low cloze endings.

Table 17

***F* values and significance levels of the ANOVAs on the effect of Cloze Probability in the Sentence Condition for the High Comprehenders**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 950 |
|---------------------------------|-------|---------|-----------|-----------|-----------|-----------|
| CLOZE | 1,6 | 1.19 | <1 | 1.95 | <1 | <1 |
| LOCATION | 1,6 | <1 | 2.09 | <1 | 1.2 | 2.43 |
| CLOZE x LOC | 1,6 | 5.57* | <1 | 46.79*** | 8.19* | <1 |
| CLOZE x LOC x ELEC ⁺ | 11,66 | <1 | 1.07 | 1.58 | <1 | <1 |

$p < 0.1$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

⁺ Greenhouse-Geisser adjusted p values

In the earliest window, Cloze Probability and Location significantly interacted with each other. ERPs were more positive in the low than the High Cloze Probability condition; this effect was pronounced at anterior but not posterior electrodes. In the window 100 – 300 ms, none of the effects reached significance. In the two following time windows (300 – 500 ms; 500 – 700 ms) a highly significant interaction between Cloze Probability and Location was obtained. ERPs were more negative in the low than the High Cloze condition; this effect

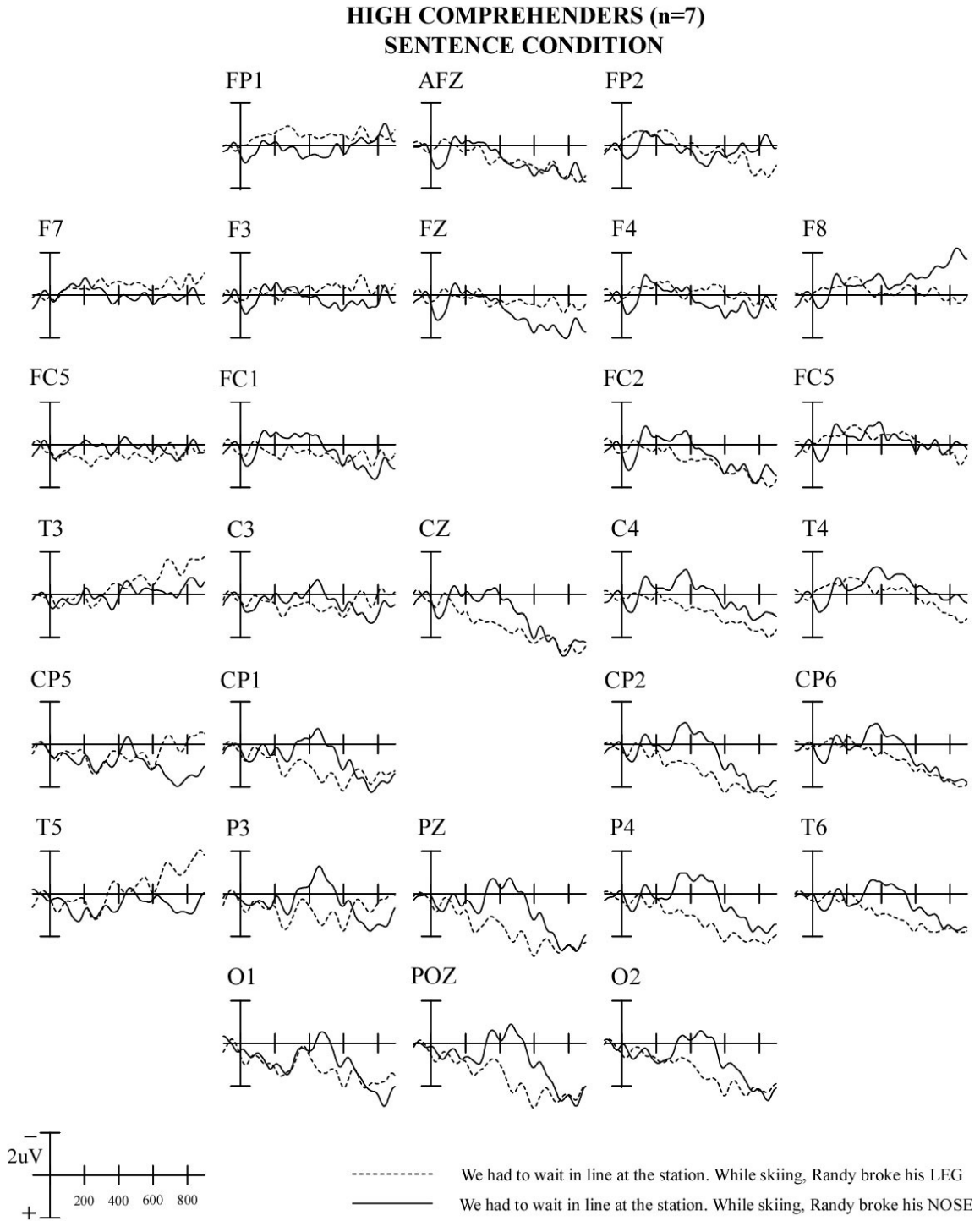


Figure 11 Grand Average ERP waveforms for the High Comprehenders to the high (dashed line) and low cloze probability (solid line) final words in the Sentence Condition

was observed at the posterior but not the anterior electrodes. None of the effects was significant in the latest time window. The N400 effect was again examined at the centro-posterior electrodes at which it was maximal; the main effect of Cloze Probability approached significance in the earlier window (300 – 500 ms: $F(1,6)=5.07$; $p=0.06$) and failed to reach significance in the later time window (500 – 700 ms: $F(1,6)=3.16$; $p=0.12$).

3.3.3.2.2 DISCOURSE CONDITION

Figure 12 shows that no clear N1-P2 complex can be distinguished for the high and low cloze CWs in the Discourse condition. The waveforms start to diverge at about 100 ms after stimulus onset and are more negative in the Low than the High Cloze Probability condition. A negative deflection with a centro-posterior distribution and a peak at around 600 ms is found in the Low, but not the High Cloze Probability condition and only at posterior but not at anterior electrode sites. This negativity is followed by a positivity that is maximal between 700 and 1000 ms which is more pronounced over posterior than anterior electrode sites. Differences between High and Low Cloze Probability conditions can be observed at posterior but not at anterior electrodes.

Table 18

***F* values and significance levels of the ANOVAs on the effect of Cloze Probability in the Discourse Condition for the High Comprehenders**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 950 |
|--------------------|-------|---------|-----------|-----------|-----------|-----------|
| CLOZE | 1,6 | 3.71 | <1 | 1.85 | 5.3# | 1.44 |
| LOCATION | 1,6 | <1 | <1 | 0 | 2.64 | 9.94* |
| CLOZ x LOC | 1,6 | 4.78# | 4.12# | 7.0* | 2.91 | <1 |
| CLOZE x LOC x ELEC | 11,66 | 1.16 | <1 | 1.87 | 2.46# | 1.21 |

$p<0.1$ $p<0.05$ ** $p<0.01$ *** $p<0.001$

* Greenhouse-Geisser adjusted p values

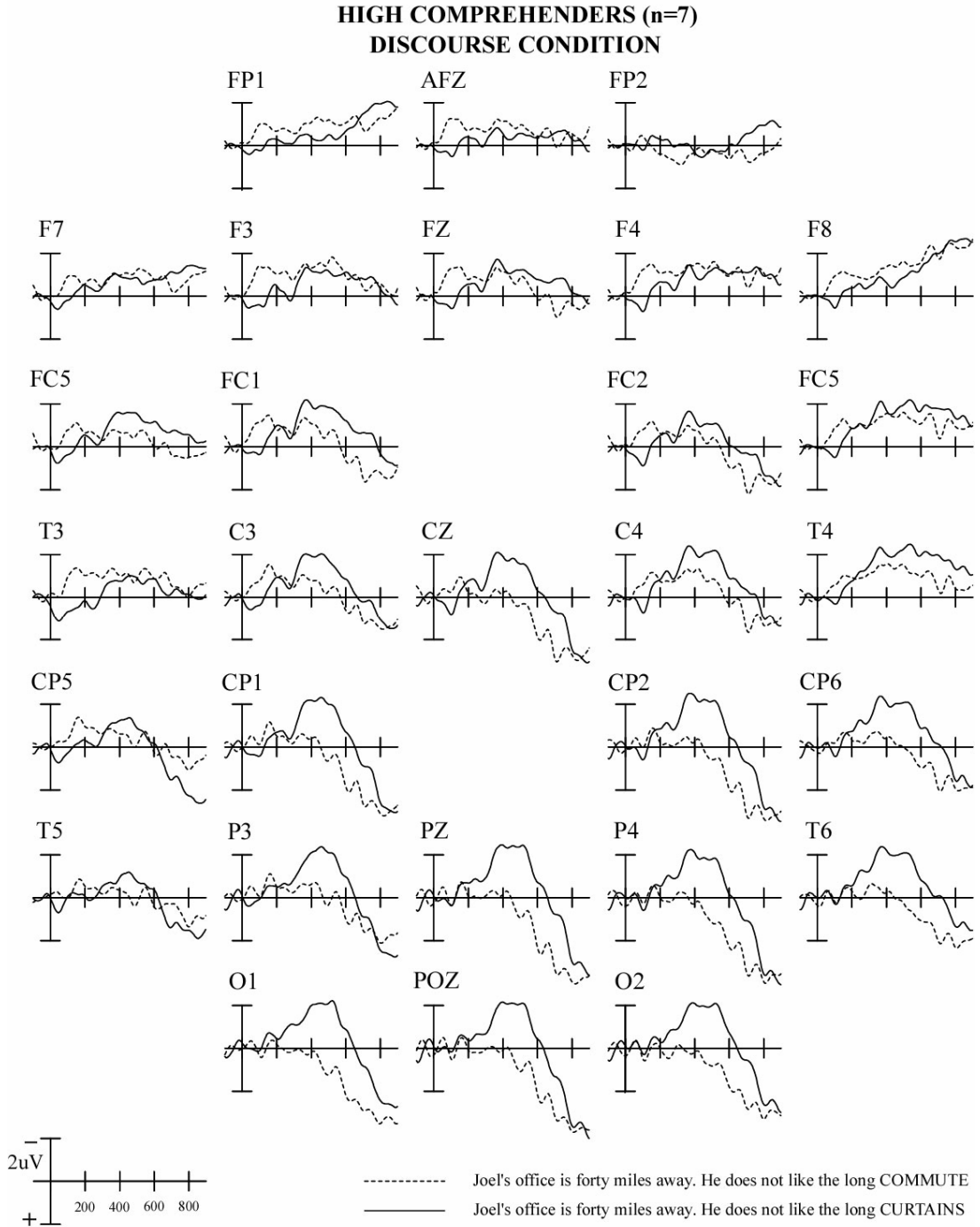


Figure 3 Grand Average ERP waveforms for the High Comprehenders to the high (dashed line) and low cloze probability (solid line) final words in the Discourse Condition

In both early windows, marginally significant interactions between Cloze Probability and Location were obtained (0 – 100 ms: ($F(1,6)=4.78$; $p=0.07$); 100 – 300 ms: ($F(1,6)=4.12$; $p=0.08$)); this supports the trend that ERPs are more negative in the High than the Low Cloze Probability condition; this effect is more strongly pronounced at anterior than posterior electrodes. In the N400 time window, the only significant effect is the interaction between Cloze Probability and Location. ERPs are more negative in the Low Cloze Probability condition and more so at posterior than anterior electrodes. The main effect of Cloze Probability only approaches significance until the following window (500 – 700 ms; ($F(1,6)=5.30$; $p=0.06$)). In the latest window, the only significant effect is the one of Location; ERPs are more positive at posterior than anterior electrodes; this does not differ between the two context conditions.

In order to omit a type II error because of the small sample size, the effect of the N400 was further examined at the centro-posterior electrode sites at which it is largest (C3, C4, CP1, CP2, P3, P4, CZ, POZ). The effect was larger in the window 500 – 700 ms ($-1.04 \mu\text{V}$; $F(1,6)=8.16$; $p=0.02$) than in the window 300 – 500 ms ($-0.90 \mu\text{V}$; $F(1,6)=3.13$; $p=0.12$).

3.3.3.3 EFFECTS OF CONTEXT

The waveforms for the coherent and incoherent CWs in the Discourse and Sentence conditions are re-arranged in Figures 13 and 14 in order to display the effects of Context. Figure 13 displays a direct comparison of the ERPs elicited by the sentence and discourse in the High condition and Figure 14 does so for the Low Cloze condition. The results of the ANOVAs (F values and significance levels) are summarized in Tables 19 and 20 for the High and Low Cloze Probability conditions, respectively.

3.3.3.3.1 HIGH CLOZE CONDITION

In Figure 13, the waveforms elicited by the sentence and discourse contexts in the High Cloze condition are plotted. Already right after the onset of the CW, ERPs appear to be more negative in the Discourse than the Sentence condition. This effect seems to be less locally circumscribed to anterior electrodes than in the two control groups. Following this early effect, the waveforms appear to be morphologically very similar in the two context conditions. It is not until about 700 ms after stimulus onset that the waveforms appear to be

more positive in the Discourse than the Sentence conditions; this difference again does not have an obvious locally circumscribed distribution.

Table 19

***F* values and significance levels of the ANOVAs on the effect of Context in the high Cloze Probability condition for the High Comprehenders**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 950 |
|--------------------------------|-------|----------|-----------|-----------|-----------|-----------|
| CONTEXT | 1,6 | 3.22 | 4.72* | 6.16* | <0 | <1 |
| LOCATION | 1,6 | 37.32*** | 12.75* | 13.46** | 4.74# | 3.88# |
| CONT x LOC | 1,6 | <1 | <1 | <1 | <1 | 2.36 |
| CONT x LOC x ELEC ⁺ | 11,66 | 1.54 | 2.44 | 1.22 | <1 | <1 |

$p < 0.1$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

+ Greenhouse-Geisser adjusted p value

In the earliest window (0 – 100 ms), there is a highly significant main effect of Location. ERPs are more negative at anterior than posterior electrodes, but they do not differ between the two context conditions. In the windows 100 – 300 ms and 300 – 500 ms, ERPs are more negative both in the Discourse than the Sentence condition as revealed by the main effect of Context and at anterior than at posterior electrodes as revealed by the main effect of Location. In the window 500 – 700 ms, the effect of Location is only marginally significant ($F(1,6)=4.74$; $p=0.07$); this indicates a trend towards more positive ERPs at posterior than at anterior electrodes. In the latest time window, again only a marginal trend is obtained for the effect of Location ($F(1,6)=3.88$; $p=0.09$); ERPs are overall more positive at posterior than at anterior electrodes.

3.3.3.3.2 LOW CLOZE CONDITION

Figure 14 displays the waveforms elicited by the sentence and discourse contexts in the Low Cloze condition. Unlike in the High Cloze Probability condition, the waveforms do not appear to diverge immediately after stimulus onset. In both conditions, a negativity is obtained which is more pronounced at posterior than anterior electrode sites and which appears to be larger in the Discourse than the Sentence condition between 300 and 700 ms. It is followed by a positivity at posterior but not anterior electrodes.

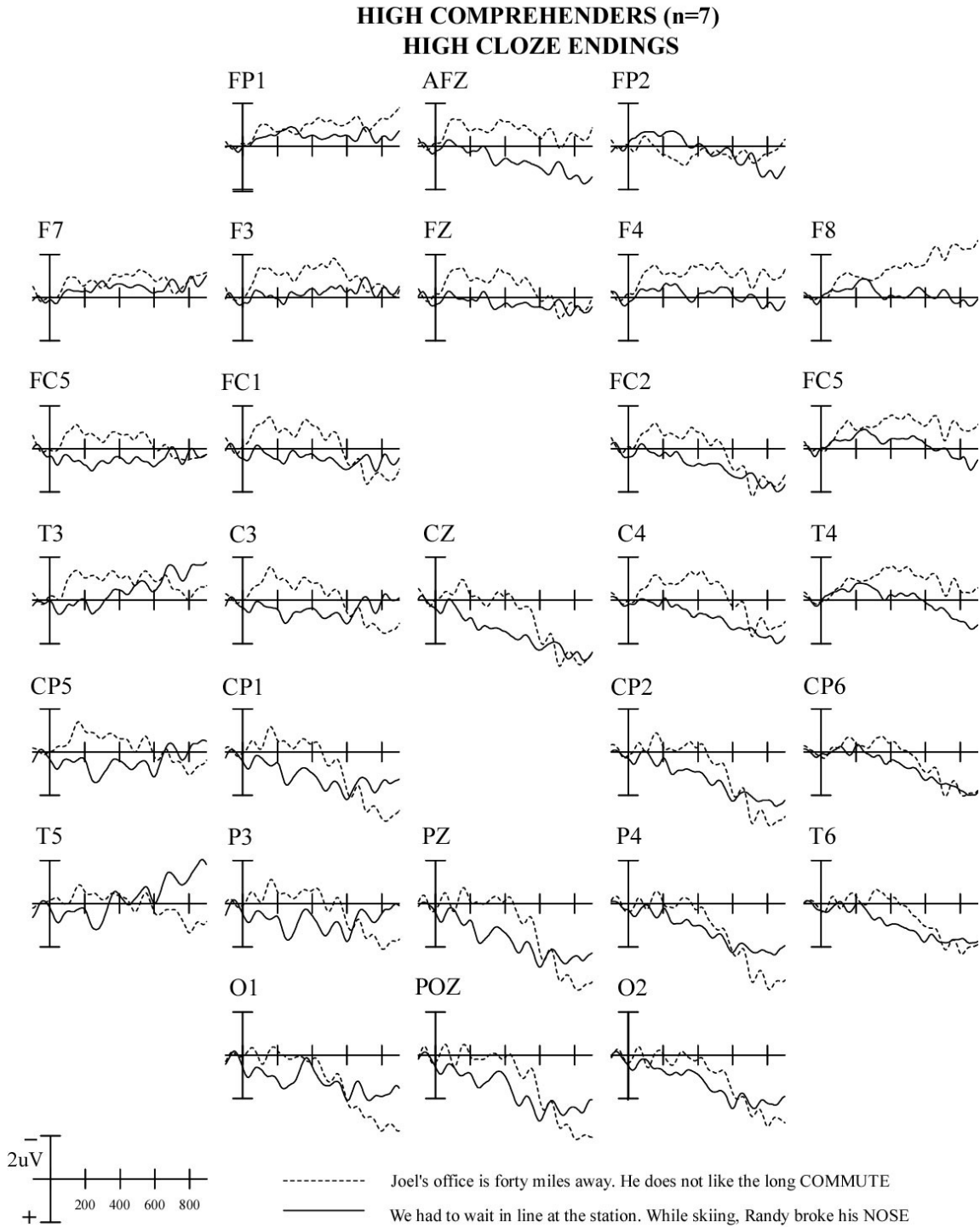


Figure 13 Grand Average ERP waveforms for the High Comprehenders to the high cloze final words in the Discourse (dashed line) and Sentence (solid line) Condition

Table 20***F* values and significance levels of the ANOVAs on the effect of Context in the low Cloze Probability Condition for the High Comprehenders**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 950 |
|--------------------------------|-------|---------|-----------|-----------|-----------|-----------|
| CONTEXT | 1,6 | <1 | 1.07 | 6.21* | 21.4** | <1 |
| LOCATION | 1,6 | 1.21 | <1 | 5.43# | <1 | 11.57* |
| CONT x LOC ⁺ | 1,6 | <1 | 1.2 | <1 | <1 | 2.58 |
| CONT x LOC x ELEC ⁺ | 11,66 | 1.42 | <1 | <1 | 1.42 | <1 |

$p < 0.1$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$ + Greenhouse-Geisser adjusted p values

In both early windows, no significant main effects were obtained. In the time window 300 – 500 ms, the only significant main effect was that of Context: ERPs were more negative in the Discourse than the Sentence condition. The effect of Location barely failed to reach significance ($F(1,6)=5.43$; $p=0.058$); this indicates a trend toward more negative ERPs at posterior than at anterior electrodes. ERPs remain to be more negative in the Discourse than the Sentence condition in the following window as indicated by the main effect of Context. In the latest time window, the only significant main effect is that of Location; overall, ERPs are positive at posterior and negative at anterior electrodes, but they do not differ between the two context conditions.

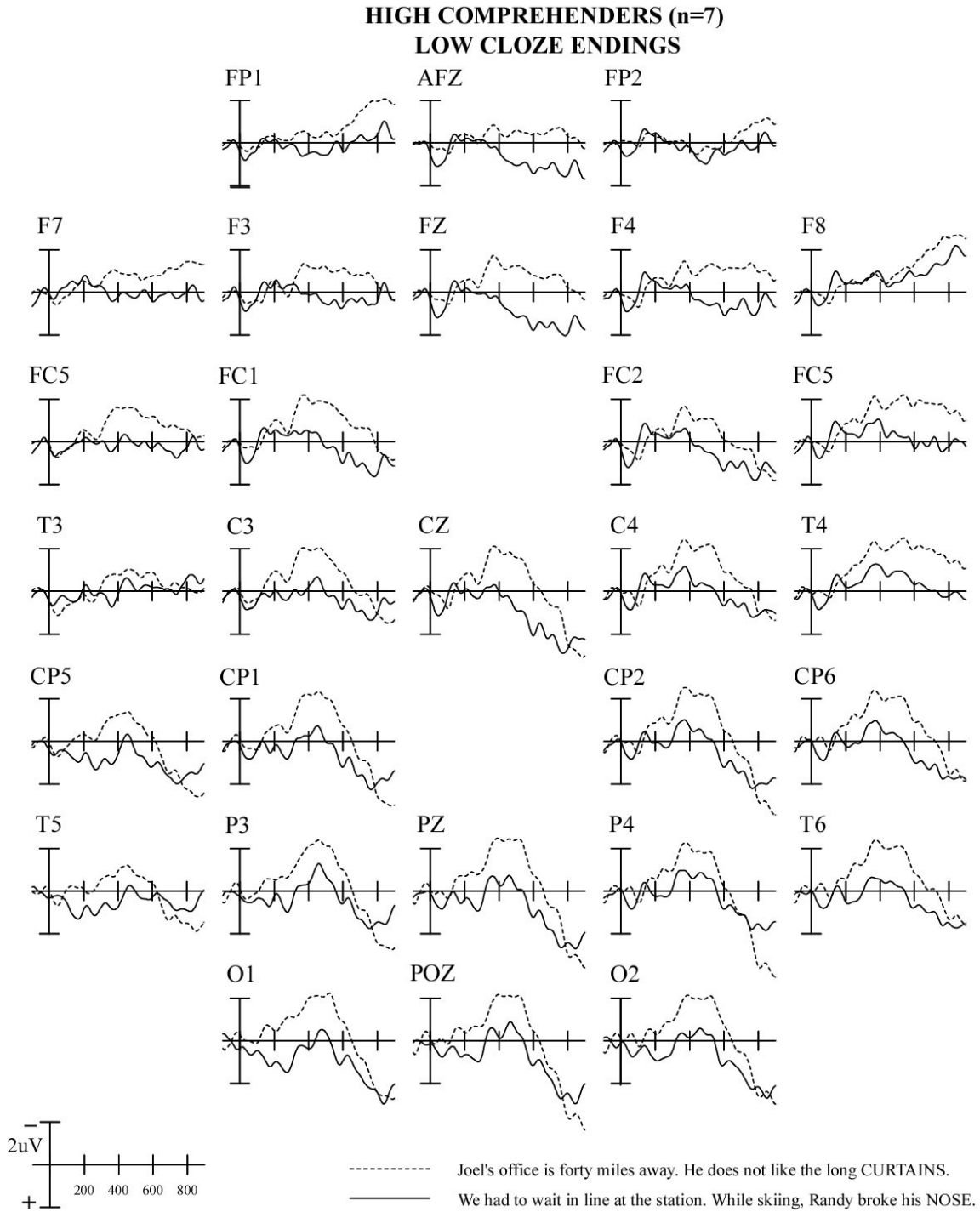


Figure 14 Grand Average ERP waveforms for the High Comprehenders to the low cloze final words in the Discourse (dashed line) and Sentence (solid line) Condition

3.3.3.4 DIFFERENCE EFFECTS / ONSET ANALYSES

Difference waves were computed by subtracting the ERPs of the high from the high Cloze Probability endings for both the Discourse and Sentence conditions; the waveforms are displayed in Figure 15. There was no significant main effect for the factor Context in the time window 300 – 500 ms and 500 – 700 ms ($F_s < 1$) indicating no differences in both time windows of the N400 between the Sentence and Discourse conditions. Thus, no onset analyses were performed. Post-hoc analyses comprising the factor Time Window reveal that in the Sentence condition, ERPs are marginally significantly larger in the earlier than the later window ($t = -2.161$; $p = 0.0517$); in the Discourse condition, ERPs were not significantly different in the two time windows.

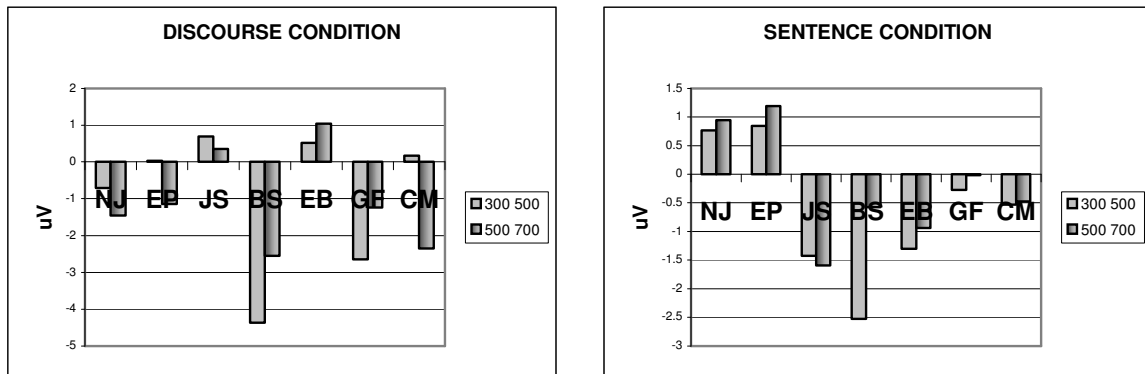


Figure 15 Single subjects difference effects for the High Comprehenders in the time windows 300 – 500 ms for the Sentence condition (left panel) and the Discourse condition (right panel).

**HIGH COMPREHENDERS (n=7)
DIFFERENCE WAVES**

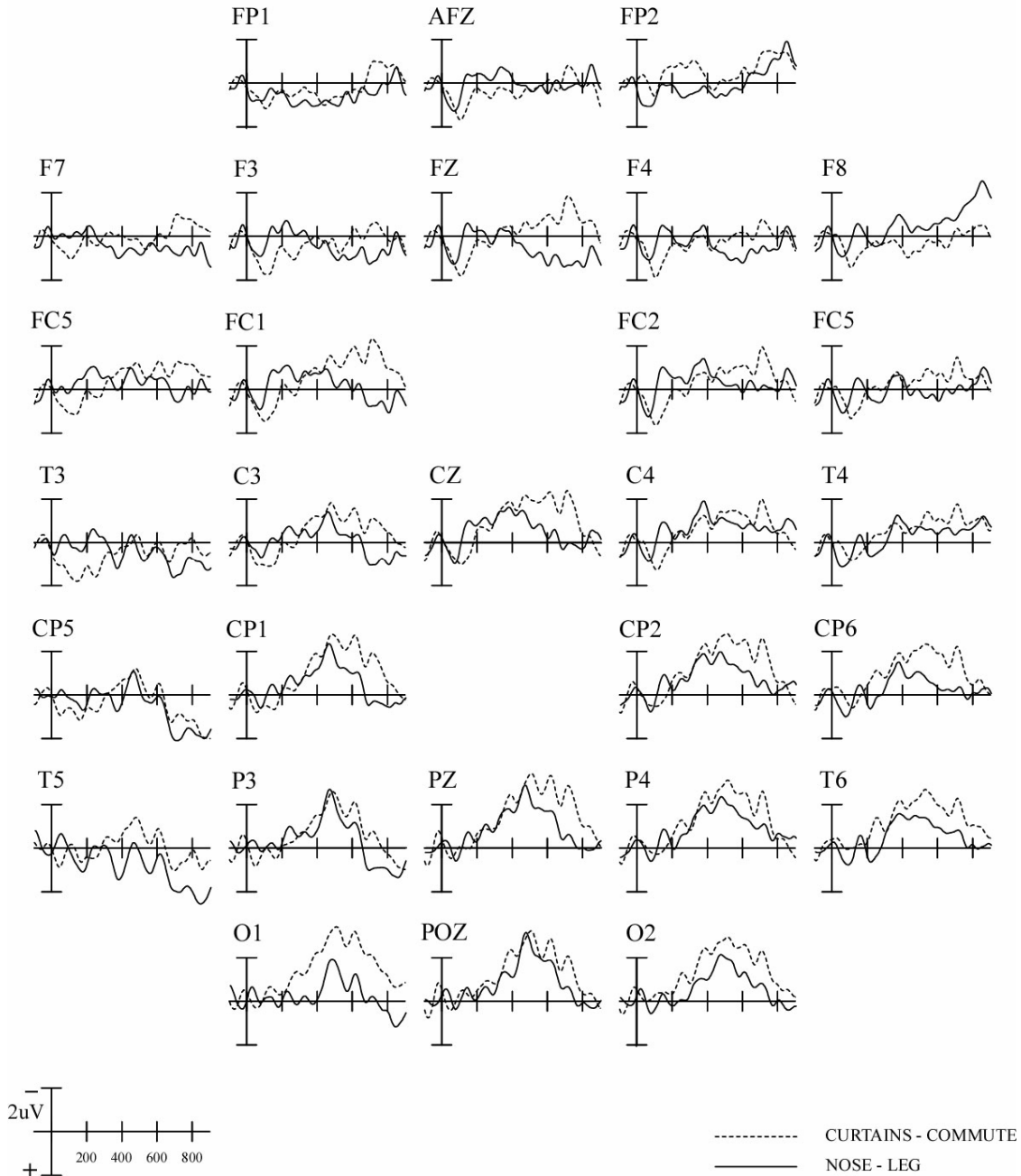


Figure 16 Difference waveforms for the High Comprehenders in the Discourse (dashed line) and Sentence (solid line) conditions. Difference waveforms were created by subtracting the ERPs elicited by the CWs in the coherent condition from those elicited in the incoherent condition

3.3.4 Low Comprehenders

3.3.4.1 OVERALL ANALYSES

The results of the initial OMNIBUS ANOVA (F values and significance levels) investigating the effects of Context and Cloze Probability in the five time windows are displayed in Table 21. Overall rejection rates were 21.2% with 18.3% in the Discourse and 24.1% in the Sentence Condition.

Table 21
***F* values and significance levels of the OMNIBUS ANOVAs on the effects of Context and Cloze Probability for the Low Comprehenders**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 950 |
|----------------------------------|--------|---------|-----------|-----------|-----------|-----------|
| CONTEXT | 1,4 | <1 | 1.05 | <1 | <1 | <1 |
| CONT x ELEC ⁺ | 28,112 | <1 | <1 | <1 | <1 | <1 |
| CLOZE | 1,4 | <1 | <1 | <1 | 1.02 | <1 |
| CLOZE x ELEC ⁺ | 28,112 | <1 | <1 | <1 | <1 | 1.09 |
| CONTEXT x CLOZE | 1,4 | <1 | <1 | 2.49 | 2.51 | 1.69 |
| CONT x CLOZE x ELEC ⁺ | 28,112 | <1 | 1.65 | <1 | <1 | <1 |

$p < 0.1$ $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

⁺ Greenhouse-Geisser adjusted p values

In the overall analyses, no significant effects were obtained in any time window. In the following, I am going to report separate analyses for the effects of Cloze Probability and Context.

3.3.4.2 EFFECTS OF CLOZE PROBABILITY

The results of the ANOVAs (F values and significance levels) for the effects of Cloze Probability are displayed in Tables 22 and 23 for the Discourse and Sentence conditions, respectively. Note that due to clipping in one subject, ERPs could only be averaged until 950 ms after stimulus onset.

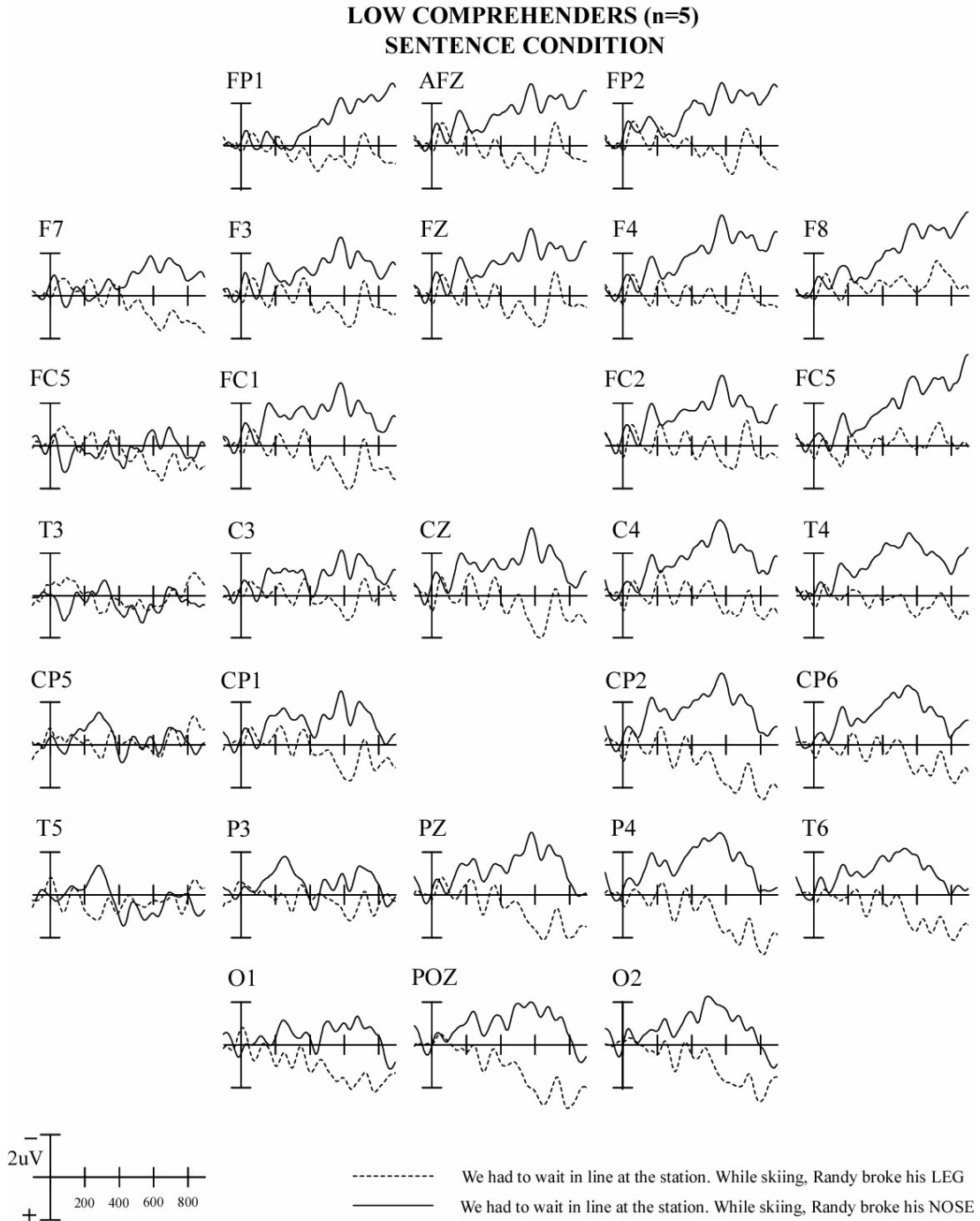


Figure 17 Grand Average ERP waveforms for the Low Comprehenders to the high (dashed line) and low cloze probability (solid line) final words in the Sentence Condition

3.3.4.2.1 SENTENCE CONDITION

Figure 17 displays the ERPs for the high and low cloze endings in the Sentence condition. ERPs are more negative in the Low than the High Cloze Probability condition, starting at about 400 ms after stimulus onset; this negativity does not have a clear centro-posterior distribution and can be observed throughout the scalp. Waveforms do not go back to baseline in the window that could be averaged.

Table 22

***F* values and significance levels of the ANOVAs on the effect of Cloze Probability in the Sentence Condition for the Low Comprehenders**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 950 |
|---------------------------------|-------|---------|-----------|-----------|-----------|-----------|
| CLOZE | 1,4 | 1.12 | 1.35 | 1.7 | 3.73 | 3.75 |
| LOCATION | 1,4 | 2.3 | <1 | 1.29 | 2.2 | 6.88# |
| CLOZE x LOC | 1,4 | <1 | <1 | <1 | <1 | 1.18 |
| CLOZE x LOC x ELEC ⁺ | 11,44 | <1 | <1 | 1.05 | 1.69 | 1.07 |

$p < 0.1$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

+ Greenhouse-Geisser adjusted p values

The apparent differences between the High and Low Cloze Probability condition in the later time windows could not be statistically confirmed. Further analyses at centro-posterior sites, i.e., at which the effect is most strongly pronounced could not confirm it either in the windows in which it was investigated (300 – 500 ms: ($F(1,4)=1.25$; $p=0.32$); 500 – 700 ms: ($F(1,4)=2.87$; $p=0.16$); 700 – 950 ms: ($F(1,4)=3.03$; $p=0.25$).

3.3.4.2.2 DISCOURSE CONDITION

Figure 18 shows the ERPs elicited in the Discourse Condition. Unlike in the two control groups and the group of the High Comprehenders, no clearly defined components with respect to morphology and topography can be seen. ERPs appear to be more negative in the Low than High Cloze Probability condition starting at about 500 ms; this difference is pronounced over anterior, but not posterior electrode sites.

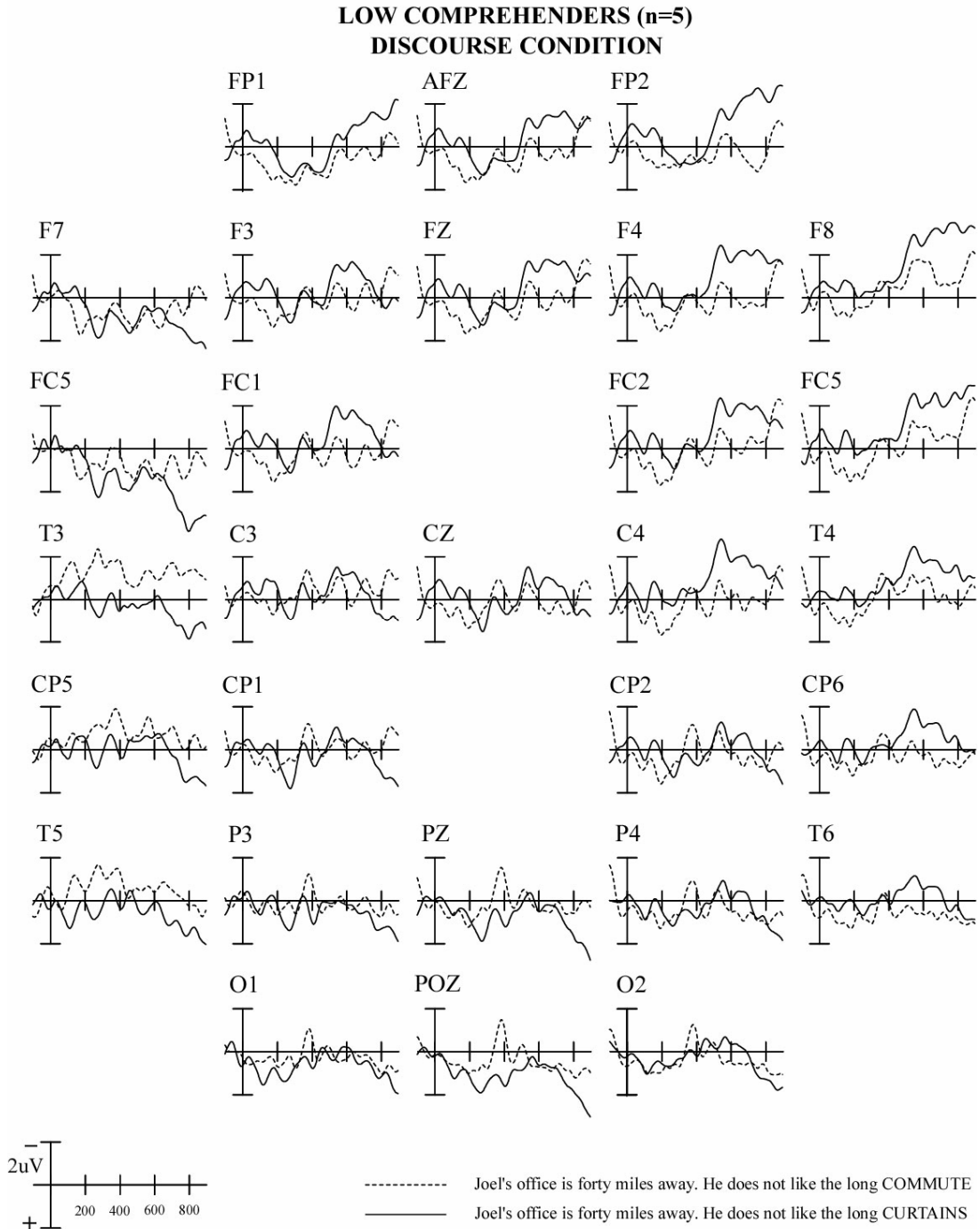


Figure 18 Grand Average ERP waveforms for the Low Comprehenders to the high (dashed line) and low cloze probability (solid line) final words in the Discourse Condition

Table 23

***F* values and significance levels of the ANOVAs on the effect of Cloze Probability in the Discourse Condition for the Low Comprehenders**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 950 |
|--------------------|-------|---------|-----------|-----------|-----------|-----------|
| CLOZE | 1,4 | <1 | <1 | <1 | <1 | <1 |
| LOCATION | 1,4 | 3.73 | <1 | <1 | <1 | 1.07 |
| CLOZE x LOC | 1,4 | 5.66# | 1.59 | 2.5 | 2.24 | 1.98 |
| CLOZE x LOC x ELEC | 11,44 | <1 | <1 | <1 | <1 | <1 |

$p < 0.1$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

* Greenhouse-Geisser adjusted p values

The only effect that approaches significance is the interaction between Cloze Probability and Location in the time window 0 – 100 ms Cloze Probability ($F(1,4)=5.66$; $p=0.07$). ERPs are negative in the Low Cloze Probability condition at anterior electrodes and positive in all other conditions.

3.3.4.3 EFFECTS OF CONTEXT

The waveforms by the high and low cloze CWs in the Discourse and Sentence conditions are re-arranged in Figures 19 and 20 in order to display the effects of Context. Figure 18 displays a direct comparison of the sentence and discourse contexts for the High Cloze condition and Figure 19 for the Low Cloze condition. The results of the ANOVAs (F values and significance levels) are summarized in Table 24 and 25 for the High and Low Cloze Probability conditions, respectively.

3.3.4.3.1 HIGH CLOZE CONDITION

In Figure 19, the waveforms elicited by the Discourse and Sentence contexts in the High Cloze condition are plotted. No apparent differences between the two conditions can be seen.

**LOW COMPREHENDERS (n=5)
HIGH CLOZE ENDINGS**

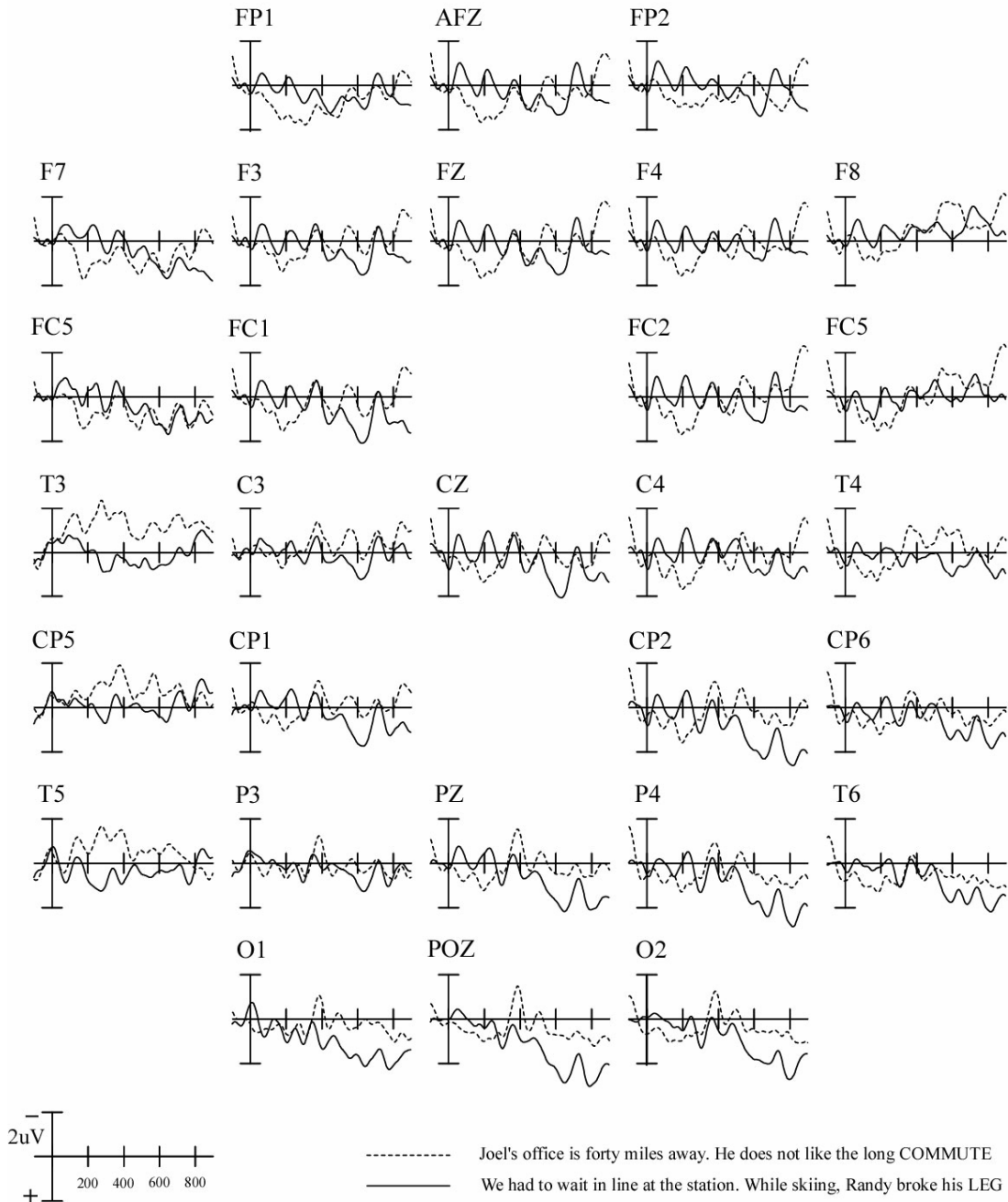


Figure 19 Grand Average ERP waveforms for the Low Comprehenders to the high cloze final words in the Discourse (dashed line) and Sentence (solid line) Condition

Table 24**F values and significance levels of the ANOVAs on the effect of Context in the High Cloze Probability Condition for the Low Comprehenders**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 950 |
|--------------------------------|-------|---------|-----------|-----------|-----------|-----------|
| CONTEXT | 1,4 | <1 | <1 | <1 | <1 | <1 |
| LOCATION | 1,4 | 1.46 | <1 | <1 | <1 | 3.04 |
| CONT x LOC | 1,4 | <1 | 1.38 | <1 | <1 | <1 |
| CONT x LOC x ELEC ⁺ | 11,44 | <1 | <1 | <1 | <1 | <1 |

p<0.1 * p<0.05 ** p<0.01 ***p<0.001

⁺ Greenhouse-Geisser adjusted p values

Statistical analyses confirm that there are no differences between the sentence and discourse contexts in the High Cloze condition.

3.3.4.3.2 LOW CLOZE CONDITION

Figure 20 displays the waveforms for the low cloze endings in the Discourse and Sentence conditions. Unlike in the High Cloze Probability condition, the waveforms do appear to be more negative in the Sentence than the Discourse condition and more so at posterior than anterior electrodes.

Table 25**F values and significance levels of the ANOVAs on the effect of Context in the Low Cloze Probability Condition for the Low Comprehenders**

| SOURCE | df | 0 – 100 | 100 – 300 | 300 – 500 | 500 – 700 | 700 – 950 |
|--------------------------------|-------|---------|-----------|-----------|-----------|-----------|
| CONTEXT | 1,4 | <1 | 1.28 | 1.21 | 2.24 | 2.1 |
| LOCATION | 1,4 | 3.49 | <1 | <1 | 1.04 | 4.06 |
| CONT x LOC ⁺ | 1,4 | 1.03 | 1.75 | <1 | <1 | <1 |
| CONT x LOC x ELEC ⁺ | 11,44 | <1 | <1 | 1.19 | 2.09 | 3 |

p<0.1 * p<0.05 ** p<0.01 ***p<0.001

⁺ Greenhouse-Geisser adjusted p values

Statistical analyses do not confirm the apparent differences between the sentence and discourse contexts in the Low Cloze condition.

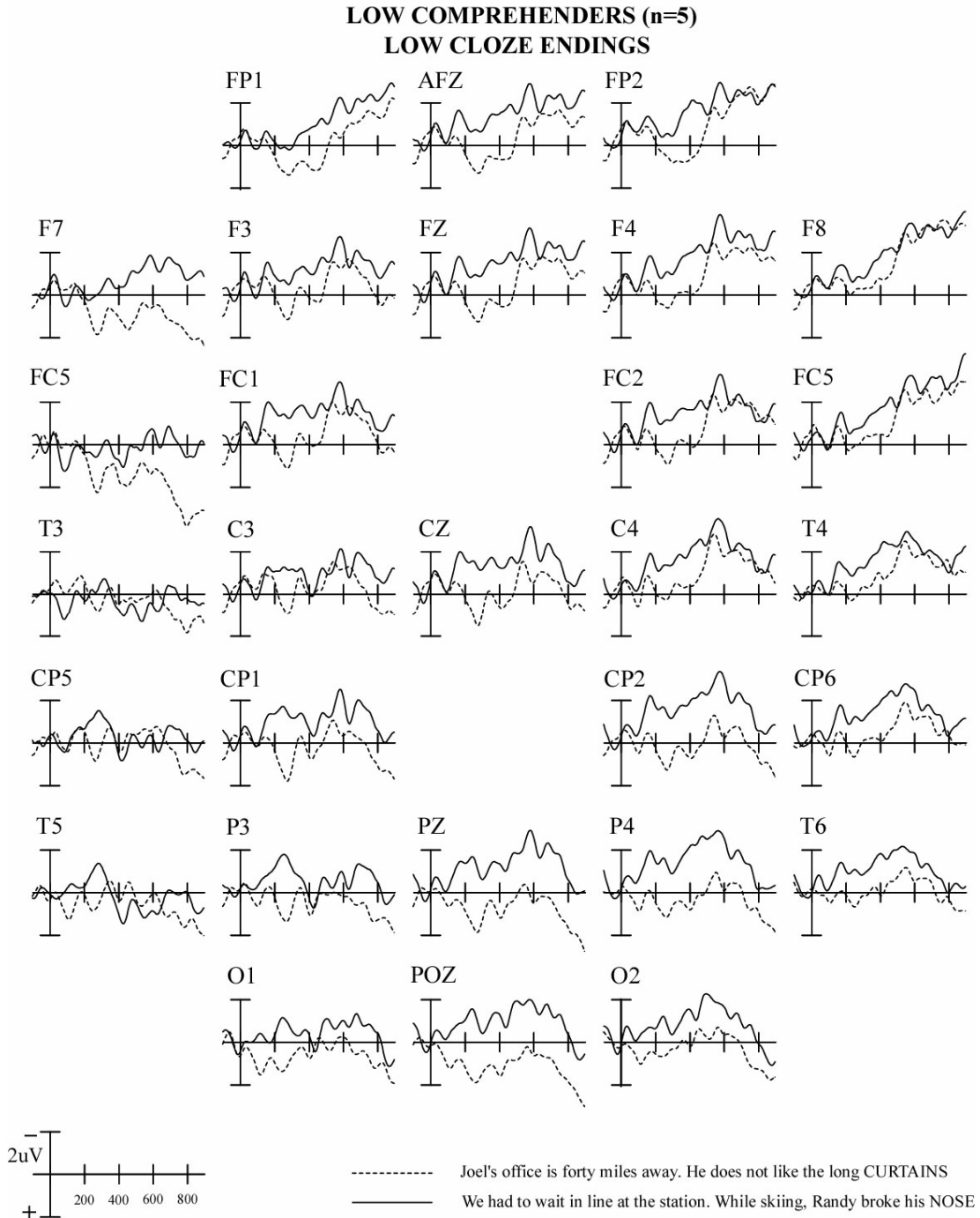


Figure 20 Grand Average ERP waveforms for the Low Comprehenders to the Low cloze final words in the Discourse (dashed line) and Sentence (solid line) Condition

3.3.4.3.3 DIFFERENCE EFFECTS/ONSET ANALYSES

Difference waves were computed by subtracting the ERPs of the low from the high Cloze Probability endings for both the Discourse and Sentence conditions. They are displayed in Figure 22; single subjects ERPs for the two context conditions are plotted in Figure 21. There was no significant main effect for the factor Context in the time window 300 – 500 ms and 500 – 700 ms ($F_s < 1$) indicating no differences in both time windows of the N400 between the Sentence and Discourse conditions. Thus, no onset analyses were performed.

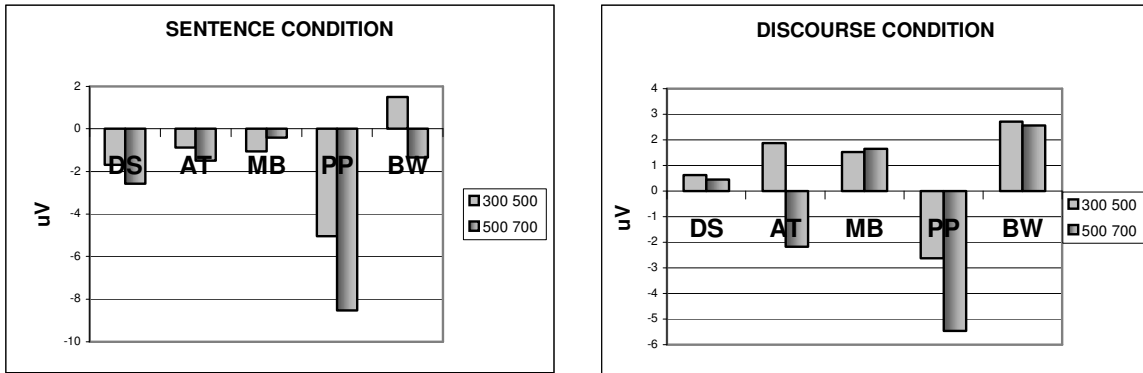


Figure 21 Single subjects difference effects for the High Comprehenders in the time windows 300 – 500 ms for the Sentence condition (left panel) and the Discourse condition (right panel).

LOW COMPREHENDERS (n=5)
DIFFERENCE WAVES

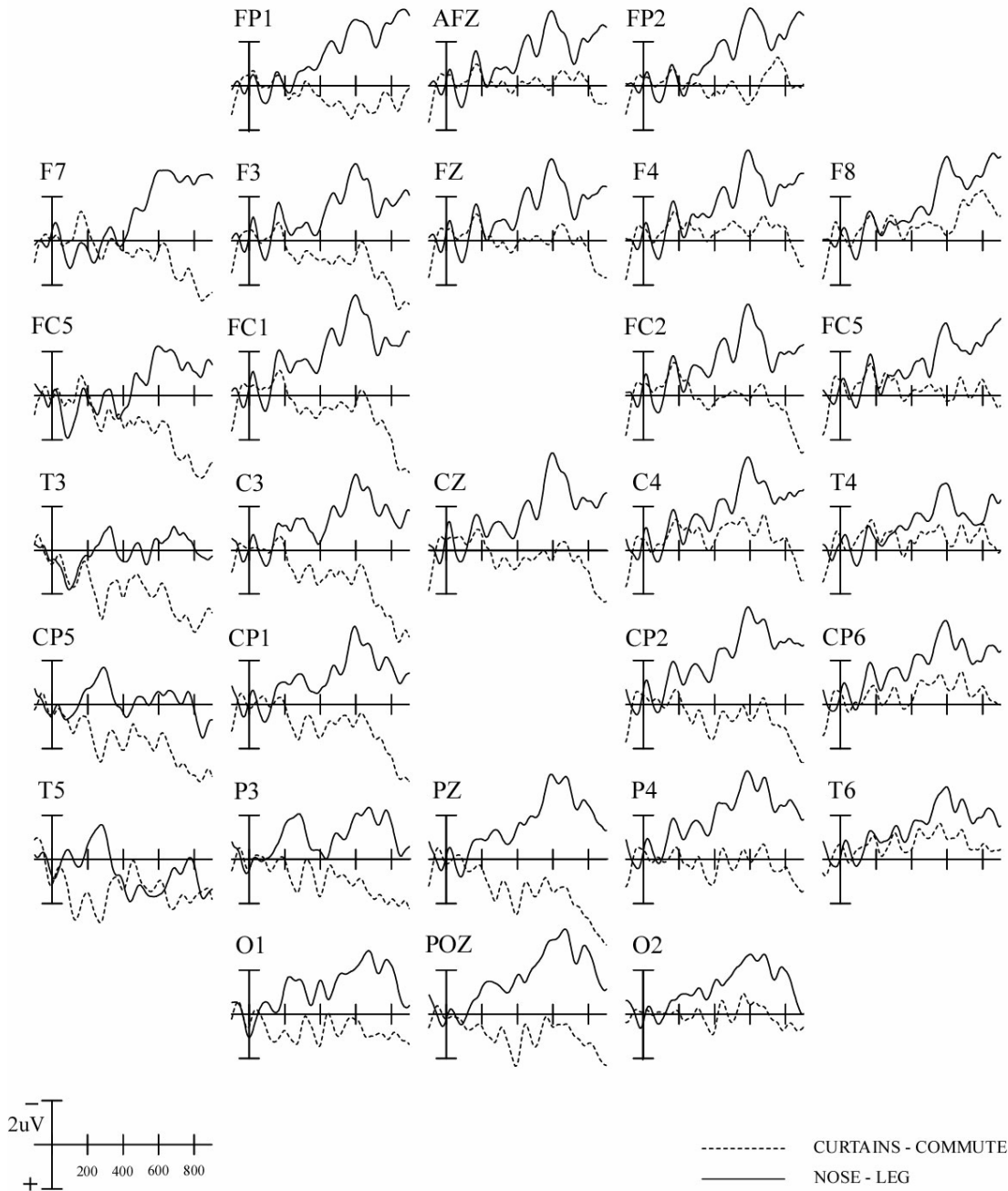


Figure 22 Difference waveforms for the High Comprehenders in the Discourse (dashed line) and Sentence (solid line) conditions. Difference waveforms were created by subtracting the ERPs elicited by the CWs in the coherent condition from those elicited in the incoherent condition

3.4 DISCUSSION

The purpose of this experiment was to further investigate the results obtained in Experiment 1; more specifically, it was to test whether the patients did indeed profit from the lexical relations determining the coherence of the CWs or whether they rather suffered from the semantic anomalies they induced. In other words, I wanted to investigate to which degree the differences in plausibility contributed to the results obtained in Experiment 1. The same design as in Experiment 1 was used, however, instead of looking at differences in coherence, differences in cloze probability in sentence and discourse contexts was examined. I am again going to discuss results separately for each group of subjects and each condition. All subjects but the Young Adults also participated in Experiment 1.

3.4.1 Young Controls

3.4.1.1 EFFECTS OF CLOZE PROBABILITY

3.4.1.1.1 SENTENCE CONDITION

As in Experiment 1, no early sensory components can be distinguished in the ERPs. A highly significant N400 effect is obtained over centro-posterior electrodes, which shows that the Young Adults are sensitive to differences in cloze probability in a sentence context. Even though the effect is significant, it is numerically smaller than in Experiment 1. This is consistent with the view that it varies as a function of the difficulty of integration (e.g. Kutas et al. 1984; Connolly et al., 1992; 1995) and that an implausible semantic violation is sufficient but not necessary to elicit an N400; thus, the effects obtained in the Sentence condition in Experiment 1 might have been primarily determined by the low plausibility of the incoherent endings. Following the integration process, ERPs are more negative over the posterior than over the anterior electrodes, but they do not differ between the two conditions, which indicates no differences in the wrap-up process for the high and low cloze probability sentence endings. Thus, only implausible, but not plausible but less expected sentence endings pose stronger demands on the wrap-up process.

3.4.1.1.2 DISCOURSE CONDITION

As in Experiment 1, ERPs in the Discourse condition are immediately more negative over anterior than over posterior electrodes with no differences between the high and low

cloze endings indicating an increased working memory load for the retrieval of discourse information. This replicates the previous findings from Experiment 1. Also, like in Experiment 1, the Young Adults are able to use discourse information to guide semantic integration at the level of a local sentence as indexed by the highly significant N400 effect that is maximal over the centro-posterior electrodes. This confirms the results both from Experiment 1 and from previous studies by van Berkum et al. (1999; 2003). In the epoch following the integration, ERPs are more negative over the posterior sites, but they do not differ between the High and the Low cloze condition; this replicates again the findings from Experiment 1, in which no differences in the wrap-up process were found in the Discourse condition. Taken together, this is further evidence for interactive processing of discourse information.

3.4.1.2 EFFECTS OF CONTEXT

3.4.1.2.1 *HIGH CLOZE CONDITION*

The same early main effect of Context as in Experiment 1 was found; this again replicates the finding of a more effortful retrieval of discourse information from working memory. Again, there are no differences in the latency and topography range of the N400 which means that a word with a high cloze probability is as easily integrated into a discourse as into a sentence context. In the period following the integration phase, LPC is larger in the Discourse than the Sentence condition over posterior electrodes which again is consistent with the view that the wrap-up process requires stronger memory capacities in a discourse than a sentence context and further replicates the findings from Experiment 1.

3.4.1.2.2 *LOW CLOZE CONDITION*

Also in the Low Cloze condition, ERPs are immediately more negative in the Discourse than in the Sentence condition over the anterior electrodes which is further evidence for the notion of very early, i.e. prelexical, effects in a discourse context, which is most likely reflecting working memory activation of discourse context. Unlike in Experiment 1, the N400 is significantly more negative in the Discourse than the Sentence condition; this is because of the overall smaller amplitudes in the Sentence condition. In the absence of lexical violations, increasing the amount of context to be integrated – as in the Discourse condition – appears to increase the constraint of that context to a degree that makes any other completion than the best one comparable to a violation. The wrap-up process following the

integration is again more strongly pronounced in the Discourse condition over the posterior electrodes. This again indicates that it requires stronger resources than the wrapping-up of a plausible sentence context.

3.4.1.3 GENERAL DISCUSSION

Taken together, the results for the Young Adults replicate the findings from Experiment 1. The similar time course of the onset of the N400 effects further supports the notion of interactive processing of discourse information. Moreover, the findings in the epoch preceding and following the integration process could be replicated: irrespective of how well the CW fits the respective context, the retrieval of context information draws stronger on working memory processes in the discourse than the sentence condition. For the wrap-up process, the findings of Experiment 1 could be extended: in both sentence and discourse condition, there are no differences of Cloze Probability which means that within each Context condition, both the high and low cloze endings are wrapped up similarly. For the sentence condition, this means that a violation is necessary to elicit a stronger positivity; a mere difference in cloze probability that does not induce an implausible semantic violation will not yield this result. However, when considering the effects of Context, it can be seen that the discourse context requires overall stronger wrap-up capacities.

3.4.2 Elderly Controls

3.4.2.1 EFFECTS OF CLOZE PROBABILITY

3.4.2.1.1 SENTENCE CONDITION

In the Sentence condition, the results closely resemble those for the Young Adults. A highly significant N400 effect is found over the centro-posterior set of electrodes which shows that also the Elderly Adults are sensitive to differences in the cloze probability in a sentence context. The size of the effect is smaller than in Experiment 1, which is consistent with the view that the N400 is an indicator of the relative fit of a word with respect to its context (e.g. Kutas et al. 1984; Connolly et al., 1992; 1995). ERPs indicate that the wrap-up process is different for the high and low cloze endings: the positivity in the Low relative to the High Cloze condition indicates that it is more effortful to wrap up.

3.4.2.1.2 *DISCOURSE CONDITION*

Also in the Discourse condition, both the effects of Experiment 1 and of the Young Adults can be replicated. The early positivity only approaches significance, which confirms that at least there is a trend towards a higher working memory demand for the retrieval of the discourse information. The N400 effect is highly significant and has a centro-posterior distribution which shows that the Elderly Adults can utilize discourse information to constrain a sentence that is unconstrained when presented in isolation. Following the integration, both high and low cloze endings require comparable wrap-up efforts as revealed by the lack of a difference between the two conditions.

The size of the effect in the Discourse condition is larger than in Experiment 1, and several accounts may explain this. For one, the N400 might be an indicator of relative rather than absolute integration difficulty: in Experiment 1, the anomalies in the Sentence condition were induced by their high implausibility which was not present in the Discourse condition. Thus, the Elderly Adults might have tried to revise rather than to integrate the yet incoherent but not implausible discourse information. However, in the absence of any implausibility, a misfit in a highly constrained discourse context might be treated rather like a violation than like a mere difference in cloze probability. All in all, the effects confirm the notion of interactive processing of discourse information as indicated by the lack of onset differences and replicates the extension of the findings of van Berkum et al. (1999, 2003) for a group of elderly adults as well.

3.4.2.2 *EFFECTS OF CONTEXT*

3.4.2.2.1 *HIGH CLOZE CONDITION*

The trends towards an early positivity in the Discourse condition is further corroborated when considering the effects of Context: an early frontal positivity is found in the Discourse relative to the Sentence condition which further confirms the results obtained in both control groups and both experiments: discourse context appears to consistently tap into working memory processes that are required to activate the information necessary for successful timely integration. There are no differences regarding the integration of the endings with a high cloze probability in both contexts. Subsequently, the more effortful wrap-up process in the discourse condition is reflected in the posterior positivity.

3.4.2.2 *LOW CLOZE CONDITION*

Also in the Low Cloze condition, immediate effects of Context are obtained over the frontal electrodes; this further supports the notion of very early, i.e. prelexical effects of a discourse context. In the integration phase, the main effect of Context shows that in the present case, the low cloze discourse ending is more difficult to integrate than the low cloze sentence endings; this suggests that the mere amount of the context can constrain a discourse context to such a degree that even the non-best continuation is treated similar to a semantic violation.

3.4.2.3 GENERAL DISCUSSION

Taken together, the results for the group of Elderly Adults replicate and extend those of Experiment 1 and of the Young Adults and further confirm the interactive nature of discourse processing. They can profit from the discourse information to constrain an otherwise unconstrained sentence to render one ending as the best one and treat the other one similar to a semantic violation. The wrap-up following the integration confirms the results obtained for the Young Adults and further replicates the extension of the findings from van Berkum et al. (1999, 2003).

3.4.3 **High Comprehenders**

3.4.3.1 EFFECTS OF CLOZE PROBABILITY

3.4.3.1.1 *SENTENCE CONDITION*

The High Comprehenders show a significant N400 effect in the Sentence condition which is – contrary to Experiment 1 – not delayed. This suggests that they can indeed use sentence information to guide lexical selection on a normal time-course. Moreover, it suggests that the relative delay observed in Experiment 1 was not due to the heuristic use of lexical information but that this group of patients suffered from the anomalous semantic violation in the Incoherent condition and did not profit from the lexical association in the Coherent condition. The High Comprehenders do not appear to differentially wrap up the high and low cloze endings.

This further supports the claim that the inferior frontal gyrus is not crucially involved in the generation of the N400. The High Comprehenders integrate sentence information

without semantic anomalies with a similar time course as the control groups despite lesions encompassing the inferior frontal gyrus.

3.4.3.1.2 DISCOURSE CONDITION

In the Discourse condition, the High Comprehenders also show a significant sensitivity to differences in cloze probability. Contrary to the Sentence condition however, this effect is delayed. Moreover, the early anterior positivity is absent; it appears to be crucial for successful and timely integration of discourse information. As in Experiment 1, the underlying problem appears to be more one of working memory than of lexical processing. Both the high and low cloze endings pose similar demands on the wrapping up process following the integration. It appears that the capacities for integration are limited in the High Comprehenders are limited. Once a critical amount is exceeded, they are no longer capable of concurrent processing of local and global coherence; but instead, they achieve it serially and process discourse information in a modular rather than an in interactive fashion.

3.4.3.2 EFFECTS OF CONTEXT

3.4.3.2.1 HIGH CLOZE CONDITION

In the High Cloze condition, no early differences are found between the two context conditions as for the control groups. This suggests that the High Comprehenders do not prelexically activate discourse information in working memory. This further supports the notion that the constant prelexical updating of the discourse contents appears to be crucial for later successful (i.e. timely) lexical integration. The N400 is significantly larger in the Discourse than the Sentence condition only in the time window 300 – 500 ms; this shows that the High Comprehenders are sensitive to the constraint of the discourse context, but with a certain cost associated with it. No differential effects are found following the integration.

3.4.3.2.2 LOW CLOZE CONDITION

In the Low Cloze condition, ERPs are not overall more negative over the anterior electrodes, and no early differences are found between the two context conditions. This is clear evidence against prelexical effects preceding the integration. The larger N400 in both the earlier and the later window shows that the High Comprehenders are sensitive to the constraint of the discourse context to a similar degree as the control groups, but with a certain delay.

3.4.3.3 GENERAL DISCUSSION

The High Comprehenders show a normal time course for the lexical integration in a sentence context but they show delayed lexical integration in a discourse context. This is further support for the notion of an integration rather than an activation deficit being the problem underlying comprehension problems in aphasia. They do not show the early frontal negativity in the Discourse relative to the Sentence condition, which suggests that a prelexical activation of the discourse content is a necessary prerequisite for later successful integration. Moreover, when relating the overall results to those of Experiment 1, it appears that the High Comprehenders did profit from the absence of a semantic anomaly in Experiment 2 rather than from the presence of a semantic relation in Experiment 1.

3.4.4 Low Comprehenders

3.4.4.1 EFFECTS OF CLOZE PROBABILITY

3.4.4.1.1 SENTENCE CONDITION

The group of the Low Comprehenders shows a broad negative deflection which does not have the centro-posteriorly distributed maximum that is usually observed for the N400. Unlike the usual N400, this effect has a much stronger frontal distribution. However, it is not statistically significant. This is probably due to the fact that mainly one subject (PP) showed an extraordinarily strong effect (300 – 500 ms: 7.25 μ V; 500 – 700 ms: 11.68 μ V). However, since Subjects were treated as a random effect in the model, this did not suffice to produce a significant result. In comparison with the results obtained in Experiment 1, this suggests that the Low Comprehenders are able perform lexical integration in semantically correct sentences - with a certain delay. Moreover, they appear to be sensitive to cloze probability, but only if a sentence is plausible. However, it appears that their impaired comprehension skills are no longer able to handle anomalous and implausible sentences.

3.4.4.1.2 DISCOURSE CONDITION

Contrary to the Sentence condition, ERPs do not share any morphological similarity with known language-elicited components. This indicates that the Low Comprehenders are obviously no longer able to use discourse information to aid lexical integration even in the absence of implausible anomalies. This supports the view of an integration deficit as the

underlying problem of aphasic comprehension (Hagoort et al. 1996; Swaab et al., 1997, 1998).

3.4.4.2 EFFECTS OF CONTEXT

3.4.4.2.1 *HIGH CLOZE CONDITION*

Statistical analyses do not reveal significant effects for the high cloze endings. Unlike for the control groups, no early differences reflecting the retrieval and activation of verbal working memory are obtained, and neither are the late effects reflecting the post-integration wrap-up process.

3.4.4.2.2 *LOW CLOZE CONDITION*

Like for the high cloze endings, no differences are found between the low cloze endings in both context conditions. This indicates that they are not differentially sensitive to violations of sentence and discourse contexts.

3.4.4.3 GENERAL DISCUSSION

In the absence of lexical violations, the Low Comprehenders show a tendency towards delayed integration in sentence contexts; this suggests that they are sensitive to changes in cloze probability in a sentence context, but that they did suffer from the semantic violations in Experiment 1. Their limited / delayed integration capacity does break down when it comes to discourse contexts. In Experiment 1, they did also not profit from the semantic relations, but rather they appear to have suffered from the violations.

3.4.5 General Discussion

The primary purpose of the present experiment was to further determine the nature of the results obtained in Experiment 1. It was to be determined whether the patients profited from the semantic relations between the CWs and certain words in the respective preceding context, or whether they rather suffered from the semantic violations that the paradigm induced. Evidence was found for the notion that they rather suffered from the violations than that they profited from the relations. It does not seem that they rely more heavily on the semantic content of an utterance to use it in a heuristic way (e.g. Caramazza & Zurif, 1976; Milberg, Blumstein, Katz, Gershberg, & Brown, 1995; Hagoort, Wassenaar, & Brown, 2003).

The linear variation of the N400 amplitude as a function of integration difficulty appears to hold only for conditions of unimpaired comprehension skills. Under the condition of impaired comprehension skills, as e.g. after brain damage, it appears to reflect increasing difficulty of integration only to a certain degree: once integration becomes too difficult (i.e. in the case of an unsolvable anomaly or a too extensive context), its amplitude decreases again.

In general, the data of the two experiments support the idea of an integration difficulty which varies as a function of the severity of the comprehension deficit, and they contradict the idea of an activation deficit as the underlying cause.

4 ODDBALL EXPERIMENT

In addition to the two language experiments, an auditory three-stimulus-oddball experiment was administered to the elderly control subjects and the two patient groups.

This was done in order to provide an internal control for the language specificity of the ERP results obtained in the patient groups, especially for the group of Low Comprehenders who did not show any significant effect in the previous two experiments. With an N400 paradigm only the claim of the language specificity of the abnormal N400 ERP effects obtained for the aphasic patients can not be made. However, if a dissociation between the N400 and another non-language-specific endogenous ERP component can be obtained, it can be concluded that the abnormal N400 results obtained in the two previous experiments are not a general consequence of brain damage per se but that they are indeed language specific.

4.1 HYPOTHESES

A three-stimulus oddball paradigm was chosen in order to potentially elicit the two subcomponents of the P300, the novelty P3a and the target P3b which are generated in different areas of the brain. The P3a, which reflects automatic novelty detection, is generated by a frontal network, and the P3b which reflects voluntary target detection, is generated by a temporo-parietal network⁹. Thus, one would expect a dissociation of the two subcomponents for the two patient groups.

Patients classified as High Comprehenders in the two previous experiments have largely lesions in lateral prefrontal cortex, especially in the inferior prefrontal cortex; in three of these patients, lesions further encompassed superior temporal regions and the temporo-parietal junction. These patients should not show a frontally distributed novelty P3a; they should however show at least a trend towards an oddball target P3b.

Patients classified as Low Comprehenders in the two previous experiments, however, have lesions that largely spare prefrontal areas and are most pronounced in superior temporal

⁹ For a more detailed overview of the P300 and its neuronal generators, please refer to section 1.1.3 in the Introduction chapter.

and parietal areas. Hence, this group of patients should exhibit a somewhat complementary pattern of results; they should show a preserved novelty P3a and have a reduced target P3b.

4.2 METHOD

4.2.1 Subjects

4.2.1.1 CONTROL GROUP

4.2.1.1.1 ELDERLY CONTROLS

The same Elderly Controls as in Experiment 1 and 2 participated.

4.2.1.2 APHASIC PATIENTS

The same Aphasic patients as in Experiment 1 and 2 participated.

4.2.2 Materials

Materials used in the oddball experiment were three categories of auditory stimuli. The standard stimulus was a 500 Hz sine wave (n=600), the target stimulus was a 1250 Hz sine wave (n=75) and the novel stimulus were 75 environmental sounds (e.g. cough, bark, door) and tones other than the standard and target (n=75).

Stimuli were presented in random order and with jittered stimulus onset asynchrony (SOA) varying between 400 and 1381 ms in order to minimize systematic overlap of components from preceding stimuli.

4.2.3 EEG Experiment

4.2.3.1 PROCEDURE

Prior to participation, written consent was obtained by a form approved by the University of California at Davis Institutional Review Board. Furthermore, subjects had to give a short medical history report in order to exclude any history of psychiatric or neurological disorders, complete the Edinburgh Handedness Questionnaire (Oldfield, 1971) and report the languages they speak.

Subjects were tested individually in a dimly lit electromagnetically shielded and sound proof booth sitting in a comfortable chair. They were instructed to listen to the series of high and low tones and random sounds and to pay attention to the high tones by counting them. Since most aphasic subjects were not able to count, they were asked to press a button when they heard the high tones. Because of the relatively high number of stimuli in each condition (n=600; n=75 for the standard and oddball and novel stimuli), subjects were not explicitly instructed to withhold blinking for certain epochs. Stimuli were played using a Creative Sound Blaster Audio PCI 64 V sound card. For the presentation of stimulus materials, the software package "Presentation" was used.

4.2.3.2 EEG RECORDING

The same EEG recording parameters as in Experiment 1 and 2 were used.

4.2.3.3 SOUND DELIVERY

The same sound delivery system as in Experiment 1 and 2 was used.

4.2.3.4 HEARING ASSESSMENT

The same hearing assessment procedure as in Experiment 1 and 2 was used.

4.2.3.5 OCULAR ARTIFACT REDUCTION

The same ocular artifact reduction procedure as in Experiment 1 and 2 was used.

4.2.3.6 DATA ANALYSIS AND DATA REDUCTION

The same data analysis and reduction strategies as in Experiment 1 and 2 were used.

4.3 RESULTS

Repeated measures of variance ANOVAs were performed on the mean amplitude of the ERPs to the CWs in five epochs: the P1 epoch (0 – 50 ms); the N1 epoch (50 – 150 ms), the P2 epoch (150 – 250 ms), and two P3 epochs (250 – 450; 450 – 600 ms), relative to a 100 ms pre-stimulus baseline. ANOVAs were performed separately for the oddball and novelty conditions. For both conditions, an initial ANOVA was done on the entire set of electrodes. In case of an interaction with the factor Electrode Site, further ANOVAs including the additional factor Location (Anterior: FP1, FP2, F3, F4, F7, F8, FC1, FC2, FC5, FC6, AFZ,

FZ; Posterior: CP1, CP2, CP5, CP6, P3, P4, T5, T6, O1, O2, PZ, POZ) evaluated the differentially distributed effects of the P3a and P3b: the maximum of the novelty P3a is more frontally distributed, and that of the oddball P3b has a more centro-posterior distribution. For evaluating effects with more than one degree of freedom in the numerator, the Greenhouse-Geisser correction was used to compensate for inhomogeneous variances and covariances across treatment levels (Greenhouse & Geisser, 1959). The respective adjusted *p*-values are reported.

4.3.1 Elderly Controls

Grand average ERPs elicited by the tones in the oddball experiment are displayed in Figure 1. Clear P1 and N1 components can be distinguished in all conditions; the P1 is largest and earliest for the target stimuli. The N1 is largest for the target stimuli and smallest for the standard stimuli. In all conditions, both the P1 and the N1 are more strongly pronounced over anterior than posterior electrode sites. The N1 is followed by a P2 which is obtained for the standards and targets but which appears to overlap with the P3a for the novel stimuli. The two subcomponents of the P300 are elicited. The amplitude of P3b elicited by the targets has a parietal maximum, and the P3a elicited by the novels has a frontal maximum.

4.3.1.1 ODDBALL

The results of the statistical analyses for the Oddball Target conditions examining the entire set of electrodes and anterior-posterior differences are displayed in Tables 1 and 2, respectively.

Table 1
F values and significance levels for the ANOVAs for the oddball target stimuli (all electrodes)

| SOURCE | df | 0 – 50 | 50 – 150 | 150 – 250 | 250 – 450 | 450 – 600 |
|------------|---------------------|--------|----------|-----------|-----------|-----------|
| ODD | 1,11 | <1 | 23.44*** | 1.63 | 22.56*** | 15.20** |
| ELEC | 28,308 ⁺ | 5.24** | 2.43 | 12.89*** | 3.0*** | 18.49*** |
| ODD X ELEC | 28,308 ⁺ | 1.25 | 2.16*** | 1.93* | 8.31*** | 20.79*** |

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

⁺Greenhouse-Geisser adjusted *p* values

In the P1 window, the no significant differences between the target and standard tones were found; the only factor reaching significance was Electrode. In the window of the N1,

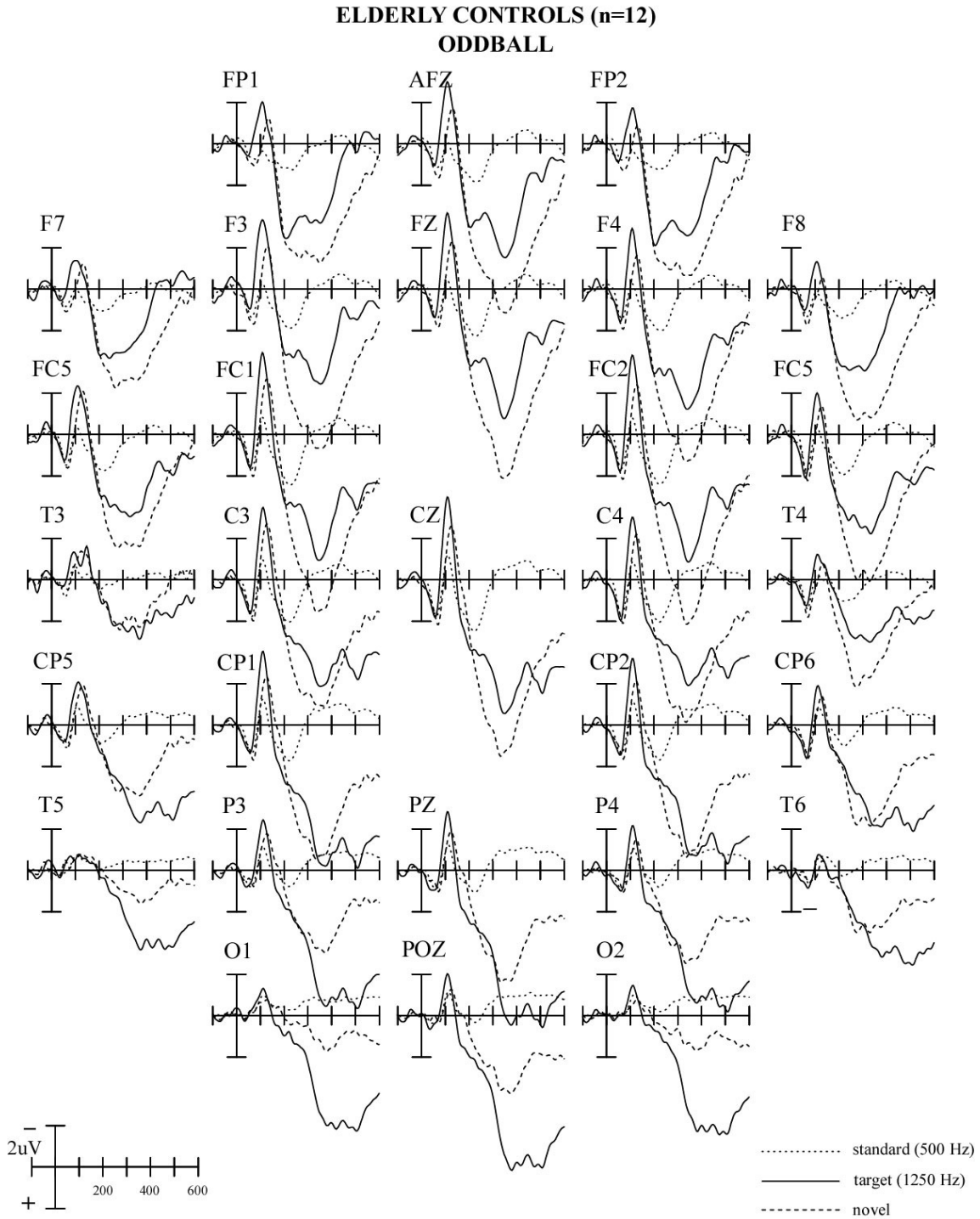


Figure 4 Grand average ERP waveforms for the Elderly Controls elicited by the standard, target and novel stimuli in the oddball experiment

there was a significant effect of Stimulus Type; ERPs were more negative for the targets than the standard tones; this effect interacted with Electrode Site. In the P2 window, there was no main effect of Stimulus Type, but an interaction between Stimulus Type and Electrode Site; overall, the difference between the standard and oddball tones appears larger over anterior than posterior electrodes. In both the earlier and the later window examining the P300 effect, there were highly significant main effects of both Stimulus Type and Electrode Site; the oddball tones elicited more positive ERPs than the standard tones; this difference appears more strongly pronounced over parietal electrodes. The distributional differences were further examined in a series of ANOVAs containing the additional factor Location; these results are summarized in Table 2.

Table 2
F values and significance levels for the ANOVAs for the target stimuli (anterior and posterior electrodes)

| SOURCE | df | 0 – 50 | 50 – 150 | 150 – 250 | 250 – 450 | 450 – 600 |
|------------------|---------------------|--------|----------|-----------|-----------|-----------|
| ODD | 1,11 | <1 | 23.09*** | 2.18 | 24.29*** | 16.29** |
| LOC | 1,11 | <1 | <1 | 21.74*** | <1 | 27.95*** |
| ODD X LOC | 1,11 | 1.08 | 11.26*** | <1 | 3.80# | 31.44*** |
| ODD X LOC X ELEC | 28,308 ⁺ | <1 | 8.56*** | 3.90* | 6.80** | 12.14*** |

p<0.10 * p<0.05 ** p<0.01 ***p<0.001

+Greenhouse-Geisser adjusted *p* values

In the P1 window, no significant effects were obtained. In the N1 window, the interaction between Stimulus Type and Location confirmed the anterior maximum of the N1 effect. In the P2 window, ERPs are more positive over anterior than posterior electrodes; whereas, there are no significant differences between the target and standard tones. A significant effect of Stimulus Type is obtained in both P300 windows: the targets elicit more positive ERPs than the standard stimuli; furthermore, the interaction between Stimulus Type and Location confirms the parietal distribution of the effect.

4.3.1.2 NOVELTY

The results of the statistical analyses in the Novelty Condition examining the entire set of electrodes and anterior-posterior differences are displayed in Tables 3 and 4, respectively.

Table 3**F values and significance levels for the ANOVAs for the novel stimuli (all electrodes)**

| SOURCE | df | 0 – 50 | 50 – 150 | 150 – 250 | 250 – 450 | 450 – 600 |
|------------|---------------------|--------|----------|-----------|-----------|-----------|
| NOV | 1,11 | 2.21 | <1 | 2.42 | 40.77*** | 11.23** |
| ELEC | 28,308 ⁺ | 3.09* | 6.82*** | 17.41*** | 28.82*** | 6.60*** |
| NOV X ELEC | 28,308 ⁺ | 1.83 | 2.98* | 5.29** | 15.25*** | 4.77* |

* p<0.05 ** p<0.01 ***p<0.001

⁺Greenhouse-Geisser adjusted *p* values

In the P1 window, no statistical differences are obtained between the novel and the standard stimuli. In the N1 window, the interaction between Stimulus Type and Electrode Site indicates distributional differences between the ERPs elicited by the novel and the standard stimuli. The same pattern of results is obtained for the P2 component: no significant overall effects are obtained, but the significant interaction between Stimulus Type and Electrode Site indicates distributional differences between the ERPs in the two conditions. Finally, significant P300 are obtained in both windows; furthermore, in both windows, there are also significant interactions between Stimulus Type and Electrode Site. The distributional differences were further examined in a series of ANOVAs containing the additional factor Location; these results are summarized in Table 4.

Table 4**F values and significance levels for the ANOVAs for the novel sounds (anterior and posterior electrodes)**

| SOURCE | df | 0 – 50 | 50 – 150 | 150 – 250 | 250 – 450 | 450 – 600 |
|------------------|---------------------|--------|----------|-----------|-----------|-----------|
| NOV | 1,11 | 2.11 | <1 | 2.59 | 41.04*** | 11.34** |
| LOC | 1,11 | <1 | 9.57* | 27.83*** | 43.85*** | 7.28* |
| NOV X LOC | 1,11 | 5.65* | 1.79 | 4.81* | 13.30** | <1 |
| NOV X LOC X ELEC | 28,308 ⁺ | <1 | 4.04* | 5.42* | 19.76*** | 6.45** |

p<0.10 * p<0.05 ** p<0.01 ***p<0.001

⁺Greenhouse-Geisser adjusted *p* values

The interaction between Stimulus Type and Location in the P1 window indicates that the P1 effect is more strongly pronounced over anterior than posterior electrodes. In the N1 window, ERPs are more positive in over anterior than posterior electrodes; no significant differences are obtained between the novel and the standard stimuli. ERPs remain to be more

positive over anterior than posterior electrodes in the P2 window; the interaction between Stimulus Type and Location confirms that this is more so the case for the novel than for the standard stimuli. Finally, a highly significant P300 is obtained in both later windows; the novels elicit a stronger positivity than the standards. Moreover; in both windows, ERPs are overall more positive over anterior than over posterior electrode sites.

4.3.2 High Comprehenders

Grand average ERPs elicited by the tones in the oddball experiment are displayed in Figure 2. Both P1 and N1 components can be distinguished in all conditions. Both the P1 and the N1 are larger for the target and the novel stimuli than for the standard stimuli; they are more pronounced over anterior than posterior electrode sites. The targets elicit a positivity with a posterior maximum which is slightly more strongly pronounced over the hemisphere contralateral to the lesion. The novel stimuli elicit a positivity over frontal sites contralateral to the lesion with a polarity inversion over electrodes ipsilateral to the lesion.

4.3.2.1 ODDBALL

The results of the statistical analyses examining the entire set of electrodes and anterior-posterior differences for the Oddball Target condition are summarized in Tables 5 and 6.

Table 5
F values and significance levels for the ANOVAs for the oddball tones (all electrodes)

| SOURCE | df | 0 – 50 | 50 – 150 | 150 – 250 | 250 – 450 | 450 – 600 |
|------------|---------------------|--------|----------|-----------|-----------|-----------|
| ODD | 1,6 | 1.90 | 2.64 | 2.32 | 2.02 | <1 |
| ELEC | 28,168 ⁺ | 2.62 | <1 | 2.57 | <1 | 2.57# |
| ODD X ELEC | 28,168 ⁺ | <1 | 1.41 | <1 | 1.08 | 2.67# |

$p < 0.10$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

+Greenhouse-Geisser adjusted p values

None of the early differences in the P1, N1, and P2 latency range reach significance. Neither does the P300 reach significance. It is not until the latest windows that there is a marginally significant ($F(28,168)=2.57$; $p=0.08$) interaction between the factors Stimulus Type and Electrode Site indicating a trends towards distributional differences of the effect of Stimulus Type.

**HIGH COMPREHENDERS (n=7)
ODDBALLS**

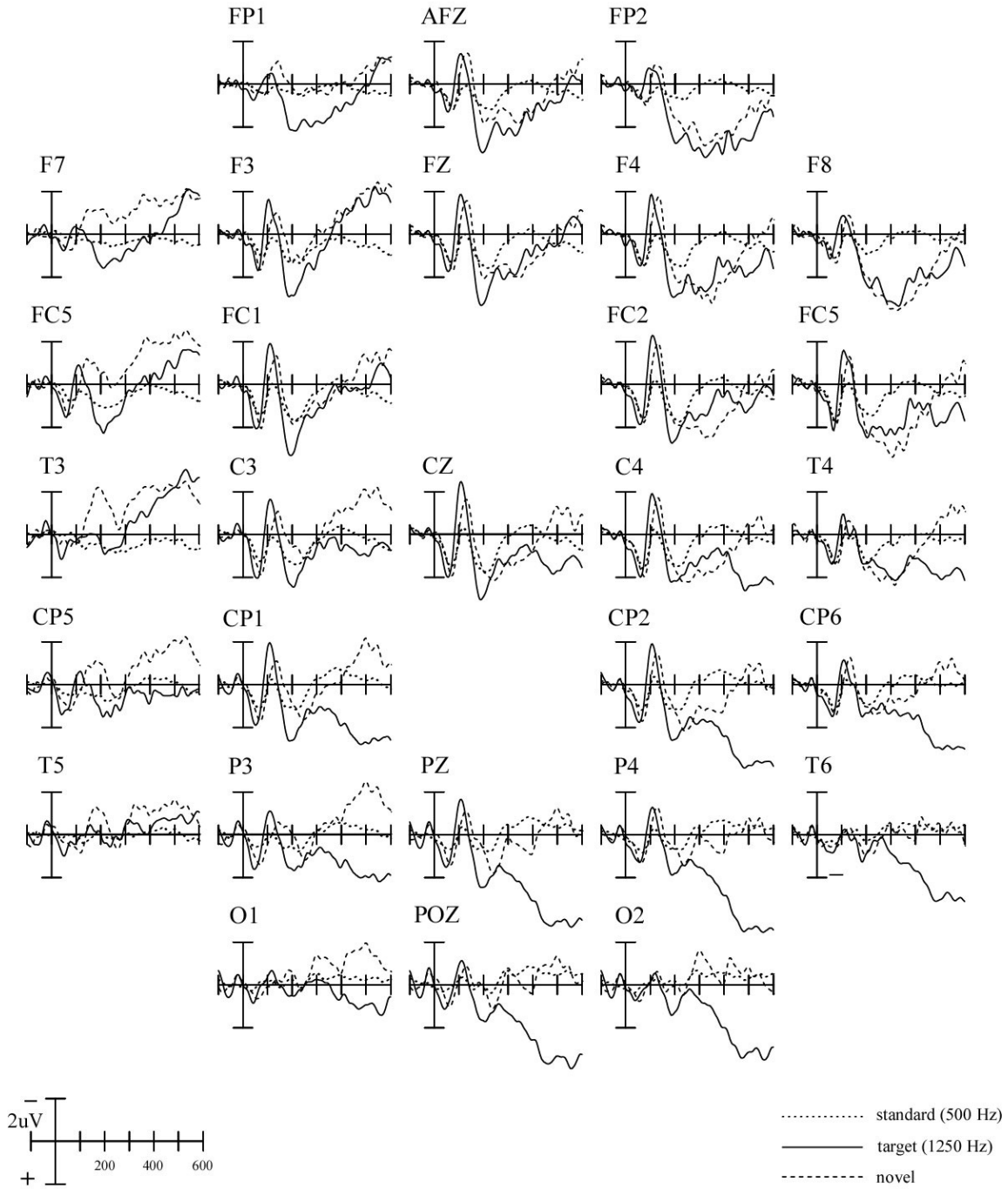


Figure 5 Grand average ERP waveforms for High Comprehenders elicited by the standard, target and novel stimuli in the oddball experiment

Table 6
F values and significance levels for the ANOVAs for the oddball tones (anterior and posterior electrodes)

| SOURCE | df | 0 – 50 | 50 – 150 | 150 – 250 | 250 – 450 | 450 – 600 |
|------------------|--------------------|--------|----------|-----------|-----------|-----------|
| ODD | 1,6 | 1.71 | 2.36 | 2.47 | 2.20 | <1 |
| LOC | 1,6 | <1 | <1 | 9.57* | <1 | 1.91 |
| ODD X LOC | 1,6 | <1 | 1.95 | <1 | <1 | 3.91# |
| ODD X LOC X ELEC | 11,66 ⁺ | <1 | 1.31 | <1 | <1 | <1 |

$p < 0.10$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

+Greenhouse-Geisser adjusted p values

When comparing anterior and posterior electrodes, no early differences reach significance. In the window of the P2, the main effect of Location indicates that the P2 is more strongly pronounced over anterior than posterior electrodes, however, it does not differ between the two stimulus conditions. The trend towards significance of the interaction between Stimulus Type and Location ($F(1,6)=3.91$; $p=0.08$) describes a trend towards more positive ERPs for the targets than the standards over the posterior electrodes. Over posterior electrodes, the difference was 2.69 μV , and over anterior electrodes, it was -0.13 μV . Moreover, the factor Stimulus Type interacted significantly with Electrode ($F(11,66)=3.77$; $p=0.0319$), thus corroborating the tendency towards distributional differences of the effects.

4.3.2.2 NOVELTY

The results of the statistical analyses in the Novelty Condition are displayed in Tables 7 and 8.

Table 7
F values and significance levels for the ANOVAs for the novel sounds (all electrodes)

| SOURCE | df | 0 – 50 | 50 – 150 | 150 – 250 | 250 – 450 | 450 – 600 |
|------------|---------------------|--------|----------|-----------|-----------|-----------|
| NOV | 1,11 | <1 | 1.5 | <1 | 3.72 | 3.69 |
| ELEC | 28,308 ⁺ | 1.67 | <1 | 4.07* | 4.77* | 2.91# |
| NOV X ELEC | 28,308 ⁺ | <1 | 1.48 | 3.6* | 3.81* | 2.04 |

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

+Greenhouse-Geisser adjusted p values

As for the oddball targets, no early differences are obtained between the standard and the novel stimuli. The significant interaction between Stimulus Type and Electrode Site in the P2 window originates from lateral differences between the standard and novel stimuli. The same holds for the P300 window.

Table 8
F values and significance levels for the ANOVAs for the novel sounds (anterior and posterior electrodes)

| SOURCE | df | 0 – 50 | 50 – 150 | 150 – 250 | 250 – 450 | 450 – 600 |
|------------------|--------------------|--------|----------|-----------|-----------|-----------|
| NOV | 1,6 | <1 | 1.25 | <1 | 4.14# | 2.71 |
| LOC | 1,6 | <1 | <1 | 3.64 | 5.47# | 5.47# |
| NOV X LOC | 1,6 | <1 | 1.96 | <1 | <1 | <1 |
| NOV X LOC X ELEC | 11,66 ⁺ | <1 | <1 | 1.67 | 3.11# | <1 |

$p < 0.10$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

+Greenhouse-Geisser adjusted p values

Adding the Factor Location to the analyses does not fundamentally alter the results for the early sensory components. There is a marginally significant effect of Stimulus Type ($F(1,6)=4.14; p=0.087$) and Location ($F(1,6)=5.47; p=0.058$); however, it is important to note that the ERPs are more negative for the Novel than the Standard stimuli, i.e. it is not a P300 that is elicited.

4.3.3 Low Comprehenders

Grand average ERPs elicited by the tones in the oddball experiment are displayed in Figure 3. Both P1 and N1 components can be distinguished in all conditions. Both the P1 and the N1 are larger for the target stimuli than for the standard and the novel stimuli; they are more pronounced over anterior than posterior electrode sites. For the target stimuli, a P2-like potential can be distinguished over posterior electrodes contralateral to the lesion site. It is followed by a small P300 which is more pronounced over posterior than anterior electrodes and which is larger over the hemisphere contralateral to the lesion; in the later time window, there is a polarity inversion over the hemisphere ipsilateral to the lesion. For the novel stimuli, the P2 can not be clearly distinguished. It is followed by a positivity which is larger over anterior than posterior electrodes and also over electrodes contralateral than ipsilateral to the lesion.

4.3.3.1 ODDBALL

The results of the statistical analyses examining the entire set of electrodes and anterior-posterior differences in the Oddball Target condition are summarized in Tables 9 and 10.

Table 9**F values and significance levels for the ANOVAs for the target stimuli (all electrodes)**

| SOURCE | df | 0 – 50 | 50 – 150 | 150 – 250 | 250 – 450 | 450 – 600 |
|------------|---------------------|--------|----------|-----------|-----------|-----------|
| ODD | 1,4 | <1 | <1 | 1.45 | 10.45* | 7.63* |
| ELEC | 28,112 ⁺ | 1.75 | 1.91 | 1.68 | 1.90 | 2.95 |
| ODD X ELEC | 28,112 ⁺ | <1 | 1.42 | 1.27 | 2.13 | 3.33# |

p<0.10 * p<0.05 ** p<0.01 ***p<0.001

+Greenhouse-Geisser adjusted *p* values

No differences between the target and standard stimuli are obtained for the early sensory components. A P3b is obtained which is significant in both the 250 – 450 and the 450 – 600 ms time window; target stimuli elicit more positive-going ERPs than do the standard stimuli. The amplitude difference is roughly the same in the two windows under investigation (250 – 450 ms: 3.85 μ V; 450 – 650 ms: 3.92 μ V).

Table 10**F values and significance levels for the ANOVAs for the target stimuli (anterior and posterior electrodes)**

| SOURCE | df | 0 – 50 | 50 – 150 | 150 – 250 | 250 – 450 | 450 – 600 |
|------------------|--------------------|--------|----------|-----------|-----------|-----------|
| ODD | 1,4 | <1 | <1 | 1.47 | 11.35* | 8.32* |
| LOC | 1,4 | 1.59 | <1 | 1.15 | 1.51 | <1 |
| ODD X LOC | 1,4 | <1 | 1.15 | <1 | <1 | <1 |
| ODD X LOC X ELEC | 11,44 ⁺ | 1.48 | 1.17 | 1.33 | 2.38 | 2.41 |

p<0.10 * p<0.05 ** p<0.01 ***p<0.001

+Greenhouse-Geisser adjusted *p* values

The inclusion of the factor Location further corroborates the analyses obtained for the entire set of electrodes. No interactions between Stimulus Type and Location are obtained.

LOW COMPREHENDERS (n=5)
ODDBALL

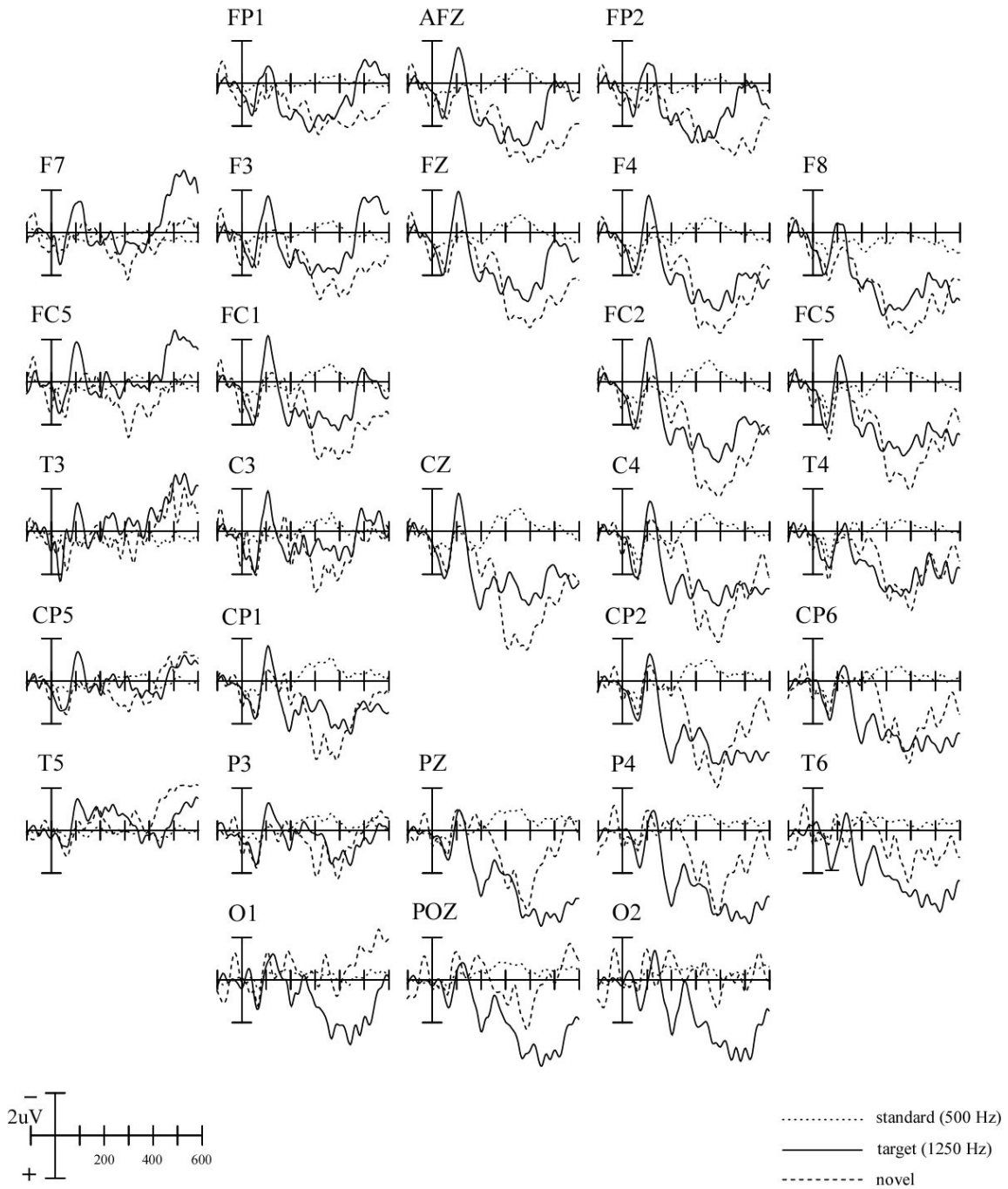


Figure 6 Grand average ERP waveforms for Low Comprehenders elicited by the standard, target and novel stimuli in the oddball experiment

4.3.3.2 NOVELTY

The results of the statistical analyses in the Novelty Condition are summarized in Tables 11 and 12.

Table 11**F values and significance levels for the ANOVAs for the novel stimuli (all electrodes)**

| SOURCE | df | 0 – 50 | 50 – 150 | 150 – 250 | 250 – 450 | 450 – 600 |
|------------|---------------------|--------|----------|-----------|-----------|-----------|
| NOV | 1,4 | 1.53 | <1 | <1 | 18.46* | 4.35 |
| ELEC | 28,112 ⁺ | 2.56 | 2.68 | 3.46# | 3.78# | 3.55# |
| NOV X ELEC | 28,112 ⁺ | 1.33 | 1.08 | 1.88 | 5.69* | 4.57* |

* p<0.05 ** p<0.01 ***p<0.001

+Greenhouse-Geisser adjusted *p* values

As for the oddball target stimuli, no differences between the standard and novel stimuli are obtained for the early components. A significant P3a is obtained in the earlier but not the later window; the respective voltage differences are 3.64 μ V and 2.34 μ V. In both windows, Stimulus Type and Electrode Site significantly interact with each other.

Table 12**F values and significance levels for the ANOVAs for the novel stimuli (anterior and posterior electrodes)**

| SOURCE | df | 0 – 50 | 50 – 150 | 150 – 250 | 250 – 450 | 450 – 600 |
|------------------|--------------------|--------|----------|-----------|-----------|-----------|
| NOV | 1,4 | 1.57 | <1 | <1 | 19.69* | 4.47 |
| LOC | 1,4 | 4.54# | 4.0 | 12.08* | 6.05# | 7.29# |
| NOV X LOC | 1,4 | 2.90 | 1.07 | 4.33 | 4.38 | 6.97# |
| NOV X LOC X ELEC | 11,44 ⁺ | <1 | 1.03 | <1 | 6.68* | 2.54 |

p<0.10 * p<0.05 ** p<0.01 ***p<0.001

+Greenhouse-Geisser adjusted *p* values

In the P2 window, ERPs are overall more positive over anterior than posterior sites, as revealed by the significant main effect of Location. The P3a is significant in the window between 250 – 450 ms. In the window 450 – 650 ms, the main effect of Location and the interaction between Stimulus Type and Location barely fail to reach significance ($p=0.054$ and $p=0.057$, respectively). This supports the notions that ERPs are overall more positive over anterior than posterior electrodes and that the P3a is has a more frontal distribution.

4.4 DISCUSSION

The purpose of the oddball experiment was to serve as an internal control experiment for the patient groups. Since with the language-related ERP components themselves, it can not be conclusively stated whether the abnormal N400 effects obtained in Experiment 1 and 2 were really language specific or whether they can be attributed to some general consequence of brain damage per se. Especially for the group of the Low Comprehenders, it was important to show that the absence of a significant effect could not be attributed to their brain damage per se; thus, it was crucial to show a different endogenous ERP component in this group of patients

A three-stimulus oddball design was shown because it provides the possibility of a double dissociation between the two functional subcomponents of the P300: the P3b involved in voluntary target detection is generated by a temporo-parietal network, and the P3a involved in involuntary novelty detection is generated by a frontal network.

In the case of a dissociation between the N400 and P300 ERP components for the two groups of patients, it can be indeed concluded that the N400 results obtained in the two previous experiments are indeed language-specific.

4.4.1 Elderly Adults

The group of the Elderly Adults show a clear double dissociation between the two subcomponents of the P300. Over anterior electrodes, they show a P3a to the novel stimuli relative to the standard tones, and over centro-posterior electrodes, they show a P3b to the oddball relative to the standard tones which is consistent with the literature (e.g. Knight & Scabini, 1998; Soltani & Knight, 2000; Polich & Kok, 1995).

4.4.2 High Comprehenders

The High Comprehenders who show near-to-normal N400 effects, do neither show a significant frontally distributed novelty P3a. However, they do show a trend towards an oddball P3b. This dissociation between the two subcomponents of the P300 shows that they are impaired in automatic novelty detection while they are not impaired in voluntary target detection. Moreover, the obtained result matches well with anatomical information: All of the High Comprehenders for whom lesion information was available show lesion in inferior

frontal areas – which is the generator of the P3a. Several of them have lesions encompassing vast areas of the left hemisphere including the temporo-parietal junction – which is the area in which the P3b is generated.

This clear dissociation between the N400 and P300 components provides strong support for the notion that the N400 results are indeed language specific and not a general consequence of brain damage per se.

4.4.3 Low Comprehenders

The Low Comprehenders in contrast do show significant P300 effects: they do show both a frontally distributed P3a and a P3b with a centro-posterior distribution. This indicates that they are indeed able to perform both voluntary target and involuntary novelty detection. Furthermore, with these results it can be concluded that even though no significant N400 effects could be obtained neither in the Sentence nor in the Discourse conditions, it is not impossible to elicit significant endogenous ERPs in this rather small group of patients and that their failure to show a significant N400 does not transfer to the P300.

4.4.4 General Discussion

The double dissociations between two endogenous ERP components confirms that the N400 results in Experiment 1 and 2 are not reflected in the P300 results and can consequently be attributed to the language comprehension deficits of the aphasic patients and not to the brain damage per se. Moreover, the differential lesion sites also differentially affect the P300 results: High Comprehenders with frontal and temporal lesions show neither subcomponent, and Low Comprehenders with more parietal lesions do show both. This provides further evidence that the P300 and N400 can be both functionally and anatomically dissociated.

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6 APPENDIX 1

STIMULI FOR EXPERIMENT 1

Marty is known to be a strict vegetarian.

Yesterday, he ate a big apple.

Yesterday, he ate a big steak.

On our last vacation, we went to the jungle.

We watched the young monkeys.

We watched the young coyotes.

On his trip to Arizona, Jeff went to the desert.

He took a picture of a beautiful waterfall.

He took a picture of a beautiful river.

I like to go to the farmers' market.

Yesterday, I bought some wonderful fruits.

Yesterday, I bought some wonderful sheets.

On her trip to Africa, Sheila went to the Sahara.

She was amazed to see so much sand.

She was amazed to see so much stuff.

On Wednesdays, I take care of my brother's horse.

It really likes to eat hay.

It really likes to eat beef.

Ira went to visit a friend in Japan.

When she was there, she ate a lot of sushi.

When she was there, she ate a lot of pasta.

I went to visit my uncle Bill who is a forester.

He enjoys working in the woods.

He enjoys working in the store.

Uncle Ron from Wisconsin is a farmer.

He likes to work in his fields.

He likes to work in his bar.

In a few weeks, Liz will give birth to her baby.

She has already bought a cradle.

She has already bought a sofa.

Sam is a professional fencer.

He just bought a new sword.

He just bought a new saddle.

Peter is addicted to smoking.

Every morning he goes to the store to get his cigarettes.

Every morning he goes to the store to get his candy.

Steve is a very heavy drinker.

He can not go one hour without his liquor.

He can not go one hour without his girl friend.

My grandfather is a skilled physician.

Every morning, he gets up early to go to the hospital.

Every morning, he gets up early to go to the bakery.

Bob's sister is a famous writer.

She proudly showed me her newest novel.

She proudly showed me her newest couch.

My next door neighbor is a famous opera singer.

I can often hear her practice her arias.

I can often hear her practice her tuba.

Paul was impressed by the young actress.

She has been hired for the theater.

She has been hired for the newspaper.

Appendix 1

James likes his job as a carpenter.

He enjoys working with wood.

He enjoys working with kids.

The French chef had prepared a wonderful dinner.

His brother brought the wine.

His brother brought the ring.

Mr. Chauncey is a dedicated winemaker.

He owns a very famous vineyard.

He owns a very famous warehouse.

Andrea and her boyfriend went to the beach.

They spent most of their time swimming.

They spent most of their time skiing.

Susanna went on a trip to the mountains.

She had so much fun hiking.

She had so much fun snorkeling.

Jill and Sam went to Las Vegas.

They really love to gamble.

They really love to hunt.

Edith and Brian bought themselves a new boat.

In their spare time, they love to sail.

In their spare time, they love to golf.

On Saturday, I am expecting the movers.

Fortunately, my friends will help me pack.

Fortunately, my friends will help me build.

The jurors did not convict the murderer.

They could not believe that such a nice person would kill.

They could not believe that such a nice person would cheat.

My aunt doesn't like to go on a plane.

She is very scared of having to fly.

She is very scared of having to talk.

John heard that Jennifer is a gifted pianist.

Tonight, he will see her perform.

Tonight, he will see her strip.

Susan gave her grandpa a new pipe.

He enjoys sitting in his armchair and smoke.

He enjoys sitting in his armchair and sleep.

Since she was a little girl, Karen has been very keen on horses.

At the age of five she started to ride.

At the age of five she started to crochet.

Aunt Laura is a an artist.

It is amazing to watch her when she paints.

It is amazing to watch her when she runs.

Kristin went to culinary school to become a chef.

Amazingly, she never learned to cook.

Amazingly, she never learned to sing.

We went to the theater and saw a very funny comedy.

When we thought about it the next day, we still had to laugh.

When we thought about it the next day, we still had to wonder.

After the storm, our lawn was covered with leaves.

We spent all Saturday afternoon raking.

We spent all Saturday afternoon sewing.

Grandma likes to do her needlework.

In the evenings, she sits on her sofa and knits.

In the evenings, she sits on her sofa and snores.

Karen bought a reliable car.

Now, she enjoys driving.

Now, she enjoys chatting.

The scouts have made a big fire.

Silently, they watch it burn.

Silently, they watch it melt.

Elise has to clean the floor.

She complains that she does not like to mop.

She complains that she does not like to jog.

The Kirk children are very loud.

They always seem to yell.

They always seem to win.

When Mary heard of the sudden death of her friend, she burst into tears.

Even now the thought of it still makes her cry.

Even now the thought of it still makes her cheer.

Sam told me about the new thriller.

He said it was very scary.

He said it was very romantic.

Sherry's daughter is suffering from anorexia.

She has become incredibly skinny.

She has become incredibly nosy.

Krysta spent her last vacation in Germany.

She did this in order to practice her German.

She did this in order to practice her Spanish.

In order to buy wine, Daniel went to France.

Fortunately, he can speak French.

Fortunately, he can speak Chinese.

Last night, we were introduced to two famous professors.

We thought they were very intelligent.

We thought they were very athletic.

When waiting for the train, we met some high school dropouts.

When talking to them, we noticed they were indeed very stupid.

When talking to them, we noticed they were indeed very nerdy.

Jane is in the eighth month of her pregnancy.

Her belly is now really round.

Her belly is now really flat.

Kristin lost 60 pounds after being on her diet.

She has become very slim.

She has become very quiet.

Joe suffers from obesity.

He is incredibly fat.

He is incredibly thin.

The little boy was almost bitten by a black widow.

That would have been very dangerous.

That would have been very harmless.

Daddy won a fortune in the lottery.

This has made him very rich.

This has made him very cool.

Sam covered his pancakes with maple syrup.

He likes them very sweet.

He likes them very spicy.

In Ohio there was a blizzard with 8 ft of snow.

I haven't been anywhere that cold.

I haven't been anywhere that noisy.

The parents took their kids to a theme park where they saw a giant.

They asked why he was so huge.

They asked why he was so lean.

Pete and Mary went to see their friend in the intensive care unit.

They had never been to a place that sterile.

They had never been to a place that dirty.

The ecology class went to visit the dump.

They told us that it was very smelly.

They told us that it was very late.

Our cat just had little kittens.

They are all very cute.

They are all very busy.

In New York City, I talked to an old woman who was homeless.

I have never met someone who was that poor.

I have never met someone who was that healthy.

On their trip to California, Ashley and Gif went to Death Valley.

They told us that it was incredibly hot.

They told us that it was incredibly nippy .

In order to surprise the kids, Uncle Bob came in walking on stilts.

They were amazed because they had never seen a person that tall.

They were amazed because they had never seen a person that short.

The mechanic has solved the problem.

The tailor went on a vacation with his whole family.

The tailor went on a vacation with his whole laundry.

Fred realized the old house was up for sale.

The lecture should last about one hour.

The lecture should last about one house.

The minister is visiting the teacher.

My mother prefers her tea with milk and sugar.

My mother prefers her tea with milk and cement.

The family goes on a vacation.

Emily was fired from her job.

Emily was fired from her cat.

Appendix 1

Daniel and Laura like to eat.

The Millers spent their vacation by the sea.

The Millers spent their vacation by the pea.

The children came home from school.

The hamburger came with french fries.

The hamburger came with french grass.

The students go home for the summer.

The ducks happily swim in their pond.

The ducks happily swim in their cup.

The butcher has slaughtered a pig.

The delicious marmalade is made of oranges.

The delicious marmalade is made of matches.

There was nothing wrong with the radio.

On a clear night, one can see the moon and stars.

On a clear night, one can see the moon and coats.

Her job was easy most of the time.

The chicken came with sweet and sour sauce.

The chicken came with sweet and sour mud.

Ashley went shopping at the mall.

The professor had to prepare his lecture.

The professor had to prepare his bushes.

They went to see the famous performer.

The gardener has mowed the lawn.

The gardener has mowed the hair.

In the distance they heard the voice.

Every morning, the kids have milk for breakfast.

Every morning, the kids have milk for paper.

No one would accuse him of treason.

Mom seasoned the soup with salt and pepper.

Mom seasoned the soup with salt and bottle.

Jim hit his horse with a rein.

George must keep his dog on a leash.

George must keep his dog on a cube.

They played catch with a tennis ball.

The movers put the sofa on the bare floor.

The movers put the sofa on the bare honey.

There is something grand about the sunset.

Mom put the pot onto the stove.

Mom put the pot onto the lights.

You can't buy everything for a girl.

That antique dates back to the eighteenth century.

That antique dates back to the eighteenth turkey.

Chad had to commute to the college.

You can't take the test without a pencil.

You can't take the test without a wall.

There was something wrong with the fridge.

The children know how to eat with knife and fork.

The children know how to eat with knife and tail.

The cigar burnt a hole in the shirt.

She was honest as far as he could tell.

She was honest as far as he could spin.

The wound left a permanent scar.

Nancy tied string around her finger so she would remember.

Nancy tied string around her finger so she would prepare.

The old man had a long gray jacket.

Vic asked her to repeat what she had said.

Vic asked her to repeat what she had worn.

We washed our hands with soap and water.

The shepherd has a lot of sheep to tend.

The shepherd has a lot of sheep to smile.

He put the ring on her finger.

The barber has a lot of beards to trim.

The barber has a lot of beards to shake.

He fried an egg and two strips of bacon.

The maiden took out the broom and started to sweep.

The maiden took out the broom and started to fiddle.

The Indian carried an arrow and a bow.

The baker has another cake to bake.

The baker has another cake to spill.

The fly got caught in the spider web.

The teacher has a lot of pupils to teach.

The teacher has a lot of pupils to trash.

Appendix 1

The pen ran out of ink.

The gangster pulled out his gun and started to shoot.

The gangster pulled out his gun and started to weld.

She won a new washer and dryer.

Getting the shot did not really hurt.

Getting the shot did not really splurge.

The boys played cops and robbers.

The usher asked the disruptive man to leave.

The usher asked the disruptive man to meow.

I sewed on the button with needle and thread.

The mute girl is unable to speak.

The mute girl is unable to glow.

She was afraid of lightning and thunder.

Once she starts talking, she won't stop.

Once she starts talking, she won't rain.

Joe hit the baseball with the bat.

Water and sunshine help plants grow.

Water and sunshine help plants film.

The old man sat on the park bench.

The choir sang hymns while the audience listened.

The choir sang hymns while the audience snowed.

The story had a happy ending.

The deaf man can no longer hear.

The deaf man can no longer boil.

Birds fly south for the winter.

The dry bread was hard to chew.

The dry bread was hard to sniff.

She looked at herself in the mirror.

The coffee was too hot to drink.

The coffee was too hot to sketch.

She put fresh sheets on the bed.

Sean has a lot of copies to make.

Sean has a lot of copies to think.

He kept his wallet in his pocket.

Robert was tired and started to yawn.

Robert was tired and started to carve.

He got a ticket for going over the speed limit.

The grass in our garden is nice and green.

The grass in our garden is nice and red.

The noise woke her in the middle of the night.

The snow in the Rockies was white.

The snow in the Rockies was black.

The messenger bowed to the king and queen.

The people at the nudist camp were all naked.

The people at the nudist camp were all feathered.

He dried his hands with a paper towel.

After the excessive eating binge, everyone got sick.

After the excessive eating binge, everyone got mute.

Jot it down on a piece of paper.

We have had a lot of snow and it is quite chilly.

We have had a lot of snow and it is quite yummy.

She solved the crossword puzzle.

The door was kept ajar.

The door was kept inky.

She let her daughter pierce her ears.

The weather in Florida is mostly warm and sunny.

The weather in Florida is mostly warm and icy.

The gambler liked to roll the dice.

We switched on the heating and the room became warm.

We switched on the heating and the room became lame.

He flushed the toilet.

Laura put cushions on the couch to make it more comfortable.

Laura put cushions on the couch to make it more conscious.

The teller sold him a round trip ticket.

The lid of the jar closes very tightly.

The lid of the jar closes very newly.

She polished her finger nails.

The chunk of old blue cheese was very smelly and moldy.

The chunk of old blue cheese was very smelly and bright.

The bowler knocked down all ten pins.

After two months without rain, the grass was very brown.

After two months without rain, the grass was very lost.

Appendix 1

He couldn't see without his glasses.

The elephants in the zoo were large and gray.

The elephants in the zoo were large and blue.

She bought a new pair of running shoes.

Stealing other people's stuff is wrong.

Stealing other people's stuff is ripe.

Ample food was made for the crew.

Michele fell into a waterhole and her pants got all wet.

Michele fell into a waterhole and her pants got all nude.

Pat blew out all the candles on the cake.

At dusk it gets dark.

At dusk it gets numb.

The ambulance rushed him to the hospital.

The snail moves very slowly.

The snail moves very sharp.

Let me take your hat and coat.

The weightlifter is very strong.

The weightlifter is very tasty.

They enjoyed looking through the family album.

The big chunk of iron was very heavy.

The big chunk of iron was very bleak.

For a headache she took two aspirin.

Sabrina is a very neat person who keeps everything tidy.

Sabrina is a very neat person who keeps everything quick.

7 APPENDIX 2

STIMULI FOR EXPERIMENT 2

After the concert, the last subway was gone.

This is why we had to take a cab.

This is why we had to take a class.

Carol had the opportunity to go on a free trip to Paris, but she did not go.

It's hard to believe that she has been so silly.

It's hard to believe that she has been so skinny.

Eric's son is a little behind in his development.

At the age of four he was able to speak.

At the age of four he was able to write.

When he is home, Jason plays his music very loud.

This annoys all his neighbors.

This annoys all his students.

Susan has heard nothing from her daughter for three weeks.

She is starting to get worried.

She is starting to get sweaty.

In my dentist's office they have started to play soft music.

When I go there now, I am no longer anxious.

When I go there now, I am no longer busy.

During the classical concert, someone in the audience was constantly coughing.

I found that very disturbing.

I found that very pleasant.

Irene studied hard for her last exam, and she received an excellent grade.

When she found out, she felt very proud.

When she found out, she felt very ashamed.

Jane is really gentle and very helpful to everyone.

She never seems to lose her patience.

She never seems to lose her keys.

Karen went to the airport to pick up her sister.

She met her at the baggage claim.

She met her at the coat check.

Jenna never arrives at the office on time.

This makes her colleagues quite angry.

This makes her colleagues quite content.

Last Sunday, Irene went to a spa and treated herself to a massage.

Afterwards, she was completely relaxed.

Afterwards, she was completely frightened.

Linda went for a walk and lost her wallet.

She asked her friend to help her search.

She asked her friend to help her cook.

Mark is in a hurry and runs out with his keys.

He hopes that he can start the engine.

He hopes that he can start the project.

After the children's birthday party, Mom was pretty exhausted.

When they were gone, she had to put away the toys.

When they were gone, she had to put away the tools.

In New York, we went to the top floor of the Empire State Building.

We were stunned by the extraordinary view.

We were stunned by the extraordinary talk.

Pete has to clean out the stable every weekend.

He never complains about the stench.

He never complains about the noise.

Rachel is very spoiled.

She simply does not know how to behave.

She simply does not know how to spell.

Robert was able to read when he was three.

He was considered to be very gifted.

He was considered to be very dumb.

When Carol went hiking alone in the mountains, she lost her way.

Later, she told her friends that she had been very scared.

Later, she told her friends that she had been very jealous.

The boy was playing outside in the cold rain.

The next morning, he had a fever.

The next morning, he had a pancake.

The manager has been working for 18 hours.

He would like to leave soon.

He would like to leave town.

The secretary has done all her work in much less time than expected.

Her boss told her that she has been very efficient.

Her boss told her that she has been very dishonest.

Appendix 2

Ron went to the store and bought a lot of food.

He had to use two carts.

He had to use two clips.

We went to the opera last night and dressed nicely.

We felt very elegant.

We felt very thirsty.

Julie's cat had spilled milk all over the kitchen.

She immediately started to mop.

She immediately started to sleep.

When Marcia came home, her son had done all the dishes.

She told him that she was very impressed.

She told him that she was very furious.

Rick started the talk with his pants unzipped.

When he finally noticed, he was very embarrassed.

When he finally noticed, he was very flattered.

Karen went outside to play in the snow.

Her Mom told her to put on her scarf.

Her Mom told her to put on her bikini.

Sue heard the bell ring.

She asked Dan to go to the door.

She asked Dan to go to the port.

It was a wild party.

Chad celebrated his 21st birthday with his friends.

It was a wild horse.

Steve went for a 10 mile run.

When he got home, he was exhausted.

When he got home, he was drunk.

Cathy is pregnant and has already gained 20 pounds.

Her pants are tight.

Her pants are black.

Neal's daughter gave birth to her first son.

He is happy to be a grandfather.

He is happy to be a doctor.

Toby lost his house and all his belongings in a fire.

Fortunately, he has a good insurance.

Fortunately, he has a good vehicle.

My plane was three hours late and I missed my connection.

When I came home, I was very tired.

When I came home, I was very surprised.

In one year, Jimmy has grown four inches.

His godfather told him that he looks very tall.

His godfather told him that he looks very dirty.

Ashley and Jeff have been dating for two years.

Last month, they got engaged.

Last month, they got hired.

Last night, the power went out.

The whole neighborhood was dark.

The whole neighborhood was poor.

Joel's office is forty miles away.

He does not like the long commute.

He does not like the long curtains.

Tony had a very serious accident.

His family is extremely relieved that he survived.

His family is extremely relieved that he passed.

Brian's wife just delivered their first baby.

He is so proud to be a father.

He is so proud to be a golfer.

My grandfather turned 85 yesterday.

Our whole family went to celebrate.

Our whole family went to Canada.

CNN presented an extended report on the terrible tornado.

We saw that there was a lot of damage.

We saw that there was a lot of storage.

Mary collapsed during the sermon.

Her boyfriend called the ambulance.

Her boyfriend called the campground.

Valerie worked hard last quarter.

She should take a vacation.

She should take a Tylenol.

Laura and Daniel got married two years ago.

Sometime soon, they would like to have a child.

Sometime soon, they would like to have a sofa.

Appendix 2

Jim had nothing to eat because he was busy all day.

He is looking forward to a nice dinner.

He is looking forward to a nice weekend.

Jack needs to write down Lisa's phone number.

He asks her for a pen.

He asks her for a dime.

A bee stung Claire in her neck.

Her mother feared that she would suffocate.

Her mother feared that she would resign.

Jo knocked over a full cup of coffee.

He felt very clumsy.

He felt very smart.

Susanna's Grandmother is visiting from Germany.

She will take a plane.

She will take a shower.

Eric told his friends that he won a million dollars in the lottery.

They were convinced that this was a lie.

They were convinced that this was a ruby.

Gail has gained 30 pounds since she left home.

Her sister told her that she has gotten fat.

Her sister told her that she has gotten lost.

Chris could not find his files anywhere.

He thought it was time to tidy up.

He thought it was time to refuse.

The Kirks attend the service every Sunday.

They are both very religious.

They are both very studious.

My tank is almost empty.

I have to get some gas.

I have to get some glue.

Simona's boyfriend is coming in from Italy.

She is going to meet him at the airport.

She is going to meet him at the bookstore.

Wayne is finally going to meet the parents of his girlfriend.

He is getting pretty nervous.

He is getting pretty rebellious.

Appendix 2

The Chinese food contained a lot of garlic.

Afterwards, we had a mint.

Afterwards, we had a bruise.

They went to see the famous clown.

He put the ring on her finger.

He put the ring on her desk.

In the distance they heard the voice.

She looked at herself in the mirror.

She looked at herself in the photo.

Few had the nerve to take the needed risk.

She put fresh sheets on the bed.

She put fresh sheets on the mattress.

They went to the rear of the long boat.
Sam could not believe her story was true.
Sam could not believe her story was told.

Every spring they held the annual meeting .
The story had a happy ending.
The story had a happy character.

He was soothed by the gentle waves.
She let her daughter pierce her ears.
She let her daughter pierce her belly.

The bull rushed into the grove.
The little boy marched like a wooden soldier.
The little boy marched like a wooden toy.

In the park the hippie touched the daisy.
On her diet she only lost one pound.
On her diet she only lost one kilogram.

They rested under a tree in the field.
The superstitious man would not walk under a ladder.
The superstitious man would not walk under a scaffold.
Helen reached up to dust the chandelier.
They rode down to the lobby in the elevator.

They rode down to the lobby in the escalator.

Barry wisely chose to pay the plumber.

Pat blew out all the candles on the cake.

Pat blew out all the candles on the mantel.

Larry chose not to join the navy.

When the two met, one of them held out his hand.

When the two met, one of them held out his badge.

She cleaned the dirt from her rug.

She told the brat to go stand in the corner.

She told the brat to go stand in the hallway.

Every month, Rick had to clean his rifle.

The prince awakened her with a kiss.

The prince awakened her with a song.

Coming in he took off his boots.

Instead of wine the children drank grape juice.

Instead of wine the children drank grape soda.

The young boy was granted a small loan.

The paint turned out to be the wrong color

The paint turned out to be the wrong brand

There are times when life seems gloomy.

He went out to warm up the car.

He went out to warm up the engine.

The kind old man asked us to sit.

The beggar asked for some spare change.

The beggar asked for some spare food.

The surface of the water was nice and glassy.

He was murdered in cold blood.

He was murdered in cold weather.

The truck that Bill drove crashed into the gate.

They left the dirty dishes in the sink.

They left the dirty dishes in the kitchen.

The senator was startled by the sudden pain in his stomach.

Ray fell down and skinned his knee.

Ray fell down and skinned his elbow.

We used to get company every Monday.

The exit was marked by a large sign.

The exit was marked by a large arrow.

No one wanted to accuse him of slander.

When you go to bed turn off the lights.

When you go to bed turn off the radio.

He disliked having to commute to the college.

George must keep his pet on a leash.

George must keep his pet on a diet.

The Smiths had never visited that area.

None of his books made any sense.

None of his books made any money.

Ample food was made for the crew.

The game was called when it started to rain.

The game was called when it started to hail.

The difficult concept was beyond his scope.

She called her husband at his office.

She called her husband at his work.

The cigar burned a hole in the shirt.

The crime rate has gone up this year.

The crime rate has gone up this summer.

The paper was too thick to use.

Her new shoes were the wrong size.

Her new shoes were the wrong style.

The was nothing wrong with the milk.

The lawyer feared his client was guilty.

The lawyer feared his client was corrupt.

Seth couldn't imagine anyone less ignorant.

The child was born with a rare disease.

The child was born with a rare gift.

In the valley, there were three small creeks.

His leaving home amazed all his friends.

His leaving home amazed all his sisters.

The girl crept slowly toward the phone.

If the crowd quiets down, the band will play.

If the crowd quiets down, the band will start.

Appendix 2

Mary was excited about the upcoming recital.

He crept into the room without a sound.

He crept into the room without a torch.

The donator was thanked for his advice.

Sue was glad they offered her maternity leave.

Sue was glad they offered her maternity clothes.

They awoke to the sound of the stereo.

He hung her coat in the closet.

He hung her coat in the hall.

No one knew how to behave in the strange church.

The dog chased our cat up the tree.

The dog chased our cat up the road.

To get better, Tim took the syrup.

To keep animals out of the garden, he put up a fence.

To keep animals out of the garden, he put up a wall.

No one had seen Jane's boyfriend.

Jill looked back through the open window.

Jill looked back through the open gate.

The evidence did not allow him to make any denials.

The old man had a long gray beard.

The old man had a long gray jacket.

Jim learned the special passage by Friday.

While away, James sent home a letter.

While away, James sent home a check.

She was the only one to see the dolphin.

The tired mother gave the dirty child a bath.

The tired mother gave the dirty child a towel.

Everyone gathered around to look at the moon.

Most students prefer to work during the day.

Most students prefer to work during the fall.

He jumped with pleasure when he saw the pope.

The car in front suddenly changed lanes.

The car in front suddenly changed direction.

We had to wait in line at the station.

While skiing, Randy broke his leg.

While skiing, Randy broke his nose.

Appendix 2

Dave knew where to store the tent.

The magician pulled the rabbit out of the hat.

The magician pulled the rabbit out of the box.

It is surprising that they did not spill.

He flushed the toilet.

He flushed the tissue.

This is a good time to learn to cycle.

A cleaning woman scrubbed the floor.

A cleaning woman scrubbed the carpet.

The blind man ran his hands across the silk.

A bicycle has two wheels.

A bicycle has two pedals.

In the attic we found a red dress.

There wasn't any toothpaste left in the tube.

There wasn't any toothpaste left in the cabinet.

We were stunned when it started to burn.

She had a run in her stockings.

She had a run in her nylon.

He warned her that she had to obey.

The yoyo had a knot in the string.

The yoyo had a knot in the cord.

Some things are hard to finish.

The boy pulled the puppy's tail.

The boy pulled the puppy's chain.

Rita slowly walked down the shaky steps.

They rented a video and watched it at home.

They rented a video and watched it at noon.

A direct attack failed, so they changed the method.

Jean was glad the affair was over.

Jean was glad the affair was finished.

There is something grand about the sunset.

He didn't get lost because he knew the way.

He didn't get lost because he knew the city.

His ability to work was impaired.

We sprayed the yard to keep away the bugs.

We sprayed the yard to keep away the flies.

Appendix 2

The breeze lifted the tablecloth.

The postman opened the package to inspect its contents.

The postman opened the package to inspect its capacity.

The accusations were followed by tears.

The shopper carried home several bags.

The shopper carried home several parcels.

This will be very easy to detect.

Please wipe your feet on the mat.

Please wipe your feet on the rug.

